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Short Papers

Recording with laser scanning of Santo Tomas Royal Monastery: a travel into the past in honour of Christopher Columbus

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Abstract

The documentation and release of Cultural Heritage represents, mainly in Castile (Spain), a basic tool for the promotion and development of the historic and cultural traces of our Knowledge Society. The diversity of our Cultural Legacy together with the difficult access to some emblematic areas, due to geographic dispersion or deficient communications, produce an initial motivation to emphasize the importance of extending this information from the general public to different experts.

This paper presents an overview about the performances of TIDOP research group (Information Technologies applied to Cultural Heritage Recording) in a project for the recording of Santo Tomas Royal Monastery using laser scanner technology. This project is framed in an international exhibition well known as 'Las Dos Orillas', which aims to commemorate the V centenary of Christopher Columbus death, through a travel into the past that combines artistic, ethnographic and anthropologic aspects in a meeting of two worlds and two cultures.

Under all this influence of cultures and ways of life, the TIDOP research group contributes in this synergic and multidisciplinary context, by means of the recording through the technology of laser scanner, in one of the more important monuments related with the Catholic Kings reign: Santo Tomas Royal Monastery, focusing in the development of a methodology that allow to integrate laser scanning and digital imaging. Particularly, the work accomplished at Santo Tomas Royal Monastery, consists in the documentation, modeling and interactive visualization combining laser scanning and digital imaging of: the main facade of the Monastery, the Chorus, the three emblematic Cloisters and the Oriental Museum. In this last case, a specific approach based on fish-eye images and panoramas creation has been developed allowing to recreate a virtual tour of the museum.

This joint event for the exchange and sharing of know-how in the areas of Cultural Heritage and Information Technology focusing on e-Documentation and Computer Graphics constitutes a great opportunity to describe our project methodology opening this important vestige of the Renascence to different experts and to the public in general.

1. Introduction

TIDOP is a research group formed by professors from the Department of Cartography and Land Engineering at University of Salamanca with responsibilities in the teaching and researching on subjects such as Photogrammetry, Remote Sensing, Surveying and Cartography.

Since we started out our professional link with the university (almost 15 years ago) two motifs have been accompanying us and, above all, inspiring our work:

On one side, a fascination for our land's Cultural Heritage and the wish to contribute to its preservation and knowledge. As it is well known, Castile is endowed with a rich variety of monuments that witness its long and intense history. Not the least important among them is the University itself. It was founded in 1218 (the oldest of the existing Spanish universities) and through its life has counted between its professors and students with illustrious jurists, scientists, doctors and writers. Thus, visiting its old buildings is like a revival of past ages, of our past. We feel honoured to belong to an institution with such an admirable tradition and this environment has foster most of the energy necessary to realize our work.

On the other side, an eager preoccupation on the technological evolution of our disciplines, which have experienced the digital revolution as so many others in our modern world. This question has made us maintain a permanent updating of the devices, methods and products of our disciplines in a continuous effort to deliver best educational standards. Geomatic has provided us the framework in which we have kept ourselves oriented in a -demanding and exciting- ever changing scene.

In this sense, we would like to emphasize that 30 years ago our University decided to amplify its humanistic and scientist traditional scope to cover also the engineering world and to do it in the cities (Ávila, Zamora, Salamanca) without university surrounding Salamanca. This wise decision has led to today synergic situation in which the University has the digital means to recover adequately and efficiently its past life to offer its clients and the whole society the resorts to enrich themselves and to enjoy while doing so.

Through this 15 years we have had the chance to record plenty of the main monuments of our city and its surroundings and, while doing so, to experience the transition from Analytical Photogrammetry to Digital Photogrammetry, from stereoscopic processing to stereoscopic and oblique processing and more recently, from the 2D sensor (camera) to the 3D sensor (laser scanner).

We are witnessing a profound change in which a quantitative question has brought a qualitative one. The generation speed of 3D point clouds has changed at such a pace (from about 1 point per second in classical Photogrammetry to several thousands points per second with the laser scanner) that the whole discipline (though based on the same Euclidean geometric principles) has changed and led to the crucial question: is the new device pushing the old ones towards extinction?.

As usual in such deep transformations, many topics are not clear enough and years of testing are necessary to clarify the situation. Among these topics we may highlight the fact that the fast, massive and automatic capture of 3D metric information may be 'too big'. On one hand, we have to deal with huge amounts of points that demand very competitive processors and delivering rates. Besides this, information is obtained in a non selective way in which blunders or irrelevant information is mixed with the proper information. Points acquired show no structure at all. Even more, the singular points which express the object geometry may not be captured at all.

To work with monuments such as the Royal Monastery of Santo Tomás provides us, beside the satisfaction of offering the society an accurate and vivid model of one of the most significant jewels of the city, the opportunity of acquiring experience and knowing the clues to asses properly this powerful tool.

2. Anthological exhibition: 'Las Dos Orillas'

'Las Dos Orillas' is an anthological exhibition supported by the Ayuntamiento de Ávila (Town Council) and the Junta de Castilla y León (Regional Government) that takes place from May until December 2006 at the Royal Monastery of Santo Tomás situated in Ávila (Spain).

The targets of this exhibition are to celebrate the fifth centenary of Columbus death and the Catholic Kings reign while stimulate the tourist flux to monuments such as the Monastery of Santo Tomás regarded as one of jewels of the Renaissance history of Avila.

The exhibition comprises 150 pieces from Spain and Latin America, on display in the Cloister of Silence at the monastery. It is divided into five sections:

I. 'The dream of Columbus', devoted to the main characters of the story. It collects navigational instruments and notes taken by the adventurers on the difficulties of the journey.

II. 'The Earth', with examples of the animals and plants founded by the europeans on their arrival to America.

III. 'Men and women', with dresses, utensils and uses of the americans of the time.

IV. 'The house and the kitchen', describes the native cuisine and houses.

V. 'The Gods', with etchings, paintings, sculptures and pictures that express the natives and the travellers religions.

The Royal Monastery of Santo Tomas was founded by the Catholic Kings as a commemorative monument to the conquest of Granada from the Moors and constructed between 1453 and 1494 by the Architect Martin Solozano with an isabelline gothic style. It was often used by the royal families during the summers and it also housed, until XIX century, the University of Santo Tomás.

The facade seems to picture Hispania, and it is stamped with the coat of arms of the Catholic Kings between the raging lions. The church is made of a whole section in the form of a Latin cross. The altar is situated at the same height of the Chorus (formed of 79 log chairs), and the altarpiece's art formed of five great scenes depicting the life of Santo Tomás is a masterpiece of Pedro Berruguete.

Santo Tomas Royal Monastery has three cloisters: one of them, known as 'Novitiate Cloister', is the oldest and smallest but with a refined style. Another one, 'Silence Cloister' is of a monastic style with isabelline arches from which a flight of steps leads into the Chorus. On the first floor is a doorway leading to the high altar, with Berruguete's altarpiece. It houses the sepulchre of the only male son of the Catholic Kings, the Prince Don Juan. Finally, the 'Kings Cloister', the biggest one, housed in its north part the rooms of the kings that spent here the hot central Spanish summers. Nowadays, it houses an Oriental Museum with a number of documents, books, kimonos, weapons, sculptures and other objects from the Buddhist and Sinthoist rites, brought by the Dominicans from their missions at the Far East.

Since we were asked by the exhibition organizers to participate in it, we decided to use our laser scanner to recording the 3D model of the most relevant elements of this monument: the Main Facade, the Chorus, the three Cloisters and some more interesting details. We also decided not to record the 3D model of Oriental Museum since it does not represents a major architectural feature, but to develop a virtual visit to it through a series of spherical panoramas structured upon the horizontal plan of its several halls.

3. Multi-Sensor description

A medium-range terrestrial laser scanner based on time of flight principle, Trimble GS200 (Figure 2), which incorporates a rotating head and two inner mirrors (one concave and fixed and the other planar and oscillating) was used. Trimble GS200 allows to acquire a scene with a large enough field of view, i.e. 360º H x 60º V, reducing the need of using lots of scan stations. Nevertheless, in order to overtake vertical range limitation, a geared head, Manfrotto 400, was adapted to laser scanner (Figure 2). The sensor accuracy is below 1.5mm at 50m of distance with a beam diameter of 3mm. Furthermore, the laser allows to acquire reflected beam intensity and RGB colours.

Figure 2: *Trimble GS200 laser scanner (www.trimble.com) and geared head Manfrotto 400 (red circle).*

A high-resolution camera, Nikon D70 (Figure 3), was used, with a Sigma 14 mm lens to overcome the poor colour information obtained from terrestrial laser scanner.

Figure 3: *Digital camera: Nikon D70 (www.nikon.com).*

In addition, a fish-eye Nikon lens with a 10 mm focal length together with a specific pano head, MrotatorTCPShort, and its tripod (Figure 4) were used to acquire images from the eight halls of the Oriental Museum in order to stitch them in a spherical panorama and create a 360º virtual scene.

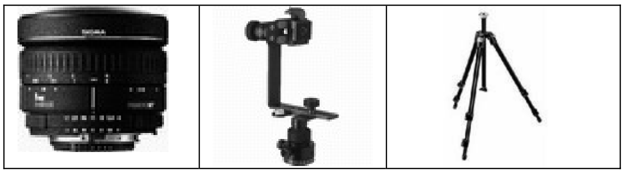

Figure 4: *360º panorama equipment: fish-eye lens, pano head and tripod.*

4. Recording Santo Tomas Royal Monastery through Laser Scanning

During the last years, the need of recording and modeling of historical places has increased due to the emergence of laser scanner, providing metric and accurate products which can be used in a wide avenue of applications offering different levels of information. The laser scanning technology is the perfect approach to recording and modeling complex surfaces, providing quality results in a short time. Nevertheless, several drawbacks have to be taken into account to laser scanner recording: from its high cost and disorganized and massive information to its poor colour resolution. In addition, a hybrid methodology which combines laser scanning and digital imaging has been put in practise to record and modelling the most emblematic parts at Santo Tomas' Royal Monastery: from the Main Façade, the Cloisters and the Chorus to the Oriental Museum. Nevertheless, in this last case a specific and independent approach based on fish-eye images and panoramas creation has been developed allowing to recreate a virtual tour of the museum.
The next scheme (Figure 5) tries to illustrate the hybrid methodology sequence.

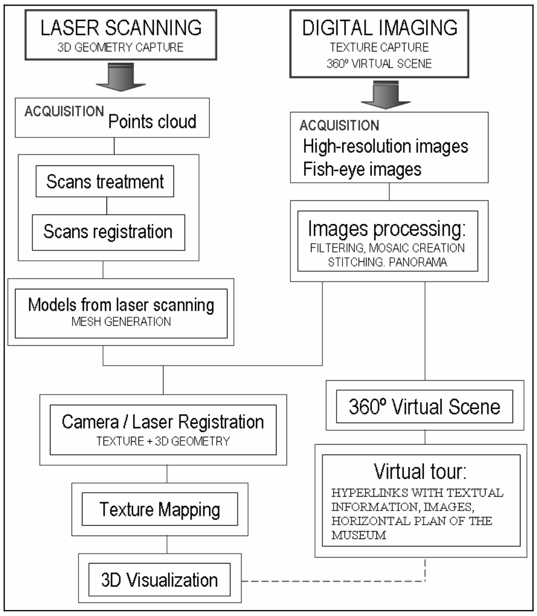

Figure 5: *Laser Scanning methodology.*

4.1 Planning

As stated above, our target was to record the 3D model of the Main Facade, the Chorus, the three Cloisters and the most relevant details of the monument. Besides this, we also wanted to deliver a virtual tour of the Oriental Museum through a series of connected spherical panoramas. These panoramas were to be complemented with hyperlinks leading to significant basic information of the different issues at the museum and also to better resolution images of the correspondent details.

Before planning our scanning project we had to solved several limitations regarding to the environment and the own objects features. Because of the museum time constraints as well as the intense presence of tourists, we decided to undertake a full time data acquisition campaign. The scanning process could only be done in a sequential fashion but while the scanner would be working, the high-resolution images and the fish-eye images could be shut in parallel. With relation to object limitations, the most critical one was the recording of ceilings with complex geometries, i.e. the corridors of Silence Cloister, which had to be solved with an adequate methodology and specific instruments. In this case, a geared head, Manfrotto 400, was used to overcome the laser scanner limitation in the vertical field of view.

Another important factor to take into account in the Laser Scanning Planning step, is to achieve a balance between the number of stations and their coverage, avoiding the presence of holes, occlusions as well as scans with high obliquity, without forgetting the presence of an overlap between scans around 10% at least. In fact, this last aspect represents a critical factor in the fusion between external and internal parts at Cloisters.

Finally, with relation to the recording of the Oriental Museum, an efficient solution was chosen which overcome efficiently the limits of conventional way to represent and describe a museum, due to the limitations of details and occlusions. In addition, a digital imaging approach based on stitching spherical panoramic images allowed us to record the museum, providing the following capabilities: Interactive (zoom and navigation); Immersive (felling you were really in the place), Informative (360º field of view, overall idea about the museum) and Integrative (Text and hyperlinks can be incorporated providing additional information).

4.2 Data Collection

Following the scheme illustrated before (Figure 5) two types of dataset were acquired:

Scan data collection

- Global scans set up with an average grid resolution of 30 mm at 25 meters of distance, with the aim of recording the Main Façade, the Chorus and the Cloisters. Particularly, the interior of the Cloisters were scanned using four stations placed in each corner in order to provide a good coverage as well as an overlap around 25%, while the exterior parts (the corridors) present more difficult, needing eight stations that guarantee enough regularity in the point cloud resolution. In this sense, stations were assumed in the middle as well as in both extremes of them and a part of the opposite facade of the cloister were also captured to provide a better adjustment of the inner and outer data. The geared head was used to acquire data from ceilings and floors.

- Detailed scans set up with an average grid resolution of 5mm at 10 meters of distance, with the aim of recording with a high accuracy and quality emblematic details such as: heraldic shields, the bulrush, gothic details and complex arches.

Image data collection

- High resolution images (using the 14 mm lens with less radial distortion) with the aim of providing a quality texture mapping. Although, this image acquisition can be performed in an independent way with relation to laser scanning, the separation between both sensors should not be very big in order to registering both dataset correctly. In all cases (except for the images inside the Oriental Museum or at the Chorus), we waited for cloudy days to guarantee an enough regularity in image illumination.

- Fish-eye images (using a 10 mm lens) with the aim of generating spherical panoramas that allow to recreate a virtual 360º scene at the Oriental Museum. In this case, seven images were shot for each hall: six of them to cover the horizon and one more with the camera axe in a vertical position to cover the ceiling. In this case, a 90º swing rotation was applied to the camera and a tripod was used to guarantee a robust enough geometry of the camera and to support long time exposures.

4.3 Data Processing

It has to do with the most expensive and time-consuming step in the laser scanning pipeline, specially the mapping textures. In fact, it usually supposes an increase about three times more with relation to data collection.

Particularly, in our case two different data processing approaches were applied. On one hand, a laser scanning processing step to modeling the most emblematic places at Santo Tomas Royal Monastery and on the other hand, a digital imaging processing based on fish-eye images with the aim of providing a 360º virtual scene and a tour of the Oriental Museum.

Scans processing

- Scans registration. Those objects that needed several scans were registered in a common reference system supported by the transference of homologous points. An overlap about 25% was maintained to guarantee good quality in the iterative registration process based on the ICP (Iterative Closest Point) algorithm.

- Segmentation and filtering. All those points or elements unnecessary were deleted. Different automatic filters combined with manual segmentations were applied to obtain a depurated laser model.

- Mapping textures. Since the majority of laser scanners provide poor colour information an external camera is necessary to register high resolution images with relation to laser model. This registration process requires time and manual interaction to achieve good results. Individual and mosaic high resolution images were registered with relation to laser models using a minimum of 8 homologous points. In some cases, several image pre-processing algorithms were applied to minimize some shadows and illumination effects. This step constitutes the most difficult one, since we are trying to link two different sensors which exhibit different features. Thus, it would be easier if both sensors would be closed each other. As a result, a projection model was computed which allowed us to connect the 2D image points with the 3D laser points.

Fish-eye images processing

- Spherical panorama creation. Each group of seven images was stitched automatically or manually based on homologous point's correspondences. The result was a 360º static image for each hall. For those big halls two groups of seven images were used.

- Adding additional information. Basic information regarding the main issues of the Museum was written. Then, hyperlinks were added to 'hot' points in the 360º panoramas to lead whether to a larger visualization of an element or to the correspondent text information.

- Virtual Tour. With the aim of providing dynamism a navigation console was added. Furthermore, a horizontal plan was developed and used as a guide to follow a virtual tour.

4.4 Derivate products

Up to now the obtaining of final products by laser scanning is something that requires time and patience yet. However, several final products such as: cross-maps, sections, triangular meshes, surveying measurements and obviously the metric support are obtained immediately.

In our case, the processing work described above led to the following products:

- A global 3D textured model of the three Cloisters (Novitiate, Silence and Kings) with an average accuracy of 5 mm (Figure 6).

Figure 6: *Global laser models at the three main Cloisters: Novitiate, Silence and Kings.*

- A global 3D textured model of the Chorus with an average accuracy of 5 mm. It is important to remark the modeling of the 79 log chairs of gothic style made of walnut wood.

- A detailed 3D textured model of the Main Façade with an average accuracy of 2 mm. It is important to remark the complex geometry with the presence of numerous gothic and isabelline details.

- A detailed 3D textured model of the heraldic shields stamped with the coat of arms of the Catholic Kings.

- A detailed 3D intensity model of the cross arches that constitute the ceiling of the church with an average accuracy of 2 mm.

- Colour orthophotographs and multi-orthophotographs of detailed scans and cloisters facades respectively. The real significance of the orthophoto is the removal of relief and tilt distortions providing an image with the qualities of a map. For example, horizontal distances between features can be directly scaled from the orthophoto.

- Virtual flies-through that combine different modes of visualization dynamically: from the intensity points cloud and wireframe models to the textured models which superimpose cross-maps (Figure 7).

Figure 7: *Virtual fly-through the corridors at Silence Cloister.*

- A Virtual scene and tour through the Oriental Museum based on spherical panorama creation (Figure 8).

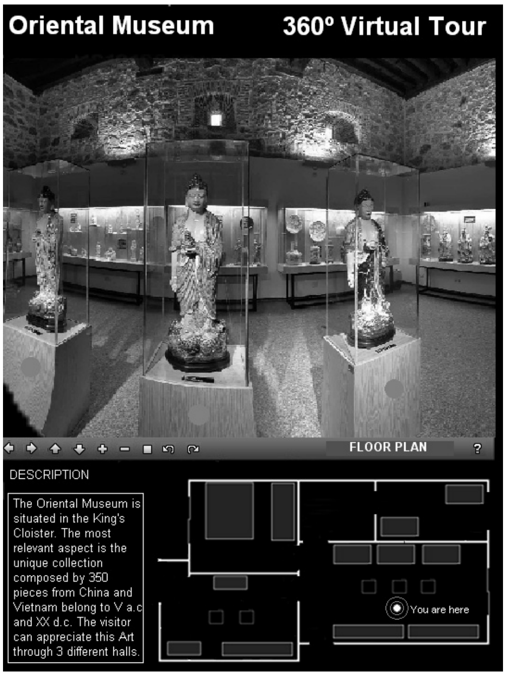

Figure 8: *360º virtual tour through the Oriental Museum.*

A total of two months were required to accomplish the recording and modeling of the Royal Monastery of Santo Tomas through laser scanning, while one month was needed to reconstruct a virtual visit at the Oriental Museum.

5. Conclusions and future perspectives

In this paper a hybrid methodology for recording the Royal Monastery of Santo Tomas has been presented. A balance between laser scanning and digital imaging seems to have been reached since both approaches complement each other.

The role of laser scanning combined with high resolution image registration for the digital recording and modeling of the most emblematic parts of the monastery have provided good results in a wide range of levels: from the metric support exploited by experts to the interactive and virtual model with tourist purposes.

Therefore, there can no doubt that the combination of both sensors and methodologies represent a basic tool for the integral recording of the Cultural Heritage. However, from our professional photogrammetric background the extraction of final results through laser scanning have required time and patience. The presence of complex and irregular geometries, event really common in isabelline gothic style, have provided that plans or vectorial documents required manual interaction, being impossible to extract scaled and metric plans from laser models automatically.

With relation to 360º virtual scenes, the virtual tours supported on spherical panoramas are a very appealing issue for the non expert public. Even more, since these users are not aware of the enormous metric capabilities of the 3D model they are rather seduced by the higher visualization quality of the former. This type of product is so, a great complement to the rigorous 3D models.

As a future perspective, we would like to complement the scheme illustrated above (Figure 5) trying to develop an integration between the 2D virtual tour and the 3D laser scanner models, so a metric support could be incorporated to this 360º scenes exploiting laser scanning and single image-based modelling approaches.

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Towards a Versatile Handheld 3D Laser Scanner

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Abstract

Over the past years, the significance of digital recording of cultural heritage has been realized as a major factor for preservation and dissemination. Due to a continuous growing interest, a numerous of digital recording techniques have been devised to meet the requirements of the cultural heritage sector. 3D digitization is one of the most important aspects in digital recording. Various techniques have been proposed for 3D digitization but still there is not an all-in-one solution due to limitation in technology. In this paper, we are discussing versatility as a key factor of a successful handheld 3D laser scanning system that is applicable to the recording of cultural heritage. The proposed system is based on laser triangulation and 3D camera tracking from a sequence of images. We are considering the case where only minimal information is available to the system prior to its usage.

I.4.1 [Image Processing and Computer Vision]: Digitization and Image Capture

1. Introduction

The significance of digital recording of cultural heritage has been realized, over the past years, as a major factor for the preservation and dissemination of culture. Nowadays, 3D digitization has already established its foundations on archiving cultural heritage as great advances in 3D technologies offer new opportunities to record every detail of cultural heritage in high precision, and to present it in a more attractive ways [TAK*03].

A numerous of digital recording techniques and methodologies have been devised and proposed in order to meet the requirements of the cultural sector. In fact, three-dimensional (3D) digitization is considered as one of the most important aspects in digital recording. It is the first stage in every digital recording project and is the process that produces the first version of the digital content. One of the biggest recognized advantages of digitally archiving artefacts is the production of un-durable works of art. Although various techniques have been proposed for 3D digitization, there isn't an all-in-one solution – that is, a solution that meets the requirements for every digitization project – due to limitation in technology. Laser scanning is one of the most successful techniques that have been developed during the past years in order to tackle with the problems of reverse engineering in industry and accurate 3D digitization for every possible application, within its technological limitations.

Present 3D acquisition systems are usually pushed to their limits when used for the recording of cultural heritage, as challenges uprise due to the physical characteristics of the artefacts. The raw materials that have been used to construct them, in combination with the morphologic complexity contribute on producing shadowy texture areas, subsurface scattering of laser light and major occlusion problems. On the other hand, the delicate and fragile nature of such treasures, prohibit their physical contact and their moving. An immovable artefact is hard to be fully digitized. Thus, we consider versatility of a non-contact scanning system as a key factor for a successful archiving project. Nonetheless, it should be able to derive accurate geometry and texture while being sensitive to the artefact's surface. Laser scanning devices have proved to be applicable in such cases as they have the ability to maintain a narrow beam over long distances [LPC*00]. An accidental collision between the scanning device and the artefact is a non-accepted situation. In fact, there is no silver bullet for safety issues and on this account laser scanning allows at least an acceptable standoff from the artefact to avoid undesirable situations.

Summarizing, the digitization of cultural heritage objects, of relatively small size, is a problem that can be successfully tackled with laser scanning techniques. As these techniques evolve and are being applied and used in real life cases, new requirements become even more evident:

easiness of usage and portability of the scanning system. A handheld 3D scanning device introduces unique flexibility at high accuracy levels and it can, thus, be considered as a highly applicable device on the delicate area of heritage archiving. Working in this light, we propose a technological framework towards a versatile handheld 3D laser scanning system that can be efficiently be used for the digitization of cultural heritage artefacts.

2. Handheld 3D Scanning Systems

Many commercial and experimental handheld systems have already been proposed. Most of them share the idea of manually sweeping the laser beam over the scene or the object. This is a great advantage as it allows the complete scanning of complex geometry from different views without constrains on motion imposed by a mechanical translation or rotation system. Handheld systems can overcome the size range limitation of static systems while keeping the cost in low levels as no mechanical structures are required. A portable handheld scanner can reduce data collection and modelling time while providing flexibility, which is a necessity. Nevertheless, a handheld scanner is not a panacea [Heb01]. In some cases, depending on the size of the object, a handheld sensor can be used as a complementary device for all those places which is hard to be reached by other static systems [LPC*00]. Building a handheld scanning device presupposes that the laser light integration time should be short enough in respect to the displacement of the sensor. It is only then possible to avoid motion blur within a single image frame [Heb01]. Laser line scanning systems are intrinsically faster but finding the correspondence of the points on the line does pose some problems [BFB*98].

For instance, “Autoscan” [BFB*98] is a portable 3D scanner that consists of a laser pointer, a pair of video cameras and a real-time processor that detects the circular spots of the laser in the scene. Its overall weight is 15 kg and the video cameras angle is at least 60 degrees to guarantee high accuracy (0.1mm at a standoff distance of 1.5 m and a baseline distance of 1m). The scanning time is a drawback of the system as it uses one laser pointer that corresponds to approximately 200 triangles per second.

A variant of “Autoscan”, the “ModelCamera”, proposed in [PSB03], involves the usage of sixteen laser pointers fixed with respect to an ordinary video camera. While the user scans the scene, the laser beams produce blobs in the video frame where they hit the objects’ surfaces. Their actual positions in the 3D space are being derived by triangulation in every frame. The registration of the frames results in an evolving model. The user can vary the sampling rate by zooming in and out. This system requires an improved blob detection algorithm when complex surface properties like colour, texture and specularity are introduced [PSB03].

Takatsuka et al. [TWV*99] used a fixed calibrated camera in combination with a handheld laser pointer on which three green light emitting diodes are always locatable along the optical axis of the laser. The positions of those LEDs in space are computed from their projections on the image plane and then they are being used to determine the optical axis of the laser. The 3D point is derived as the intersection of the viewing direction of the camera and laser axis.

Hebert [Heb01] presented a handheld system based on structured light projection that integrates both shape measurements and self-referencing. The configuration proposed consists of two synchronized cameras and a laser diode projecting two perpendicular light planes. “HandyScan 3D” [Han06] is a commercial product which is based on similar principles. Its weight is almost a 1 kg and its accuracy is 0.25 mm on a distance up to 500 mm. Another good example is the “FastSCAN” [Pol06] series by Polhemus. The “FastSCAN” series is designed to scan non-metallic, opaque objects using 1mw lasers and either a single or double camera configuration.

Bahmutov et al. [BPM06] describe an efficient and interactive system for modelling large scale building interiors. The system is based on the structured light technique following a custom approach of projecting a matrix of 11 x 11 laser spots in the field of view of a digital camera. The depth is calculated using multiple dense colour and sparse depth frames which share the same centre of projection. As a result the resolution of the obtained geometry is not enough for the description of objects with high complexity.

Marc Pollefeys et al. proposed in [PVV*03] a handheld 3D model acquisition system that at its first step of operation is quite similar to the system proposed in this paper. The system initially estimates the motion of the camera and sparsely approximates the 3D scene. These data are used to produce a dense estimation of the reconstructed geometry using a flexible multi-view stereo matching scheme. The similarity between Pollefeys approach and the one proposed in this paper lies in the camera motion estimation part. However, Pollefeys’ approach for dense mesh generation using stereo matching appears to be computational expensive and inadequate for ill conditioned image sequences, like sequences where not enough significant points to match are available, or sequences where the transitional motion of the camera does not provide the appropriate pixel disparity between a stereo pair.

Rusinkiewicz et al. proposed in [RHL02] a real-time handheld 3D model acquisition system that permits the user to rotate an object by hand and see a continuously-updated model as the object is scanned. The advantage of this system is that the user can find and fill holes in the model in real time and determine when the object is completely covered. The disadvantage of this system (as presented) is that it requires physical contact with the subject and specific and synchronized hardware.

2.1. The handheld laser scanning system (or Versatility is the key)

The proposed system is based on simple and well established notions in order to deduce the geometry of an object using a sequence of images taken from a video camera (or a photographic camera). Since we are considering the uncalibrated case (only minimal knowledge for the camera is available and a calibration process is not applied), these notions involve camera tracking techniques in order to acquire knowledge of the position and orientation of a camera in a 3D space. The principle of triangulation is employed in order to resolve relative positions of points of the scanned object in the 3D space. In such a system, the coordinates of an imaged point of the object at a given time can be computed by typical matrix multiplications that reflect both the camera model and the camera position and orientation:

$$\overline{C} = I \cdot E \cdot \overline{c} \tag{1}$$

where $\overline{C}$ is the vector of coordinates to be computed, $\overline{c}$ is the vector of the point coordinates in the image plain and I and E are the intrinsic and extrinsic camera parameters in the form of matrices. The matrix of the intrinsic parameters (in an augmented form) is usually defined as:

$$I = \begin{bmatrix} fc_x & \varphi \times fc_x & cc_x & 0 \\ 0 & fc_y & cc_y & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \tag{2}$$

where fc_x, fx_y represent the focal length in units of horizontal and vertical pixels, φ is the angle between x and y sensor axes (typically $\varphi \times fc_x = 0$) and cc_x, cc_y are the coordinates of the principal point (ideally the centre of the image sensor).

These parameters are called intrinsic because they are specific to the type of camera used and are constant for a given camera. Matrix I is estimated once for every digitization project. On the other hand, the extrinsic parameters refer to the orientation and position of the camera relative to a reference world coordinate system (the coordinate system of the scanned object). These parameters' values can vary significantly throughout the process of digitization. The extrinsic parameters matrix is defined (in an augmented form) as:

$$E = \begin{bmatrix} \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix} & \begin{bmatrix} t_x \\ t_y \\ t_z \end{bmatrix} \\ 0 \quad 0 \quad 0 & 1 \end{bmatrix} \tag{3}$$

where the 3x3 upper-left matrix with the r_{ij} elements is the rotation matrix and the 1x3 upper-right vector with the t_i elements is the translation matrix.

Figure 1 depicts a possible configuration of the proposed system, as well as a graphical representation of the process of triangulation for a point in space.

In order to keep the cost of the proposed system low, a common arrangement of both the camera and the laser was followed. They are positioned in such way that they form an imaginary triangle with the target point. The baseline distance between the camera and laser diode is denoted by d, while φ is the angle of the camera and θ the angle of the laser both with the axis vertical to the line that connects them. In total, the variables that are the known parameters of this arrangement are:

- The camera field of view (angle, *FOV*)
- The camera frame resolution, i.e. the frame width w and the frame height h
- The relative topology of the arrangement, i.e. the camera and laser angles φ and θ and the distance between them (d)
- The key value of the camera focal length can be deduced from the known parameters:

$$\left.\begin{aligned} \tan\left(\frac{FOV}{2}\right) &= \frac{r}{f_c} \\ (2r)^2 &= w^2 + h^2 \end{aligned}\right\} \Rightarrow fc = \frac{\frac{\sqrt{w^2+h^2}}{2}}{\tan\left(\frac{FOV}{2}\right)} \tag{4}$$

It should be noted here that all these parameters and the deduced geometries are based on the pinhole camera model.

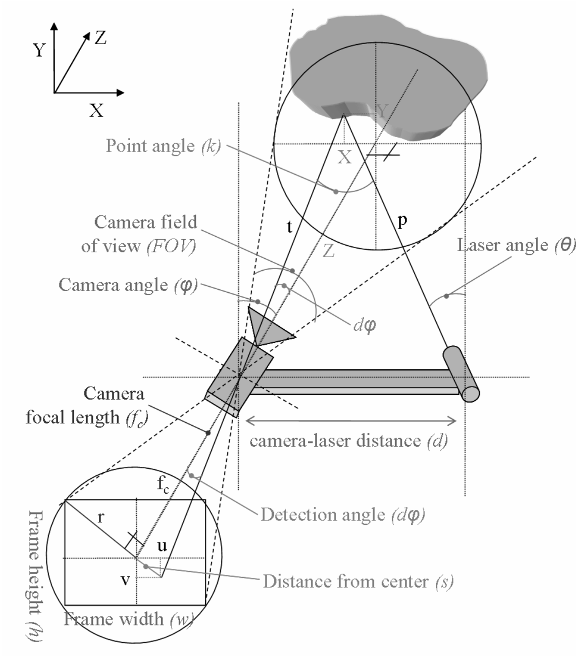

Figure 1: *The proposed system and the process of triangulation for a point in space*

As stated, one of the two stages of the proposed system is the triangulation for the estimation of the position of an unknown point of the scanned object in space. Triangulation is based on the law of sines, which states that if the sides of an arbitrary triangle are a, b and c and the angles opposite those sides are A, B and C:

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = 2R \tag{5}$$

where R is the radius of the triangle's circumcircle.

In our case, (5) becomes:

$$\frac{d}{\sin k} = \frac{p}{\sin\left(\frac{\pi}{2} - \varphi + d\varphi\right)} = \frac{t}{\sin\left(\frac{\pi}{2} - \vartheta\right)} \tag{6}$$

In this topology the problem is a typical geometric problem that can be easily solved, as:

$$k+\left(\frac{\pi}{2}-\varphi+d\varphi\right)+\left(\frac{\pi}{2}-\vartheta\right)=2\pi \Rightarrow \tag{7}$$
$$k=2\pi-\left(\frac{\pi}{2}-\varphi+d\varphi\right)-\left(\frac{\pi}{2}-\vartheta\right)=\pi+\varphi+\vartheta-d\varphi$$

and, as of this, the unknown distance from the camera is:

$$\frac{d}{\sin k}=\frac{t}{\sin\left(\frac{\pi}{2}-\vartheta\right)} \Rightarrow t=d\frac{\sin\left(\frac{\pi}{2}-\vartheta\right)}{\sin(\pi+\varphi+\vartheta-d\varphi)} \tag{8}$$

The only unknown variable here is the angle $d\varphi$, which can easily be estimated trigonometrically:

$$\tan(d\varphi)=\frac{s}{f_c} \Rightarrow d\varphi=\arctan\left(\frac{s}{f_c}\right) \Rightarrow \tag{9}$$
$$d\varphi=\arctan\left(2\frac{\sqrt{u^2+v^2}}{\sqrt{w^2+h^2}}\tan\left(\frac{FOV}{2}\right)\right)$$

In practice, it is more convenient to estimate the *X, Y, Z* coordinates of the detected point instead of its distance from the camera *t*. This can be achieved if instead of working with the distance s we estimate angles in *X* and *Y* axis separately. The notion is depicted graphically in Figure 2, where the detection angle $d\varphi$ is represented by two angles that are relative to one axis, i.e. $d\varphi_X$ for *X* and $d\varphi_Y$ for *Y*.

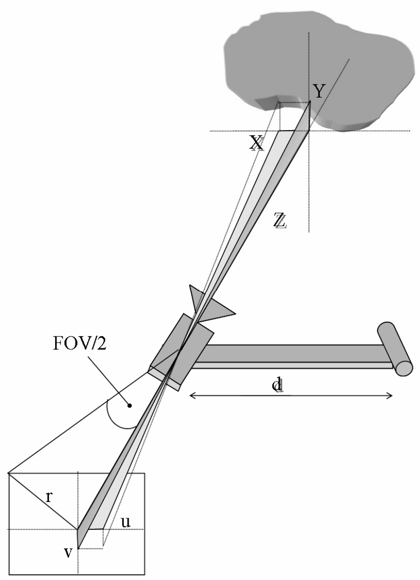

Figure 2: *A more practical approach to the estimation of the unknown coordinates of a detected point*

The estimation of these angles is equivalent to the estimation of $d\varphi$ in (6). The final equations are:

$$d\varphi_X=\arctan\left(\frac{u}{r}\tan\left(\frac{FOV}{2}\right)\right) \tag{10}$$
$$d\varphi_Y=\arctan\left(\frac{v}{r}\tan\left(\frac{FOV}{2}\right)\right)$$
$$L=2\tan\left(\frac{FOV}{2}\right)\Big/\sqrt{w^2+h^2}$$
$$Z=d\frac{\cos(\arctan(uL))\sin(\pi-\vartheta)}{\sin((\pi-\vartheta)+\varphi+\arctan(uL))}$$
$$Y=ZvL$$
$$X=ZuL$$

Another basic stage of the proposed system is the estimation of the camera position and orientation in every frame of the sequence. This is usually referenced as the *camera tracking* problem and is a typical photogrammetric procedure. Consecutive frames, coming out of a single camera moving around a 3D object (often referenced as rigid motion), are processed in a way that emulates the stereoscopic vision of humans. Further processing using photogrammetric algorithms and the colinearity and coplanarity equations may lead to the creation of the 3D shape (but not the exact size) of the object space. If additional information of the scale of the 3D objects is also provided, the exact size of them could be acquired. The main positive consequences from the determination of the relative orientation of two camera frames are:

- the stereoscopic viewing ability (produced through the epipolar geometry and usage of special stereo viewing hardware configuration [Pom99])
- the restriction of the matching algorithms (from 2D to 1D) for the determination of conjugate points [TSP00] and the further processing using space intersection algorithms for the determination of the imaged points' 3D coordinates [Gru01]

Several algorithms have been proposed for the determination of image points' conjugates of two consecutive camera frames. We have used and tested two algorithms for the extraction of points of interest and their matching in two consecutive camera frames:

- Kanade-Lucas-Tomasi (KLT) tracking [ST94].
- Scale Invariant Feature Transform (SIFT) [Low99].

KLT is based on the selection of regions of interest and their tracking in a sequence of images according to a dissimilarity metric that is used to quantify the change of appearance of a feature between frames. This dissimilarity metric is defined as:

$$\varepsilon=\iint_W [J(Ax+d)-I(x)]^2 w(x)dx \tag{11}$$

where *J* and *I* are two consecutive images, *A* is a deformation matrix, *d* is the translation of the feature window's centre, *W* is a given feature window and *w(x)* a weighting function (taken either as 1 or as a gaussian function). Thus the problem of determining the motion parameters is that of finding the A and d that minimize the dissimilarity in (11).

SIFT is similar in notion to KLT. Its goal is to select scale-invariant features by employing a staged filtering approach that results in multiple SIFT keys. These keys are used to identify candidate object models. The main advantage of this method is the improvement expected by using SIFT features that are largely invariant to changes in scale, illumination and local affine distortions. The SIFT detector appeared to be the most effective algorithm in this approach. The implementation of the SIFT detector we used has been created by Alexandre Jenny [Jen04] and has been embedded in our implementation in order to extract conjugate points between two consecutive camera frames. The relative orientation algorithm accepts as input the conjugate image points' coordinates in two camera frames and produces the 5 relative orientation parameters:

- βy, βz translation parameters along the Y and Z axes relative to the translation along X axis and
- $\delta\omega$, $\delta\varphi$, $\delta\kappa$ rotation of the camera axes of the second image relative to the first.

These estimated parameters are used to determine the camera position and orientation in order to be used after the triangulation process so that the relative estimated coordinates can be transformed to the world coordinate system.

In order to achieve high accuracy on the determination of the rotational parameters of the camera a large number of points should be identified between consecutive image frames. In order to extract a large number of interest points from one image to be matched in the next one, the texture of the images should be high enough while their relative rotation could either be low or high. The SIFT detector has the ability to match two camera frames no matter how great their relative rotation is. In our case the simulated images have been enriched in texture and the rotation between camera frames is relatively low. This is why, in most cases, the algorithm succeeded to provide the correct relative estimates of the camera frames.

2.2. Experimental results

The proposed system has been tested using synthetic data, i.e. image sequences of primitive 3D objects exported by 3dStudioMax. The sequences were produced using a simulated 28mm video camera with an active sensor frame size that corresponds to 640x480 pixels resolution. The produced sequences correspond to videos of a 25 frames per second. Thus, the test data correspond to data equivalent to the PAL system. Several sequences have been produced, with the camera forced to perform multiple translations and rotations simultaneously and individually. The laser that has been simulated was a monochromatic green line projected on the surface of the scene objects. Figure 3 depicts a sample sequence of the test data set in gray-scale format.

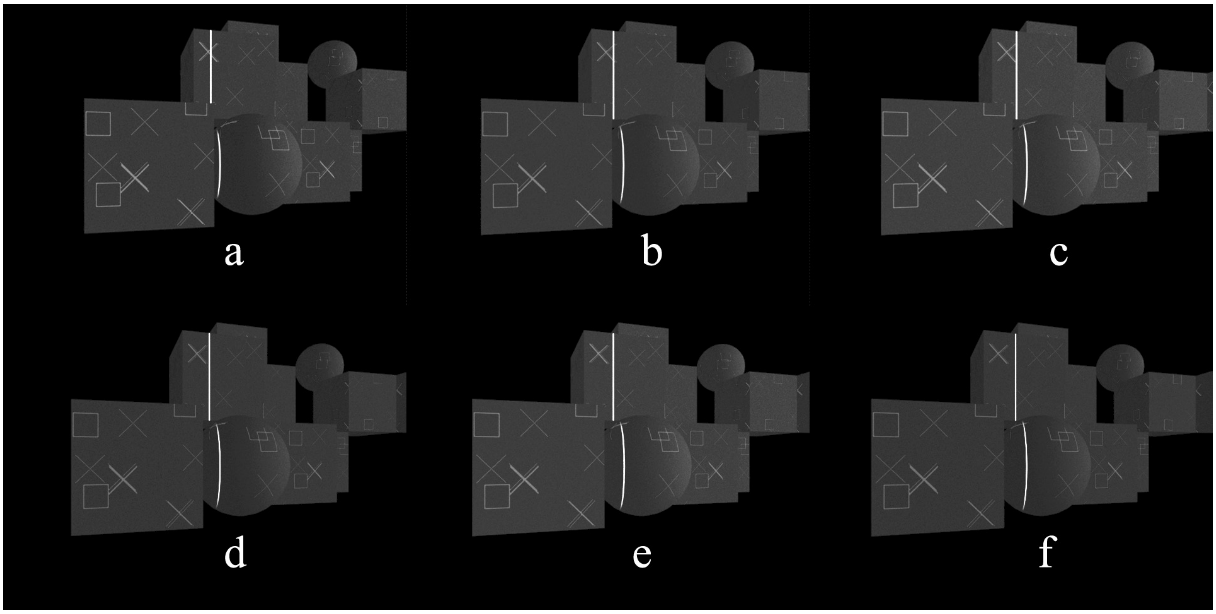

Figure 3: *Six (a to f) consecutive images (with a step of two images) from the test data set. The bright vertical line is the laser projected on the object.*

These preliminary experimental results verified that such a system is actually feasible. The accuracy as well as the resolution and productivity (i.e. time per scanning) of the system are a subject of our further work on this system. Extensive experimentations are also being planned in order to investigate possible system restrictions at extreme cases. Figure 4 depicts the results of the digitization process, at two different time instances as the triangulation algorithm operates on the data set.

3. Conclusions

In this work we attempt to combine the idea of single camera laser triangulation with the idea of 3D camera tracking in order to produce an operational friendly and safe 3D digitization device for both the user and the scanning subject. The proposed system is applicable to the digitization of cultural heritage artefacts and is aimed to be extremely simple and of low cost as well as able to support freeform handheld 3D scanning with no mechanical constraints while following a smooth video shooting procedure. The main advantage of the system is its simplicity and easiness of usage. Extensive experimentations are being planned in order to investigate any possible restrictions and to identify extreme cases. Additionally, error estimates are going to be conducted accompanied with accuracy, resolution and productivity measurements.

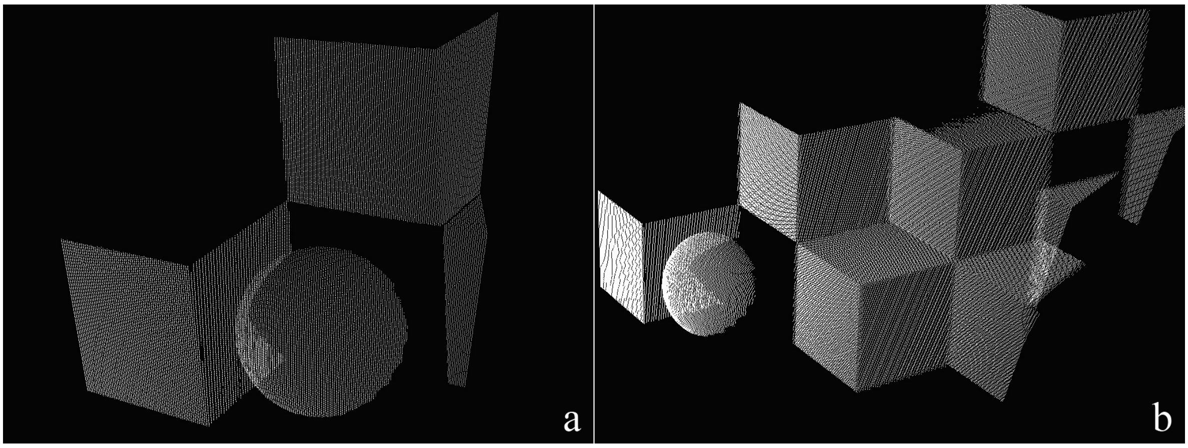

Figure 4: *The result of the digitization process (point cloud) at different time instances.*

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Cultural Itineraries in the Region of Xanthi Using Web-based GIS Technologies

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Abstract

Alternative forms of tourism, like cultural tourism, are constantly gaining appreciation as more and more people disengage from the standard forms of mass tourism. Cultural tourism focuses, mainly, in the promotion of local and regional cultural heritage and can contribute to its protection and preservation while providing new means for regional development and for dealing with typical problems of tourism, such as the shrinking seasons. Modern technologies based on Geographical Information Systems (GIS) can be efficiently applied in the promotion of cultural tourism due to its strong geographic nature. The combination of cultural heritage, tourism and GIS is the main idea in this work. The implemented system offers cultural itineraries in a user-friendly way, aiming to attract people to areas not so popular so far. Region of interest is the region of Xanthi, located in Thrace (Northeast Greece).

H.2.8 [Database Management]: Database Applications: Spatial databases and GIS

1. Introduction

Culture and Cultural Heritage are of great significance and interest worldwide. Tourism on the other hand, is a universal phenomenon based to the human need for pleasure, escape from the daily routine and often curiosity to meet new places, people and cultures. The merging of the two – Culture and tourism – has produced the alternative type of tourism known as "cultural tourism" that accepts great appreciation since the '90s.

Greece, rich in culture and based, on a great extent, financially in tourism, can be one of the most attractive cultural destinations. Furthermore, the possibilities offered by the new technologies can contribute significantly to the dissemination of the Cultural Heritage attracting consequently a larger number of visitors.

Cultural Heritage, Tourism and GIS are the focus points of this paper. Cultural itineraries are offered in a friendly and easily accessible way aiming to familiarize and attract people to areas not so popular to tourists so far. Specifically, the region of Xanthi, located in Thrace (Northeast Greece) is the region of interest in this work. Rich in culture and art, Xanthi has to offer a number of different cultural itineraries to a visitor that wishes to acquaint himself with the area. Archaeological sites, monuments, local architecture, museums, folk traditions and festivals are some of the focal points that indicate the continuity of the region from antiquity until nowadays. Moreover, an on-growing stream of visitors appears to come to the region and gradually tourism becomes an issue of a financial importance. Taking under consideration the above, the technologies of Geographic Information Systems (GIS) along with the technologies of dynamic and interactive publishing through the Internet have been employed in order to promote the cultural polymorphism of the region of Xanthi. The result is a system based on a geographical database, which includes topographic information along with data about the present status, architectural and historical evidence, folklore and bibliographic references. The Internet application that represents the front-end of this database presents an interface that guides the users in the cultural content through cultural itineraries. In order to cover the needs and demands of various types of visitors, the suggested itineraries are offered in three different forms: chronologically, thematically and in the form of daily excursions.

2. Tourism

Tourism is a global social and economic phenomenon that originates from our need to escape everyday life, have entertainment, contact with nature and meet new places, people and cultures. The industry of tourism is considered one of the most prominent, worldwide, due to its contribution to regional growth and development, by building a stable comparative economic advantage, enhancing the competitiveness of the region and by exploiting the possibilities and characteristics of the region.

Mass tourism is the main form of tourism, today, following the model of the sun-sea package. This form of tourism, though, comes with the significant disadvantages that it introduces spatial and temporal concentration and has a very low level of exploitation of the cultural wealth. It is important today to enrich the tourist product with new and special forms of tourism (alternative tourism), that will be friendly to the environment, concentrated in providing new experiences and adapted to the regional and local communities.

Alternative tourism, apart from its symbolic significance, refers to any special form of tourism, which attracts tourists with special interests, contributes in the protection of environment, promotes the cultural heritage and, finally, offers solutions to the tourist seasons problem. Main characteristics of alternative tourism are the search for authenticity, the contact with nature, the denial for impersonal tourist offers or even the rejection of packages for secular beaches [Tan02].

Cultural tourism, a form of alternative tourism, is based on a mosaic of places, traditions, art forms, celebrations and experiences that portray the diversity and character of a nation and its people [Une82]. It refers to visits to archaeological sites, monuments and museums and to a need for discovering the way of life of people of the past and the present [PK04]. One of its main purposes is to promote the value of monuments and cultural sites, contributing to their protection and preservation. Travellers who engage in cultural tourism activities visit art galleries, theatres and museums, historic sites, communities or landmarks, participate in cultural events, festivals and fairs, meet ethnic communities and neighbourhoods, architectural and archaeological treasures.

According to studies ([NEA06], [TCA06]), more and more travellers include cultural, arts, heritage or historic activities while on their trips, which, in some cases, leads to the extension of their trip time. The impact of tourism is such that many international organizations have already shown interest in the formation of progressive strategies in order to promote cultural tourism and protect cultural heritage. Travel trends that will probably dominate the tourism market in the near future reveal, on one hand, a need for an adaptation to the interests of the individual consumer (personalization) and on the other, that arts, heritage and other cultural activities are becoming one of the top five reasons for travelling and tourism. These trends empowered by solutions provided by the technology in the form of the proliferation of online services and tools, make it easier for travellers to choose destinations and customize their itineraries based on their interests.

3. New technologies in tourism

Modern technologies may offer, today, access to a significant amount of information through user-friendly and intuitive virtual environments and interfaces, offering interactivity, multilayered navigation and representation and new experiences through the reconstruction of old civilizations by exploiting the capabilities of networking.

This way, modern technologies can attract visitors with different scientific, social and educational background, rendering tourist programs and cultural collections significantly more accessible, with the result of making cultural heritage more comprehensive and the experience of discovering it more entertaining.

Specifically, GIS technologies can be used very effectively in cultural tourism, in order to provide dynamic and Internet-based user interfaces to a multimedia-rich digital content, for a better way of tourist product promotion. Since now, only a few attempts to exploit the capabilities of this technology for cultural tourism can be traced on the Internet. Among them, three are presented here as case studies:

- *PASTMAP – Bringing history to life:* PASTMAP brings together datasets owned by Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) and Historic Scotland and allows users to locate and obtain information on archaeological sites and historical buildings of Scotland. It also provides detailed information on those sites and buildings that are protected by law, which were not available in the internet. Main objective to this project was to disseminate this information effectively and to improve the public's knowledge of historic sites in Scotland [Pas06].
- *Military architecture – Cultural Itineraries*: "Cultural Itineraries on the Internet" is a pilot application which uses new technologies in order to map the traces of military architecture networks formed by the Venetians and of the Knights of the Order of St. John, during their migrations in the Mediterranean area. More specifically, the main objective of the project is to promote cultural heritage as a determining factor of territorial development as well as to attract alternative tourism in those areas [HMC02].
- *Atlas of Hellenism*: It is an attempt to map the Hellenic world during a period of 2500 years, from the archaic period to the pre-liberation period from the Turkish occupation. It includes the vital space of Hellenism through the ages and from Gibraltar to River Indus (Alexander the Great), including part of Africa (Byzantium) and the Black Sea (Byzantium). This project aimed at the popularization of the historical information ([SAK02], [SAK04]).

4. Cultural itineraries in the region of Xanthi

The project aims at the development of a GIS application to emphasize and popularize the cultural wealth of the region and to promote the historical continuity since the archaic period. The scenario of this application is based on the construction and presentation of cultural itineraries that connect sites and places of significant cultural value. These sites are connected in various ways leading to different itineraries both thematic and in terms of duration. All the itineraries are grouped into three major categories:

- Chronological: in this category, sites are connected to form itineraries that follow a strict chronological similarity, i.e. sites of cultural value that date back to the archaic period are grouped together.

- Thematic: in this category, itineraries are formed through the connection of sites that share a common thematic ground, i.e. sites of importance due to the existence of Byzantine ruins are grouped together
- Daily excursions: various single-day excursions are proposed that cover both thematic and chronological categories, providing a representative sample of the cultural wealth of the region.

The user can, of course, choose and combine any of the proposed itineraries according to his/her interests and the available time.

The choice of the cultural content was a significant task during the designing of the web application and depended mainly upon the specific application's objectives. Considering that the site was designed in order to provide information to both general and scientific public, it was decided that the application would include the most popular tourist destinations. An important factor taken under consideration during the selection of the sites was their archaeological and historical significance and plenitude of documentation. Moreover, practical issues, like easy access to the sites, were also important selection criteria. The selected sites of cultural interest were those that represent, in the best way, the historical continuity of the region. On the total, 52 sites were inserted in the database including spatial and descriptive data.

The GIS system that was chosen to become the development and deployment platform for the application was a combination of ESRI's ArcGIS products [ESR06]. For the creation and editing of the Geodatabase the ArcInfo product [ESR04] was used, while for the web deployment the ArcIMS server [ESR05a]. ArcInfo is one of the most successful platforms for GIS development that provides a high level of functionalities and easy to use interface. ArcIMS is a light-weight choice of server software to publish dynamic GIS content over the Internet. Main advantage of this package is that it can guarantee high productivity as a result of its user-friendliness and the inclusion of site templates and plenty of informative source code for further development.

4.1. Creation of the Geodatabase

The creation of the Geodatabase (the GIS database) was a process of three (3) phases. These phases are described in this section. Figure 1 depicts an overall workflow diagram of the Geodatabase development phases.

- *Phase 1 – sites selection and data collection*: a literature review was carried out in order to select the necessary information to describe the sites of cultural interest. The cultural content consists mostly of information based on text and photographic material. A GPS device was using for the acquisition of the exact coordinates of the sites. Finally, the required digital cartography data (georeferenced maps) were acquired from the Cartography and Geo-Informatics Laboratory of the Dept. of Geography of the University of the Aegean.

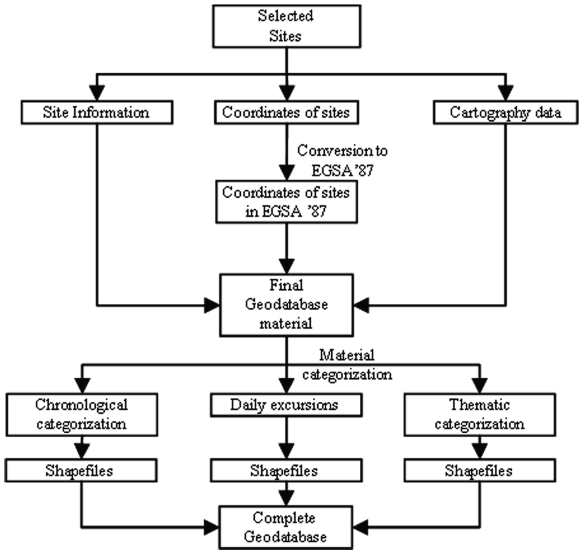

Figure 1: *Tasks during the Geodatabase construction*

- *Phase 2 – data processing and grouping*: the collected data of cultural interest were processed, evaluated and grouped into the following categories:
  - Chronological periods (antiquity, Byzantine period, modern times)
  - Thematic categories (archaeological sites, Byzantine monuments, castles, monasteries, bridges, watermills, traditional architecture, museums, folklore)
  - Daily excursions (four different daily excursions)
- *Phase 3 – data transformation*: the collected coordinates were transformed into the Greek projection system. The digital data were transformed into forms recognizable by GIS, resulting in the production of many different shapefiles, one for each itinerary.

4.2. Web publishing

A very important step in most web publishing applications is the analysis of needs and requirements. These requirements include:

- User friendliness in navigation and functionality
- Fast access to the pages of the web site
- Capability for further examination through the provision of links to specific electronic and paper material

The main requirements were dealt with by adopting the following rules:

- Comprehensive and easily readable content
- Linear and transparent access to the functionalities

- Large range of information given in a concise form
- Compliance with international standards (Cultural Website Quality Principles – Minerva)
- Consistent interface

The final web-site format was adopted from the Hyperlink template of the HTML viewer provided by the ArcIMS [ESR05b]. Figure 2 depicts a screenshot of the web application with some brief explanations.

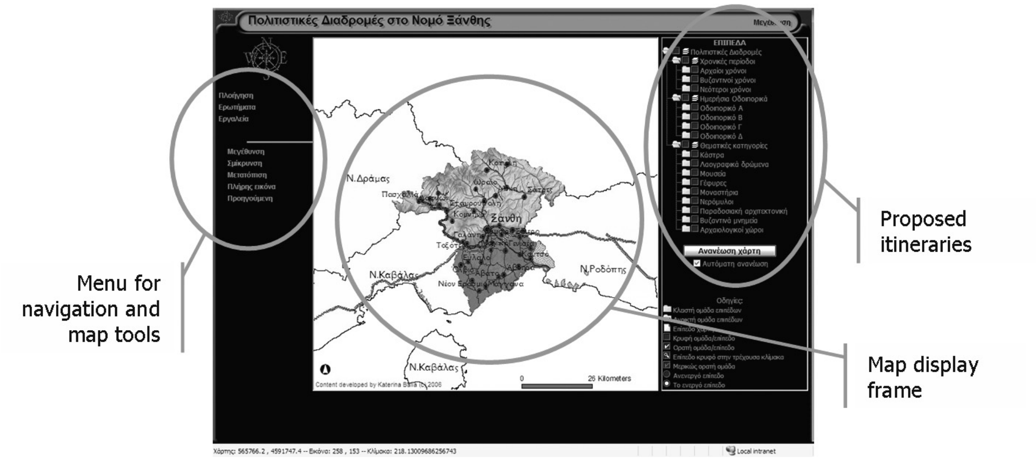

Figure 2: *Screenshot of the web application (in Greek)*

5. Conclusions

This work is an attempt to combine cutting edge technologies of web-enabled GIS with cultural heritage in order to propose a new way of promoting culture in the region of Xanthi in the North-East part of Greece.

The web application aims at making a visit to the region even more constructive and pleasant by proposing cultural itineraries that cover thematic, or chronological, or trip duration needs of the visitors, It also aims at attracting even more visitors and at contributing to the development and expansion of tourism of the region, while at the same time it aims at providing a solution to the problem of tourist spatial and temporal concentration.

Some of the topics for future investigation involve the enrichment of the Geodatabase, the inclusion of on-line reservations and the 3D representations of monuments.

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Short Papers

"The Warrior of Caere": an example of virtual reconstruction

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Abstract

The technologies of virtual reality allow us to use the analysis of data and documentation to reconstruct highly accurate and richly detailed digital representations of real objects. This work is part of an interdisciplinary study project on Etruscan painting in the sixth century BC. The acquisition and reconstruction phase was a long one, involving the processing of data and the subsequent virtual reprocessing of the slab with the warrior discovered in Caere during the 1963 excavation campaign. The interventions performed on the virtual model of the slab were organized in two phases: during phase one we completed the restoration and virtual integration of the missing portions of the slab; in phase two we reconstructed the architectural model and the structure by which the slab was held to the wall. Through the technologies of virtual reality and immersive use, we have sought to recast the context of the slab with the warrior in accordance with a structured knowledge differing from the past. Possessing complete knowledge of the object analyzed through the use of virtual recomposition techniques is of essential importance both for cataloguing and preserving the asset, and for working out possibilities for restoration, investigation, and preventive care.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism - Virtual Reality; J.2 [Physical Sciences and Engineering]: Archaeology; I.3.4 [Computer Graphics]: Graphics Utilities - Graphics packages

1. Introduction

This work is part of an interdisciplinary study project on Etruscan painting (sixth-fifth century BC) on coarse-grained slabs, with participation by Soprintendenza archeologica per il Lazio (the Lazio region superintendency of archaeology), CNR-ISCIMA (Istituto di studi sulle Civiltà Italiche e del Mediterraneo Antico), and ENEA (Ente per le Nuove Tecnologie, l'Energia e l'Ambiente).

Within the scope of this project, virtual recomposition techniques were used to formulate hypotheses for the reconstruction of a funerary slab. The reconstruction was seen as a point of arrival in the long process of studying and analyzing the information related to the finds brought to light during the excavation campaign.

The slab was discovered in July 1963, in a sort of well or cistern, perhaps belonging to a temple complex, in the town referred as "il quartuccio" in the municipality of Ceri, to the south of Cerveteri, giving rise to hypotheses for restoration and replacement in context.

Between the ninth and seventh centuries BC, artistic activity in Etruscan centres paralleled that in other Mediterranean countries, including Greece. We know little of the Etruscan cities, as they were generally destroyed by the subsequent empire in the Roman era [Cri84]. The modern city (Cerveteri) partially overlies the ancient one of Caere, which rises about 50 Km north of Rome (Italy). However, it was in the archaic period (sixth century BC) that the area was to see full-blown monumentalization, with a series of decorated buildings gravitating around a triangular space, in which a residential area reserved for representatives of a high social class may perhaps be recognized [BCP73].

The virtual reconstruction of the slab followed that of the context in which it was placed.

Figure 1: *Virtual recostruction of the Temple*

The work was thus organized in the following two phases:

- *phase one* identified and processed the data and documents leading to the slab's virtual restoration;

- *phase two* studied the information regarding the building that is supposed to have contained the slab, and the temple looking out on the public space, complete with all the decorations, was developed (see Figure 1).

2. Reconstructing the slab.

The first intervention called for completing the figure of a warrior wearing a red chiton and an Attic helmet with a very high plume. A disc-shaped breastplate, anchored at chest level by four leather straps, is painted on the clothing.

The warrior's attitude – pointing a long rod towards the ground, the ends of which are no longer preserved – is a unique one. The work appears to be a top-tier archaeological document for understanding the Caeretan artistic culture that flourished in the late archaic period.

The very high style of the painting on the terracotta slab kept at Museo di Cerveteri has attracted scholarly interest for the originality of its iconographic theme (see Figure 2).

Figure 2: *Slab in terracotta with figure of warrior (Cerveteri).*

The terracotta surface was thus restored, and the elements composing the image coloured in. It was also necessary to consolidate the fractures and insert some elements that although "missing" were indispensable for the slab's virtual reconstruction in accordance with the scholars' hypotheses.

The digital image of the slab, made with a full cell, taken with an 8 megapixel digital reflex camera at a resolution of 300 dpi and with dimensions equal to 2,362 x 3,543 pixels, was used both to document the slab's morphology and decay, and to define project interventions. The image of the slab in question belonged to a series of images made with different time/diaphragm and color temperature values.

The approximately 4,500 x 2,200 pixel image corresponds to actual dimensions of 120 x 54 cm for a single slab; in the phase of application of two side slabs of the same size, the image becomes about 4,500 x 6,600 pixels.

The interventions performed on the slab's digital model with the application of software tools as Macromedia Fireworks (http://www.macromedia.com/) version Mx 2004, regarded the following elements:

- the warrior's legs; the attempt was made to place them in such a way as to justify the body's proportions and attitude within the depiction;
- inserting two side slabs, complete with decorations and support holes;
- filling in the gaps;
- filling in the image's decorative elements based on the original ones, from the same historical period and geographical area (spear head, shin guards, helmet, armour, and skin colour);
- the entire surface.

This made it possible to simulate the reconstruction intervention through a priori evaluation of the impact it would have in reality (see Figure 3).

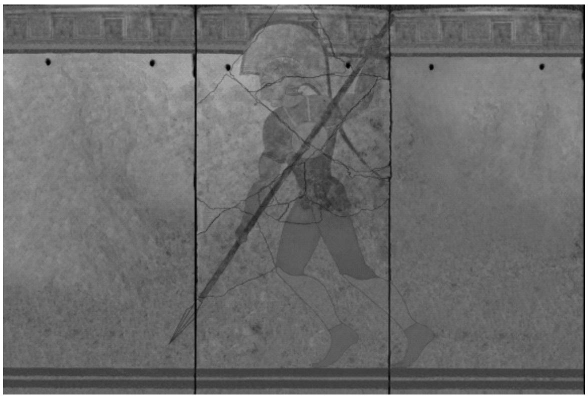

Figure 3: *Virtual reconstruction of the slab.*

3. Reconstructing the architectural space

Virtual Reality (VR) has the potential to at least partially solve the problem of conservation. By recreating a monument using VR, virtual tourists can explore without interfering with the real monument [Woo93], [DeL99]. Indeed VR can in some cases provide a better experience than a visit to the real site [FLKB01], [VWVV*05]. For instance, users can explore the model alone, without crowds or queues and at their own pace, 24 hours a day. A review of the range of projects on the Internet described as Virtual Heritage shows numerous examples of virtual environments build as reconstructions of historic sites [PSOA*05], [SP05], [DM01].

Virtual archaeology makes it possible to recreate – on the basis of scientific data – monuments, landscapes, and environments that time has reduced to being fragmented, incomprehensible "ruins." Archaeological information is thus translated from fieldwork (digs, research, documentation, archiving) to digital knowledge, tracing a unique, integrated path of knowledge and communication.

This context represents the long evolution of the human civilization of the culture of knowledge – from oral tradition to the networked present and the digital future.

Figure 4: *Interior view of the virtual Temple*

A 3D reconstruction of the slab was made by re-examining its environmental setting. 3D Studio Max 5 software [3DS05] made it possible to create the architectural structure and the objects of the entire representation (slab with warrior, wooden beams, nails, and architecture), through specific modelling of all the elements.

The main objective was to place the slab with the warrior within its setting, taking into account the archaeological sources and documents through which the reliability of the elements used to reconstruct the environment can be verified (see Figure 4).

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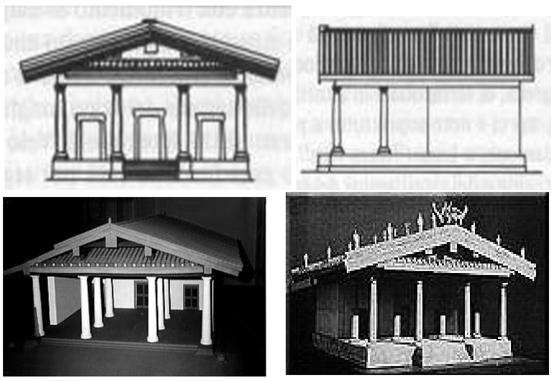

Figure 5: *The geometric model of theTemple*

The geometric model of the temple (see Figure 5) was derived from the sources and from the model of *Temple A* in Pyrgi, made by Istituto di Etruscologia at Rome's Università della Sapienza, and on display at Museo di Villa Giulia.

The three-dimensional reconstruction of the temple was followed by hypotheses as to how the slab with the warrior was set within it. By reconstructing buildings no longer in existence, the modelling was able to bring out in a historicized setting those things that had been destroyed in the past, and to do away with those things that had yet to exist in the historical phase being reconstructed.

The slab's placement in the temple hypothesis finds points of reference in the House of the Vettii in Pompei, which may be dated to the mid first century AD, characterized by a garden with painted decoration; in addition to the atrium's elegant decorations, highly renowned are those in the environments that open onto the peristyle, with mythologically-themed works, as in the case we developed (see Figure 6).

Figure 6: *Particular of the slab inside the* peristyle *of the Temple*

The animation that was produced was developed by the graphical technique of rendering, in four distinct phases characterized by growing degrees of complexity and detail.

The first phase (see Figure 7) is an example of wire rendering: the objects present in the scene are displayed in an approximate fashion with a geometric grid specifying only the shape. This phase is generally used to set the scene.

Figure 7: *Firts phase of modeling and reconstruction of the architectural space.*

The second phase (see Figure 8) adds the details to the surfaces in such a way as to best display the distribution of volumes.

Figure 8: *Second phase of modeling and reconstruction of the architectural space.*

Phase three (see Figure 9) represents a realistic rendering example: the materials, subtleties, and effects of light present in the scene are produced.

Figure 9: *Third phase of modeling and reconstruction of the architectural space.*

The phase of modelling and reconstructing the architectural space also involved applying daytime lights, which are used to simulate daylight and sky effects.

Figure 10: *Exterior view of the virtual Temple.*

The daytime lighting system can add lighting outside the scene based on the area, geographical position, and atmospheric conditions. In this case, the light's geographical placement coincides with the area of Cerveteri at 13:45':13".

It was thus necessary for each face of the depicted elements to be realistically lit. The completion of the reconstruction process involved applying the weavings (see Figure 10).

4.Conclusions

Our heritage is our past reality, which gives us an insight into what has happened and how life actually was. Some of the heritage has been excavated whilst much more has not.

Our cultural heritage is not confined to the visible architectural remains.

Our work presents a base, on which a more complex virtual heritage simulation will be built. The next step will be the integration of virtual humans to increase the realism of architectural models. This scenario, based on historical sources, will add a new dimension in understanding our past.

Acknowledgements

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Short Papers

Large Orthorectified Photo Mosaics for Archaeology

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Abstract
We present a robust, low cost technique for creating photographic mosaics of sizeable wall surfaces at archaeological sites. Observing current limitations in real-world photo mosaic acquisition, our method is designed to obtain photographs for larger wall regions than have been previously practical and to reduce setup time. Also, our system can capture data quickly in order to maintain consistent lighting for outdoor subjects. We present a practical demonstration of this system at the temple of Ramses II in Egypt. As an additional step, we show that the resulting data can be used to create orthorectified images by exploiting range data from laser scanning.

Categories and Subject Descriptors (according to ACM CCS) I.3.3 [Computer Graphics]: Rendering – Texture Mapping, Image and Video Processing – Image Processing, Modeling – Object Scanning / Acquisition

1. Introduction

High quality representations of archaeological inscriptions have already been demonstrated for ~1m^2 sample regions [EHD04]. The value of exploiting 3D scan data to produce orthomosaics for larger epigraphic regions (~5m^2) has been subsequently shown [KKN05]. Our technique focuses on the capture of larger panels, demonstrating practical image acquisition for wall regions up to ~150m^2.

2. Image Acquisition at the Temple of Ramses II

In this short paper, we demonstrate our approach using data collected at the temple of Ramses II, under the supervision of the Centre de Recherches des Musées de France.

Figure 1: *A wall under study at the temple of Ramses II, Thebes, Egypt.*

We capture a matrix of input images by positioning a digital camera at regular grid intervals, maintaining a uniform distance offset from the wall under study.

Figure 2: *Input 3x4 photo matrix (left), a remotely controlled camera is placed atop a custom vertical rig (right).*

Camera angle invariance is a key aspect of our technique and helps to solve two common problems found in current mosaic approaches. First, when mosaics of tall subjects are created using photographs from terrestrial viewpoints, self-occlusion of surface features is often noted. Second, surface reflectance is seen to vary with camera angle, which yields radiometric artefacts when mosaics are stitched [LT05]. Our technique minimizes object self occlusion and reflectance variations by ensuring that the camera is normal to the wall during acquisition for each image. The camera is elevated via a ~9m vertical tripod (Figure 2); its base is very small (<1m) so that the rig can be used to photograph walls that are obstructed by columns and other elements.

3. Mosaic Assembly

Source images acquired in the field are first processed to account for radial lens distortion by means of a simple low-order polynomial approximation of real-world lens distortion. The corrected lens radii r_u of each 2D point is related to the distorted (input data) radii r_d by:

$\boldsymbol{r_u = r_d + k_1 r_d^3}$ where $k_1 > 0$ for barrel distortion and $k_1 < 0$ for pincushion.

To create an orthographic rectified mosaic, first we define a reference coordinate system in which the axis of the wall under study is fit to the XY plane. Next, for each input image the user manually identifies four or more matching feature points between 3D range data and 2D digital photography (Figure 3).

Using these point correspondences as a basis, we compute an initial approximate scaled orthographic projection of the camera pose (rotation and translation) with respect to the wall. For this we use a variant of the POSIT algorithm adapted for coplanar image to surface point correspondences [ODD96]. When using scaled orthographic projection, pose candidates are always computed in pairs. We use user input to select the best pose option from each given solution pair; this camera pose estimate is then iteratively refined until convergence. The process yields a 3x3 rotation matrix of the scene with respect to the camera, and a 3x1 translation vector from the camera's centre of projection to the origin of the scene coordinate system.

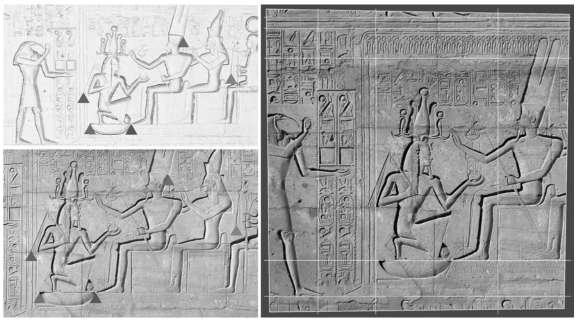

Figure 3: *User-supplied correspondences between scan data (top left) and photo data (bottom left); rectified image region via POSIT with lines added for reference (right).*

Having recovered the rotation and translation of the input images relative to the 3D data for the wall, we bring the camera coordinate system for each image into alignment with the wall. We compute orthographic output tiles by obtaining pixel projections in each transformed camera system for each input image (Figure 3). Lastly, using simple 2D translation in image space, the rendered tiles are composed into a single mosaic. Minor photometric differences between output images are resolved by creating multiresolution splines along image boundaries and blending via the existing software Enblend. A completed photo mosaic is shown in Figure 4, covering a ~32m^2 wall area. In total, 14 wall segments were sampled during our work at the temple of Ramses II, covering a combined total surface area of approximately 1250m^2.

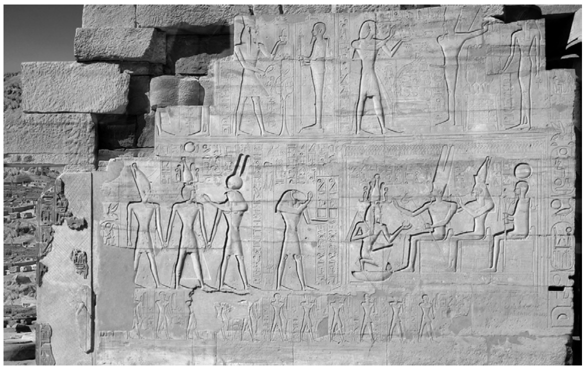

Figure 4: *A completed orthographic mosaic. Note that cast shadows from separate input photos are shown to closely align as images were acquired within ~20 minutes.*

5. Conclusions

As noted in the introduction, promising mosaic assembly techniques designed specifically for cultural heritage have recently been demonstrated, such as [LT05]. However, for most image-based orthomosaic techniques it is generally not possible to establish a strong estimate of global image error relative to ground truth measurements. This type of error quantification is required by archaeologists who wish to use orthomosaics as a basis for creating epigraphic line drawings. Also, many existing mosaic approaches tend not scale well to large image sets. The method we have presented addresses these two issues. First, by using terrestrial scan data as input feature points, the resulting rectified images have known accuracy. Second, as no global image alignment step is required by our technique, arbitrarily large numbers of input images can be accommodated.

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Short Papers

A City Revealed.

New Technologies Increase Our Knowledge of Roman Lucca

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Abstract
With the aim of reconstructing the city of Lucca as it was in the Roman Age, a computerised system based on GIS (Geographical Information System) technology is being set up within the scope of the research project: "Computer Science Technologies for the knowledge and conservation of our Cultural Heritage: an integrated system for Roman Lucca", which will enable the integrated management of all existing documentation (cartography, iconography, surveys, images, descriptive data, bibliography). The system will above all shed light on a heritage that is otherwise inaccessible or difficult to explore, given that many of the Roman remains in Lucca have been incorporated into later structures or are no longer visible. It will also enable documentation of the archaeological, architectural and historical evidence under research to be monitored and updated in real time, so creating an archive of layered information concerning not only current but also past situations, tracing a detailed history of the structures under analysis.
Such a system will not only enable all existing documentation concerning Roman Lucca to be stored and processed, but also new fundamental data to be added through the acquisition of further information derived, for example, from surveys carried out with innovative techniques (quick photogrammetric systems, 3D scanner laser, etc…).
Apart from the management and enjoyment of knowledge about Roman Lucca, the aim of the project is also to create a tool that although originally thought up specifically for an urban contest, is also exportable. The methodology used will shape an environment that suggests multiple cognitive paths differentiated by varying user requirements, but that is also able to produce reliable, objective and immediately interpretable information of a scientific nature.

H.2.8 [Database Applications]: Spatial Databases and GIS

"Beware of saying to them that sometimes different cities follow one another on the same site and under the same name, born and dying without knowing one another, without communication among themselves.
At time even the names of the inhabitants remain the same, and their voices' accent, and also the features of the faces; but the gods who live beneath names and above places have gone off without a word and outsiders have settled in their place."
(I. Calvino, *Invisible Cities*)

1. An urban GIS: LUCA

LUCA is an Information System designed as part of the research project: "*Information Technology for the knowledge and conservation of our cultural heritage: an integrated system for Roman Lucca",* a work in progress within the Research Doctorate in "Technology and Management of Cultural Heritage" at IMT Lucca Institute for Advanced Studies.

Modern Lucca is the result of the successive stratification of different periods spanning from its foundation as a Roman colony in 180 B.C. to the present day. In its general layout the city preserves numerous manifestations of its Roman urban fabric: viewed from above (fig.1), the perimeter of the ancient city with the outline of its main road axes are clearly visible within the circle of its Renaissance walls [BEL73], [MZ82]. One section of the ancient city walls is incorporated in the Church of Santa Rosa (fig.2), [BIN31], [MAT33], [CIA95], [MEN01]. The name San Michele in Foro bears witness to the Roman forum: archaeological excavations under the paving of the church have confirmed that the heart of Roman Lucca was located in this area [CIA06].

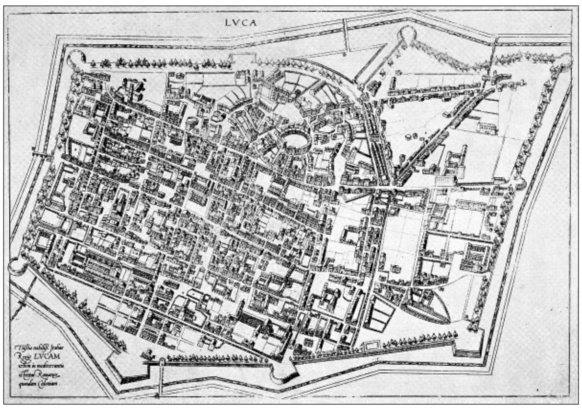

Figure 1: *Lucca, Birdview sight, (Braun, 1576)*

The Piazza Anfiteatro of today coincides with the ancient amphitheatre, the perimeter of which is readily discernible, and the arcades, pillars and marble consoles are still visible, incorporated in the external façades of later buildings (fig.3), [SG74]. The church of Sant'Agostino and its bell tower lean against the remains of parts of the Roman theatre (fig.4), [SG75], [CIA92B]. The excavations have contributed further to our picture of the ancient fabric of the city, in many cases confirming previous hypotheses [MZ82], [CIA92A], [CIA92C], [DEM92], [CIA98].

Lucca is a perfect example of a stratified city centre, where ancient monuments have survived into later ages and become part of a "different" city: their preservation has been possible because of this transformation. Similar evidence, though not always so clearly discernable, can be found in numerous Italian and European city centres.

Figure 2: *Remains of roman wall in Santa Rosa Church*

In contexts of this kind, GIS would appear to be the most suitable tool of inquiry for the elaboration of complex phenomena able to reveal the ancient [FOR02]. The LUCA information system has been designed for the analysis of stratified urban contexts, and poses as a pilot project in archaeological sector where GIS applications are not yet widely used.

Information and Communication Technology enables us to enrich our knowledge and documentation of data from any discipline and offers an invaluable support in all operations involved in the conservation, enhancement and management of our cultural heritage. So, the aim of LUCA is to reconstruct Roman Lucca using GIS technology.

At the basis of our theoretical and methodological approach lies the creation of an advanced system in which it is possible to integrate the management of all existing documentation (cartography, iconography, surveys, images, descriptive data, bibliography). The information collected will be processed after analysis, tackling some of the problems involved in a cognitive approach to our heritage, leading to proposals for action strategies. In addition, the system we intend to create will enable us to monitor and update records of the archaeological, architectural and historical heritage that are the object of our research, so as to build up an archive able to produce layers of information concerning both current and previous situations. In this way it will be possible to piece together a detailed picture of the history of the buildings analysed.

LUCA has been designed for the acquisition of all types of data concerning Roman Lucca from multifarious sources such as old and new digs, architectural records, and measures in force for the safeguarding of archaeological areas and monuments.

It is important to underline that the nature of the system and the heterogeneity of the data entered will make it useful to, and usable by, a wide range of users: e.g. protection, conservation and management entities (Supervisory offices), scientific bodies (universities and research bodies) and local administrations, with a variety of aims: e.g. applying and administrating archaeological and architectural restrictions; working out programmed maintenance strategies; planning restoration; organising exhibitions; carrying out scientific studies; or experimenting new technology for the safeguarding of historical buildings. In addition, the non-specialist user will be guided towards a discovery of Lucca's hidden Roman heritage, which would otherwise risk remaining unknown to the public.

Figure 3: *Roman Amphitheatre.Remains in later buildings external façades*

2. LUCA: looking at an Urban Context Archive

The first stage of the project was to gather all existing material about Roman Lucca: current and historical maps on various scales, pictures, general and specific surveys, descriptive data and bibliographical data.

Most of the cartography is already in raster graphics and, in some cases, also georeferenced. In this project the main base-map is a scale 1:1000 cadastral map draped over a georeferenced satellite image. All the other cartography, whether current or historical (IGM maps and specialist maps, such as geological maps), must be put into digital format by scanning, and subsequently georeferenced using the same geographic reference system (fig.5).

Various kinds of images have been collected: aerial photogrammetry taken from flights over the city at different times; satellite images; current and historical photographs of architecture and architectural details in Lucca. While the aerial photogrammetry and satellite images will overlay the main basemap and so be georeferenced on it, other images will be managed together with the various information they refer to.

Figure 4: *Roman Theatre. Remains near Sant'Agostino Church*

The iconography relates to paintings and historical representations of Lucca and its monuments: this data typology is still considered "imagery" in that it has been put into digital format and managed as those described above.

Shots of architecture and architectural details of one kind and another are in raster or vectorial graphics. In both cases they will overlay the LUCA basemap (fig.6).

The project is developed in ESRI ArcGis 9.1 environment and all the information will be memorised and managed inside a Geodatabase (in MsAccess© 2000 format). This is structured along the lines of a relational database, but contains geographic information that is linked to the geometrical elements represented in the Information System, and is filed alongside descriptive and bibliographic information, together with information gleaned from the analyses of texts and material taken from sectoral supervisory offices and archives (fig.7).

The study of documentation has highlighted the need for an implementation of the information available; most surveys of Roman buildings date back to the end of the seventies and it is sometimes no longer possible to overlay this on the current situation. Human intervention or alterations caused by chemical, physical or biological factors have changed the morphological and structural character of these buildings. For this reason new data acquisition campaigns have been planned using innovative surveying systems. The introduction of information sciences to this sector has drastically modified the acquisition stages, especially the subsequent operations of elaboration and management.

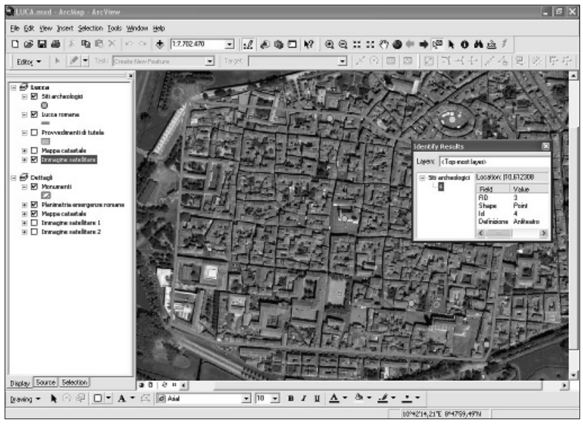

Figure 5: *GIS environment. Perimeter of roman Lucca with example of Info Tool query*

Today, innovative techniques offer the possibility of adding the wealth of qualitative and morphological data pertaining to the colour and details of a photographic image, to the mensural precision of photogrammetry, together with the additional possibility of measuring, calculating surface areas and creating thematic variations.

The reliefs obtained with the new quick photogrammetric surveying methods, which make use of equipment and software able to show metrically controlled, i.e. measurable, images in stereoscopic or monoscopic environments, will be found in LUCA Information System [SNV*05].

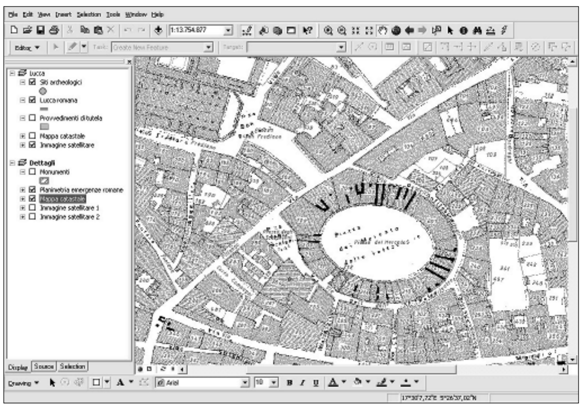

Figure 6: *GIS environment. Cadastral map with in black the remains of roman Amphitheatre*

The application of these photogrammetric surveying techniques to monuments in Lucca will enable us to bring in additional information that is currently unobtainable from existing documentation. The quality and quantity of data contained in an orthorectified image of a stretch of wall or the remains of a theatre is considerable, so it will not be necessary to return the survey in detail, but will be enough to overlay information concerning items such as materials, state of conservation and any deterioration pathologies, directly on the image.

In the case of the amphitheatre, in view of its particular morphological characteristics we will experiment with 3D laser scanner digital acquisition in order to secure extremely accurate geometric information for the monument, and at the same time obtain a three dimensional model. In this way it will be possible to study the amphitheatre both from a geometric/morphological point of view and from that of its state of preservation, and also put forward further new critical interpretations. The three-dimensional model will also make the amphitheatre readily visible both for the specialist user and the general public [SCO06].

The methodological approach will therefore be to set up a process whereby the acquisition and examination of all the documentation, can lead to the formation of an initial cognitive base for Roman Lucca that is open to subsequent updates and implementations.

LUCA was designed as a tool for integrated information analysis by which it will be possible to obtain cognitive elements from its elaboration of input data, such as: the calculation of surface areas that have deteriorated in a similar way; the number of elements made from the same material; or the presence of particular deterioration pathologies.

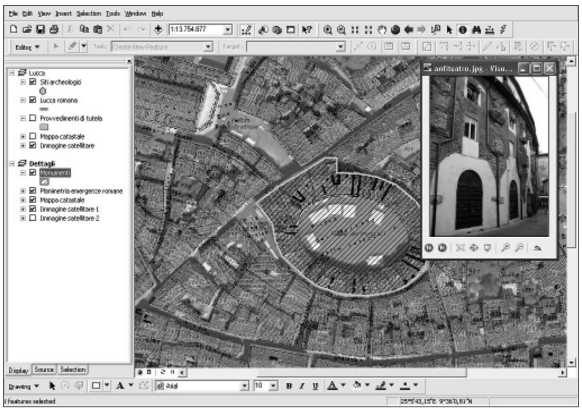

Figure 7: *GIS environment. The roman Amphitheatre in evidence, with the superimposition of an image*

Setting up an informatic environment in order to analyze and to synthesize information will enable the overlay of several themes for an object under examination, and the interpretation of different phenomenologies.

Finally, in order to return a complete view of Roman Lucca, LUCA can integrate two dimensional information with a three dimensional elaboration. It will build a model where the cartography and images are integrated with a 3D reconstruction making the built-up area of the ancient city easily discernible. In this way, the far from obvious appearance of Roman Lucca will be effectively recuperated even for the non-specialist. The new technologies enable users to see ancient remains from the point of view of the inhabitants of old, bringing cities to life.

3. LUCA: an eye to the future

New technologies make it possible to create integrated data management models. In so doing, not only do they enable our cultural heritage to be studied in multifarious ways, but they also stimulate new proposals for interpretation, satisfy various needs and enquiries, and encourage greater awareness and appreciation.

Therefore, data management within LUCA will bring greater visibility, understanding and appreciation to an otherwise inaccessible, or barely explorable, heritage since most of the remains of the Roman city have been incorporated into later buildings and are no longer visible. Thanks to the system we intend to create, it will be possible to "visit" Roman Lucca by alternative paths that are difficult to trace in real life, where spaces, monuments and archaeological remains will be placed in relation to each other, revealing the ancient city within the modern one. So, this operational tool will become fundamental not only for the safeguarding, preservation and valorisation of this Roman heritage, but also for its enjoyment by non-specialist users.

Finally, the purpose of this work is to plan and create an Information System that can be applied to architectural and historical-artistic records from earlier periods, within the same urban context. The main aim is to create a pilot project that enables all bodies concerned with preservation, research, restoration and valorisation, to share information and study, exchange data, and operate synergically, reaching and guaranteeing the total monitoring of cultural heritage. Use of the system described will serve not only to file and process all the existing records of Roman Lucca, but also to add new fundamental data through the acquisition of further information from sources such as innovative surveys on artefacts [SN06].

As well as knowledge optimisation and management for Roman Lucca, the aim of the project is also to set up an exportable tool i.e. one that can be applied in different contexts. Italy's rich archaeological heritage, preserved in town centres, is deteriorating to the point that it risks disappearance due to building expansion and neglect. Efficient, easy-to-consult tools are urgently required to facilitate preservation and enhancement efforts. We should hope that bodies concerned with management, protection and preservation, particularly Supervisory offices, will avail themselves of an Information System that guarantees real time monitoring of a situation that by its very nature is in constant evolution.

The proposed methodology sets up a unit in which it is possible to create a multiplicity of study paths, differentiating according to different user needs, able to produce readily interpretable, objective, reliable and scientific information.

Knowing an ancient city is fundamental if it is to be respected and protected so that it will continue to live and represent a reference point for the identity of its inhabitants.

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Short Papers

Automatic Coarse Registration by Invariant Features

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Abstract

The increasing availability of relatively low-cost range sensors such as laser scanners and structured light systems has dramatically changed the traditional approaches to the documentation, monitoring and fruition of cultural heritage findings. Three-dimensional shape modeling is often the final goal of the processing pipeline which starts from the acquisition of overlapping scans of the entire work of art. A crucial step in the processing pipeline is the optimal alignment of the scans in a common coordinate system, the so called registration step. In this paper we present a new feature-based approach to the coarse registration between partially overlapping range images. We first extract some "feature points" from the range images and then we characterise them by invariants to Euclidean transformations. The novelty of our method relies on the choice and design of the invariants which is supported by the theory of moving frames recently developed by J.Olver. This provides us with an algorithm to find the fundamental sets of invariants necessary to parameterise a signature manifold that characterises the original manifold up to Euclidean transformations. To maximise performance against noise we can design invariants that depend on distances and 1st order derivatives only. To reduce the overall computational complexity, the invariants are estimated on a subset of the data. This consists of feature points where the Gaussian curvature of the surface underlying the data reaches a local maximum. Preliminary results on standard 3D data sets from web repositories and on original scans of works of art show the effectiveness of the proposed registration algorithm.

Categories and Subject Descriptors (according to ACM CCS): I.3.5 [Computer Graphics]: Geometric algorithms, languages, and systems I.3.8 [Computer Graphics]: Applications

1. Introduction

Recently, the appearance on the market of affordable range sensors such as scanner lasers [Bla04, Bes89] and structured light systems [PSGM03], together with the rapid development of a wide variety of processing methods for three-dimensional (3D) data [BR02], have created new approaches to cultural heritage [Ls00, Rs00, TBG*03, ATS*03]. The cultural heritage community well recognizes the potential of accurate virtual 3D digital models of works of art. Indeed, they can support more traditional approaches such as photogrammetry in the documentation and monitoring of works of art and monuments [Leb01, ABC04, GBA04, ATS*03]. The data processing pipeline for shape modeling of 3D structures starts with the acquisition of a set of scans overlapping the 3D structure [BR02]. The acquisition of the entire object surface generally requires several scans obtained by successively repositioning the device around the target object. The procedure for the optimal alignment of the obtained data sets in a common coordinate system, the so called registration step [HH03, PMW05], requires the recovery of the relative poses between the sensor and the scanned object. Solutions based on position measurement devices are sometimes unfeasible, expensive, or even impossible, and the manual registration approach is time consuming and requires trained operators. An emerging alternative is the automatic (unsupervised) registration, where the information about the relative poses of the scans is estimated from the data only. In this paper we describe an automatic registration method which solves a basic step of the general problem of registering multiple scans; the registration of pairs of partially overlapping scans, or pair-wise registration. For some comprehensive reviews on registration see [HH03, PMW05, CF01, MSFM05], and for recent developments see [RFL02].

Our goal is the coarse registration of two scans [HH03, CF01], where a suboptimal alignment is estimated from scratch. This is an essential task to perform before mov-

ing on to the next step in the pipeline: the fine registration of multiple scans [RL01] where, starting from a given alignment estimate, an iterative optimization leads to the final optimum. Up to now a wide variety of coarse registration methods have been developed; see the reviews and [CHC99, Thi96, LDC02, PFC*05] for some recent works, and [ABC04, GBA04] for specific applications to cultural heritage.
According to the classification in [PMW05, CF01], our method belongs to the class of feature-based registration algorithms. We work directly with sets of 3D points (no extra structures are assumed). We characterise the data sets by signatures computed from sparse feature points. The feature points can be chosen arbitrarily, as long as they are reliable and invariant to Euclidean motion. Here we chose points of local maxima of the Gaussian curvature of the surface underlying the data. They were extracted by the curvature map of the data set, evaluated as in [KLM98, Pet02]. Neighbouring feature points are grouped in triplets on which we evaluate a set of 7 invariant functions that depend on the 3 interpoint distances and on local 1st order derivatives. We define the signature as the set of 7D vectors obtained evaluating the invariants on all the triplets. The signatures are interpreted as points of a multidimensional signature manifold that is invariant to Euclidean transformations. If the signatures generated by two scans have a sufficient number of corresponding points then there will be overlapping patches on the scans. The best matches between the signatures allow the estimation of the optimal alignment thus solving the coarse registration problem. Compared to other feature-based approaches [Thi96, PMW05], the novelty of our approach relays both on the theoretical bases which support the choice of the invariants in the signatures and on the proper design of the minimum set of invariants to be used. In fact the theory of moving frames recently developed by J.Olver [Olv05] provides us with a framework to define a fundamental set of invariants used to parameterise a signature manifold that characterises the original surface up to Euclidean transformations. To maximise performance against noise we choose signature invariants that depend only on distances and 1st order derivatives. We could have even chosen invariants that only depend on distances, at the cost of an increased computational complexity. The paper is organized as follows. In Section 2 the main results of the theory of moving frames and the signature characterization of triplets is discussed. In Section 3.1 the curvature estimation and the feature point extraction procedure is described. Section 3.2 describes the triplet matching procedure. Preliminary experimental results are shown in Section 4 and finally, the conclusions and some future work proposals are discussed in Section 5.

2. Moving frames and joint invariants

We introduce some general concepts about the theory of joint invariants and joint differential invariants developed in [Olv01](see also [Olv04] for a shorter exposition). In Olver's work, the classical theory of moving frames first developed by Cartan [Car35] is extended to give a procedure to obtain fundamental sets of joint invariants that are functionally independent and that generate any other invariant to the transformation group being considered. In particular, we can assume that our transformation group is the one of rototranslations in the usual 3D space. Indeed, that is the sort of motion the acquisition system undergoes when we change its position in order to scan the whole object.
For a surface in 3D space, classical invariant theory leads to the Gaussian and Mean curvatures, which, together with their 1st order derivatives with respect to the Frenet frame parameterise a signature manifold that completely determines the surface up to rototranslation i.e. two surfaces are the same up to rototranslation if and only if their signature manifolds are the same. In practical situations, derivatives of 3d order amplify noise too much to be reliable. Here is where joint invariants came to the rescue: they are invariants that depend on more than one point at a time, enabling us to build a signature of lower order (i.e. one depending on derivatives of smaller order) and therefore less sensitive to noise. Basically the moving frame method allows us to find a set of fundamental joint invariants of order zero. The joint differential invariants (order ≥ 1) can be obtained by invariant differentiation of the fundamental joint invariants with respect to some differential operators that depend only on the transformation group. By varying the number of points the invariants depend on, we can control the order of the invariants that are necessary to parameterise a signature that characterises the surface up to rototranslation. As a result we can control the order of the signature. The more the points the invariants depend on, the lower the order of the signature. In particular, with 3 points the invariants are of zero and first order. We found that this choice allowed us to achieve both computational feasibility and robustness.

2.1. Signature definition

Let p_1, p_2 and p_3 be three points of the surface. If the surface is smooth we can define the normal n_i at each point p_i. Furthermore, (see figure 1), we set $r = \dfrac{p_2 - p_1}{\|p_2 - p_1\|}$ and $n_t = \dfrac{(p_2 - p_1) \wedge (p_3 - p_1)}{\|(p_2 - p_1) \wedge (p_3 - p_1)\|}$ to be the normal to the plane through the 3 points.

The zero order invariants are the 3 interpoint distances $I_k(p_1, p_2, p_3)$ for $k = 1, 2, 3$:

$$I_1 = \|p_2 - p_1\|, I_2 = \|p_3 - p_2\| \text{ and } I_3 = \|p_3 - p_1\|$$

The first order invariants are the following:

$$J_k(p_1, p_2, p_3) = \frac{(n_t \wedge r) \cdot n_k}{n_t \cdot n_k} \quad \text{for } k = 1, 2, 3$$

and

$$\tilde{J}_k(p_1, p_2, p_3) = \frac{r \cdot n_k}{n_t \cdot n_k} \quad \text{for } k = 1, 2, 3$$

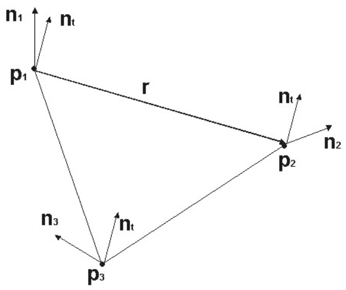

Figure 1: *Triplet with associated normals*

By algebraic means we showed that J_3 and $\tilde{J}_3$ are functionally dependent on J_1, J_2 and $\tilde{J}_1, \tilde{J}_2$ respectively and can thus be discarded. For each triplet (p_1, p_2, p_3) of the surface we can then associate a point of the signature given by $(I_1, I_2, I_3, J_1, J_2, \tilde{J}_1, \tilde{J}_2)$. As the invariants depend on 3 points, each of which has 2 degrees of freedom on the surface, the signature will be a 6-dimensional manifold embedded in 7-dimensional space. After generating the signatures, if we wanted to check whether two surfaces share a common subset up to rototranslation, we would have to compare them to see if they intersect. If they did in a subset whose dimension equals that of the signatures, it would imply that the two surfaces share a common patch. Conversely, if the signatures did not intersect in such a subset then the surfaces cannot share any patches. Unfortunately our scans come as discrete sets of points rather than continuous surfaces, thus requiring us to adapt the concepts of signatures and signature matching to the discrete case.

3. Registration algorithm description

The core of the algorithm is based on the theory of joint invariants illustrated above. To approximate the continuous signature, the most natural choice would be to generate a point of it from each triple of points in the data set. However, due to the size of the scans, this is computationally unfeasible. Our solution consists in restricting the computation to a subset of feature points of the data set, which results in a subsampled signature. Subsequently we compare the signatures by means of Euclidean distance between their points. If there are enough corresponding points we conclude that the signatures share a common portion. Although a single correspondence could bare enough information to perform the registration, to add robustness to the registration stage a greater number of correspondent points is required. We can subdivide the algorithm in three parts: feature points detection, signature generation and matching, rototranslation estimation. Due to the early stage of the work, any considerations about algorithm optimization have been postponed to a subsequent phase. Algorithms and parameters have been tailored in order to complete the coarse registration of a pair of scans within a few minutes on a consumer PC. It is worth mentioning that the signature generation and matching is by far the most time consuming part of the algorithm.

3.1. Feature points detection

The feature points can be any set of points that are characterisable and searchable upon the surface. They can be based either on geometric properties of the surface (maxima of curvatures, umbilic points, crest lines [Thi96]) or, if available, on the luminance or colorimetric properties of the underlying images. The requisites they must have are robustness against acquisition noise and invariance up to rototranslation. It is well known that acquisition devices produce noisy scans due to the limited accuracy of the measuring device itself and to the sampling process (two overlapping sets of points are points lying on the same surface but not necessarily the same points). In our algorithm the feature points are defined as the points of local maxima of the Gaussian curvature of the surface underlying the data. The feature points are detected from the curvature map of the data set, evaluated as in [Pet02]. The choice of the scale, i.e. the size of the neighbourhood used for curvature estimation, has been set to 5-10 times the median distance between the points of the scan set. This choice has proved to be a good trade-off between resolution (finer scale) and robustness (coarser scale). After Gaussian curvature estimation the local maxima are selected as feature points. To limit computational costs only the $N \sim 200$ points of highest curvature are included in the feature points set (see figures 2 and 3).

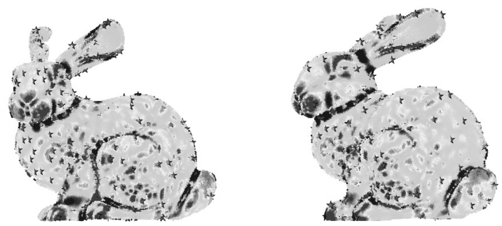

Figure 2: *Gaussian Curvature of two scans* (0° *and* 45°) *of the Bunny set.*

3.2. Signature generation and matching

The surface signature is calculated according to the definition in Section 2.1. For each triple of feature points a 7-value point of the signature is generated and stored. Since it is unlikely that two far away points belong to overlapping areas of the two scans, in order to limit computational complexity and memory requirement we impose a limit on the maximum

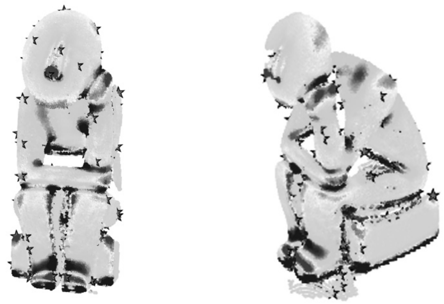

Figure 3: *Gaussian Curvature of the front and left scans of the Thinker.*

Figure 4: *The Thinker.*

distance between the points of the triple. By setting the limit to half the scan size, we can reduce the number of signature points to less than 1/4 of the total whilst preserving almost all the points originating from the overlapping parts of the scans. After generating the points of the two signatures we check if they intersect. Since we are not dealing with continuous signatures, but only with sparse points of them, we cannot determine an intersection in the proper sense. Instead we look for points of the two signatures that are close enough (Euclidean metric) to reasonably claim they originated from the same triplets of points. In practice we set a threshold in a heuristic way and search all the couples of points of the two signatures whose distance is under the threshold.

3.3. Rototranslation estimation

The output of the previous stage of the algorithm is a set of corresponding points of the two signatures. Each correspondence establishes a relationship between two ordered triplets of points of the two scans and so it determines a rototranslation that will take the points of one triple to the respective points of the other. Therefore each correspondence carries enough information to solve the coarse registration problem. In practice, however, the simplifications we adopted to calculate the signatures may lead to spurious solutions. In order to make the estimation process more robust we separate the correct triplet correspondences from the outliers by means of a RANSAC algorithm [FB81] applied to the rototranslations associated to the correspondences.

4. Experimental results

The registration algorithm described in the previous section has been implemented in a preliminary version and tested on two different scan sets. The first is the well know Bunny set available from the Stanford Repository. The second is an original scan set of the Thinker in figure 4, a small statuette recalling ancient Cycladic Art acquired with a laser scanner Minolta Vivid 910.

The Bunny set consists of 6 lateral scans and the Thinker set of 8 lateral scans. In both cases the sets of scans cover the surface of the object almost entirely. Figures 2 and 3 show the Gaussian curvature and its maxima calculated on two scans from the Bunny set and on two scans from the Thinker set respectively. For both sets, each couple of adjacent scans has been fed to the coarse registration algorithm which gave a rototranslation matrix as output. The two compositions of all the coarsely registered scans in a common reference frame are shown in figures 5 and 7. The refinements after processing the coarse registrations with ICP [RL01] can be seen in figures 6 and 8.
To evaluate the effectiveness of the algorithm on both scan sets, we have applied the ICP algorithm to each couple of coarsely registered scans. The results are illustrated in tables 1 and 2. The distance threshold for matching closest points within the ICP algorithm was set to be about twice the resolution of the scan sets. In each column of the tables we specify the scans S_i that were registered (the subscript i indicates the approximate rotation angle), the number N_i of points of each scan, the number N_{coarse} of matching points between the two scans before the start of the ICP iteration cycle, and the number N_{fine} of matching points after the last iteration of ICP. As we can see, the numbers of matching points before and after the ICP fine registration are very similar, indicating that our coarse registration is very close to the right solution and the ICP has to do little work to reach the global minimum. Notice that the last column in 1 and the last two columns in 2 refer to the fine registration of pairs of scans that were roughly 90 degrees apart. Despite the overlapping area was a mere 15% of the area of the scans, our algorithm managed to register them well enough for the ICP to converge to the right solution.

Table 1: *Number of corresponding points after coarse and ICP refined registration for the Thinker scan set.*

	S_0, S_{45}	S_{45}, S_{90}	S_{90}, S_{135}	S_{90}, S_0
N_1	49864	64085	56402	56402
N_2	64085	56402	58388	49864
N_{coarse}	26295	27099	28639	7001
N_{fine}	26366	27120	28657	7312

Table 2: *Number of corresponding points after coarse and ICP refined registration for the Bunny scan set.*

	S_0, S_{45}	S_{45}, S_{90}	S_{90}, S_{180}	S_{90}, S_0
N_1	40256	40097	30379	30379
N_2	40097	30379	40251	40256
N_{coarse}	29810	15642	7271	9731
N_{fine}	29854	15633	7334	9819

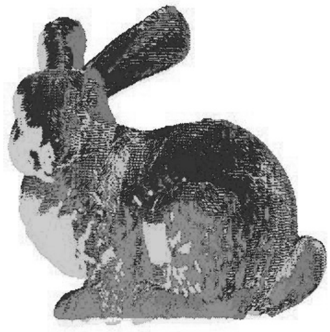

Figure 5: *Bunny coarse registration.*

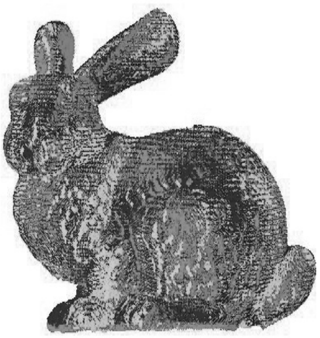

Figure 6: *Bunny fine (ICP) registration.*

5. Conclusions

This paper describes a new approach to automatic coarse pair-wise registration of partially overlapping 3D point sets usually generated by laser scanners, structured light or stereo systems. Our method consists of two steps: the first one is the detection of feature points (local curvature maxima) present in the data of the two scans. The second is the characterisation of feature points by invariant signatures and their match. The novelty of the approach relays in the use of an optimised set of invariants designed on theoretical bases, which are more robust to noise than other differential invariant commonly used in feature-based approaches to registration. The results on standard data show the effectiveness of the approach, which is also supported by visual inspection and the availability of ground truth for the alignment transformations. The average number of corresponding points does not change significantly after the ICP processing of the coarsely registered scans. This indicates the effectiveness of our method. In perspective, the performance of the proposed registration algorithm with noisy data should be investigated, and more work should be done to optimize the computational time.

Figure 7: *Thinker coarse registration .*

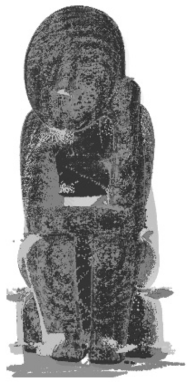

Figure 8: *Thinker fine (ICP) registration .*

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Short Papers

Designing a Real-Time playback system for a Dome Theater

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Abstract

Most dome display systems today employ pre-rendered shows for attracting visitors. In addition since the technology is well established, developers have many tools at their disposal for creating such shows. On the contrary real-time shows for dome displays are just starting to appear. As a result the production of such shows is not a standardized process. Slowly, progress is made. Graphics generator cards are able to support the required SXGA+ resolutions and the supporting cluster systems are able to supply the processing power and memory bandwidth that such real-time systems require. Tools have to be developed and new processes have to be established. The Foundation of the Hellenic World (FHW) having produced numerous real-time productions for immersive flat display systems has great experience in realizing such shows. In this paper we present the technological developments for the production of real time applications for digital dome display systems.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computing Graphics]: Three-dimensional Graphics and Realism – virtual reality. I.3.2 [Computing Graphics]: Graphics Systems – distributed/network graphics. I.3.6 [Computing Graphics]: Methodology and Techniques – device independence.

1. Introduction

Curved-screen spherical projection (dome) theaters are commonly associated with planetariums and other installations that project pre-rendered content, which can be compared to movie or video setups. The final image the "Dome Master" is generated offline using specially designed video editing tools and rendering software to perform the radial projection and image stitching. Depending on the projection system, this is then processed in special vendor specific tools to separate the stream for each projector and store it on disks [EMM01]. Real-time synthesized imagery is not very common in such type of installations due to the high complexity and performance demands of the underlying system.

The real-time virtual reality (VR) dome theater of FHW, utilizes a fully digital projection system, configurable in a monoscopic, stereoscopic or a mixed mode of operation. Six pairs of seamlessly blended SXGA+ projectors project the stereo synthesized imagery on a tilted hemispherical reflective surface of 14.4m in diameter Figure 1. The auditorium is designed to host up to 132 visitors at the same time. They will be transferred into virtual worlds and enjoy a truly immersive and interactive experience.

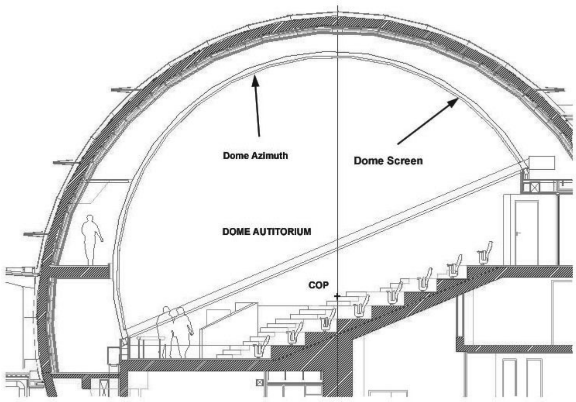

Figure 1: *The Dome Theatre of FHW. 132 seats, 14.4 m dome diagonal, 20 º of dome surface.*

During the design and implementation of the "Tholos" dome virtual reality system, many issues had to be addressed, regarding both the real-time rendering/simulation engine and the content production pipeline. These issues will be discussed in more detail in the following sections involving, the spherical projection configuration and reconfiguration, computing system architecture, the desktop production previewing tools and finally the stereoscopic display problems as well as the integration of interaction and video streams into a unified media platform.

2. Features and Benefits of Real-Time Dome Display

Today's digital domes provide impressive architectural setup and design, pre show areas, which attenuate the anticipation and prepare the visitors for the show while at the same time allow their eyes to adjust to the dark environment in the dome area. The projectors used provide high-resolution imagery on the dome surface, which covers the whole peripheral vision of its visitors. Special designed seats, tilted, with proper body support to provide comfortable view, supplement the plethora of dazzling features offering a much more exciting experience for a larger audience, fostering an increased willingness to suspend disbelief.

Additionally by incorporating controls on each seat an increased level of participation can be reached, turning each show into a performance where spectators participate actively in the unraveling story. Currently the most common way in dome for mass interaction is by employing a voting/poll system where the visitors influence the storyline by placing their votes at discrete time frames using the chair controls.

Furthermore, a real-time dome display system can combine pre-rendered and real-time graphics in a seamless manner, as well as incorporate interactive, live on-stage action. The possibilities are limitless, provided a flexible, extensible and sustainable infrastructure is properly designed and built. The ability to host large audiences make dome theaters almost ideal for demonstration purposes and large-scale visitor attractions providing greater throughput, cost effectiveness and profit sustainability.

3. Real-Time Rendering Issues

3.1. Projection Setup

Real time engines for Dome projection differ in various aspects from engines designed for standard wall projection single screen systems. The primary difficulty is the need to render to multiple tiles seamlessly providing overlap for blending. This implies the generation of multiple, overlapping off-axis (oblique) projection frusta, which correspond to the frusta from the common center of projection (COP) to the dome surface. The combination of various streams of different projectors to a unified picture is not feasible without proper alignment and hardware to cover the edges between adjacent tiles. Mechanical alignment on the projector position and calibrations are not adequate for pixel perfect transitions, which are not noticeable by the eye. Therefore projectors use special composition for stitching and warping the output streams onto the Dome surface to match their geometry and blending masks to help fade seamlessly the black levels and color image from one tile to another.

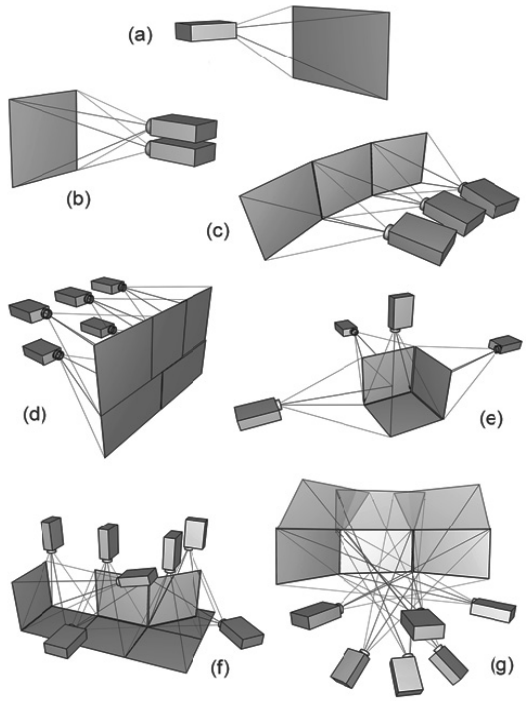

Figure 2: *Examples of display tile configurations possible with TiDE: (a) planar active stereo, (b) planar passive stereo, (c) curved-screen reality center, (d) large video wall, (e) CAVE like, (f) arbitrary topology, (g) dome.*

Warping and Stitching can be done either in software on the driver level as is shown in open source solutions [BOU05], [JJ05] or with external hardware. The later solution is preferred for midsize to large planetariums and was also the preferred choice for the FHW Dome because it introduces no additional software path, which might slow down the overall application and offers greater flexibility in alignment and setup.

Having all that in mind, we have implemented a display module, named TiDE (Tiled Display Environment) [GGD*06], which operates as a projection matrix configuration adapter between the actual rendering process and the graphics outputs of a system. An XML configuration file provides a list of any possible scripted configurations, defining the actual tiles in space, the COP, monoscopic or stereoscopic rendering. So the user of the system does not have to worry about frusta and display channels. If one knows the physical positioning and size of the target projection surfaces, any arbitrary view can be transparently generated see Figure 2. The FHW Dome consists of six pairs of projectors rendering in stereo with 72% field of view on the Dome surface with 20% overlap.

3.2. Computing Cluster

In order to drive a multi-display environment such as a dome, multiple graphics outputs need to be synchronized at each frame to generate partial views of the same panorama. One convenient solution, traditionally available was the purchase of shared memory multiprocessor/multi-pipe systems from custom vendors. Unfortunately these solutions are being phased out since the market and scientific community turned to cluster architecture of individual machines which provided lower cost of maintenance and upgrade, support for the latest advancements in hardware and better performance.

For powering the FHW Dome spherical display, twelve projectors and cluster PC's were chosen, each projector being powered by one machine and each pair of projectors/machines providing the stereo imagery for one of the six tiles on the surface. We have implemented an asymmetric master/slave cluster configuration, which provides a highly parallel execution and has almost zero scaling overhead (frame lag) when adding new node (see taxonomy in [ZK02]). Each node is a completely self-contained VR system, advancing at each frame according to the user and application dependent variables. However, this set of data is very small and only consists of the user interaction primitive actions (e.g. button presses, tracker input, joystick values) and a global application reference clock. The role of the master is reduced to that of a coordinator of the other nodes (slaves) and only provides synchronization for the global clock and the user input data. The above functionality, synchronization and data exchange layer is handled by an application-independent library we have developed, named EVSSyncer.

For defining the projection setup each node has its own display configuration script (XML file) using the TiDE framework described earlier and therefore knows how to render the appropriate area.

3.3 Audio Hardware

One of the most important and impressive features of digital domes is their sound design. Multiple subwoofer and stereo boxes are placed at specific positions behind the dome surface to provide immersive surround sound conforming to THX or Dolby Surround specifications. The sound software must support the setup and provide 3D sound sources and specially designed fading mechanisms for 3D panning the sound source inside the dome.

We have implemented a custom driver layer above OpenAL [OAL] for adjusting its functionality to the sound system used. A special sound subsystem PC is used to handle, playback and synchronize the sound media.

3.4 Interaction Hardware

To increase customer participation every seat has it own unique controls, which have to be collected and processed by the applications. Besides the problem of how to interpret all these data developing the interaction metaphors there is also the burden to collect it. Each seat provides a 2 axis joystick with analog values [0-1] and at least 4 buttons with discreet values [0/1]. Usually a dedicated PC handles the entire input load and communicates its result to the master.

We have implemented the same approach using a custom PC, which interfaces the input hardware and communicates the data over UDP connection to the master. The VRPN [RTC*01] framework had already this client – server architecture and software daemons and was adapted to our setup.

3.5 Video Integration

Virtual reality theaters often need to switch to analog or digital video sources in order to project pre-rendered or live captured video content. The integration of streaming video into a multiprojector display environment can be done at a physical level, by redirecting the video source to the proper projector. Although this may work fine for a planar, slightly curved or cylindrical projection surface, it is not recommended for a dome system with fixed projectors. It is more flexible to be able to control the video output without caring about the physical configuration of the projection system. This means that the same production can be played at a different theatre without any modification.

We have implemented a simple yet effective mechanism for combining external video sources from files or other sources with the 3D environment [PGC03]. All video streams are handled as textures and may be applied to any type of geometric primitive or prepared geometry with or without a blending mask. Furthermore, an input stream can be on the fly combined and synchronized with a separate alpha-value stream (e.g. from chroma keying).

4. Desktop Production Previewing Tools

The usual practice is that a full-featured VR system, that drives a show, is only installed at the exhibition/VR theater site due to the specialized computing and audiovisual hardware integrated into it. Therefore, the development of the VR engine and the creation of the production content are very frequently done on a different platform than the one the final production is targeted for. Typical single-screen graphics workstations are used for both the aforementioned tasks and the application is then tested at specific milestones in the actual VR environment (the dome here). The VR industry has resorted to providing simulators of specific commercial environments (e.g. the CAVE simulator of VRCO's CAVElib) that run on single-screen workstations to alleviate this problem. In the case of the dome of the FHW, the use of simulators was imperative since the application and content development began well before the system was installed.

Unfortunately, there were almost no platform simulators available which would work on real-time content. Such simulators exist for Caves, Walls, Curved-Tilted displays, but for domes the tools available were only suitable for pre-rendered content. Although specific providers (such as Evans and Sutherland) [DIGISTAR] do distribute such proprietary dome simulators, as closed libraries for their hardware and software system, such a solution was not considered open enough.

Provided that the real hardware setup is calibrated correctly, the final result of all masked/blended projector images is a seamless hemispherical image. It became clear that to simulate successfully such a setup with high frame count, projections should be done by the graphics hardware. Essentially what was required was to place the dome virtually inside the 3D environment and project everything onto its surface, see Figure 3d-e. Cubic Environment Mapping [GRE93] supported in OpenGL since version 1.2 and Direct3D version 9, can be used to project six rendered images onto any geometry. The 6 texture tiles images can be conveniently rendered placing the virtual camera in the COP of the Dome, and rendering the scene 6 times with the appropriate viewing transformation. These images are then projected transparently without seams onto the dome. Practical cube map implementations [SA04] result in very small texture stretching since the texture tile that is most perpendicular to the normal vector at a given point is chosen for texturing the surface.

The final implementation of the dome simulator is parametric, tilt, aperture, center of projection can be adjusted to match different setups. Another, application specific piece of functionality that was added involved the ability to simulate the vista from any of the 132 seats of the FHW dome and from arbitrary points in space. This allowed us to get a very clear idea about the apparent distortion from the visitors' point of view as can be ssen in Figure 3a-c. As the simulator is hardware-accelerated, the frame rate remains high despite the overhead of rendering the scene 6 times to produce the cubemap and it can be easily tied to any 3D graphics engine. The dome simulator provided a reliable preview mechanism and observation of various peculiarities and viewing problems of the dome production.

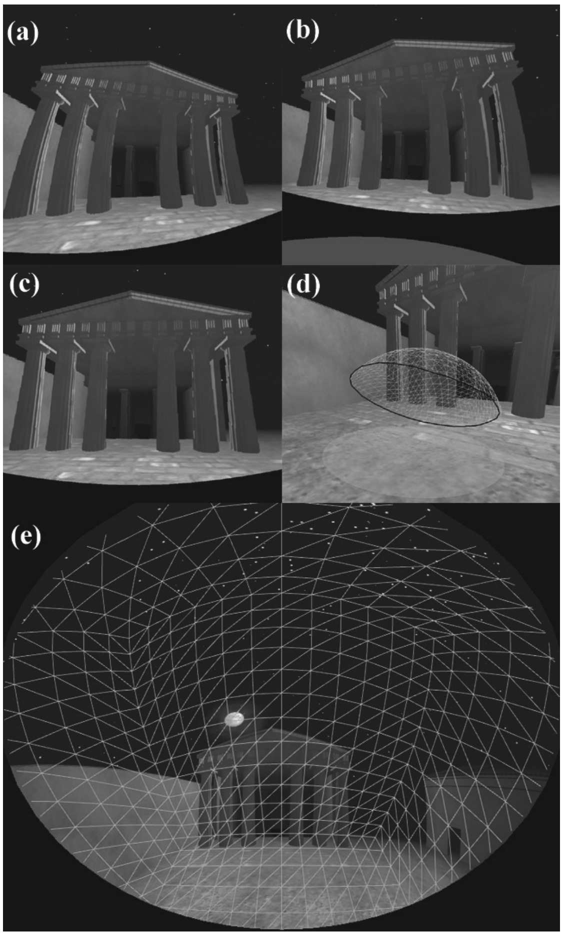

Figure 3: *The dome simulator (d-e) and resulting distortion tests. (a-b) Vantage points away from the center of projection. (c) View position in the vicinity of the center of projection.*

5. Viewing issues with respect to spherical Displays

Transferring a production pipeline from traditional wall displays to Domes introduces various problems and issues both in rendering and interaction.

5.1. Motion Magnigfication and Navigation

In Dome displays the limitations and restrictions, of high frame per second (FPS) and smooth motion, applying to real-time systems are even stricter. Because of the wide FOV, size and orientation of the display, the resulting motion magnification makes lower frame rates, even during small periods of the application, totally unacceptable. This also means that any sudden/abrupt change in the navigation introduces "cyber sickness". If control is not smooth enough the audience may feel disoriented.

Artifacts and rendering problems are also magnified and are harder to hide. In general low polygon geometry looks a lot worse than in traditional systems, which suggests that an increase of geometric quality is needed.

Useful metaphors for large audience interaction have also to be developed. Instead of 1-2 user devices an interactive dome has to handle a large amount of input data, usually equal to the amount of visitors. Currently the vote-poll mechanism is widely used but other ways of interaction are open for research. When voting-polling, each visitor has a button/joystick, which he uses to influence the storyline and feel part of it.

5.2. Stereoscopic Display

Stereoscopic viewing and depth perception in VR is achieved by generating a pair of images, one corresponding to the viewpoint of the left eye and one of the right and then directing them to the corresponding eye using simultaneous or interleaved image projection.

The established eye-separation mechanisms for non-contact viewing systems (head-mounted displays) are active and passive stereo. However, for stereo in a large dome theater, not all technologies work well. Active stereo is more expensive, not only due to the active projectors and the active stereo glasses, but also because of the high bandwidth demand on the rest of the system including image generators, interfaces, cables, switchers etc. In addition, active stereo glasses break easy so they are not suited for large public audiences. Polarization-based passive stereo also is not fitted for domes due to its narrow field of view due to possible cross-talk (ghosting) and the requirement of high gain reflective polarization-preserving screen. The Infitec™ (interference filter technology) passive stereo solution does not require special screen coating on the other hand [JF03]. Infitec™ delivers stereo separation without ghosting, with full freedom of motion, independent of head tilt. The images (left and right) arrive simultaneously from a pair of projectors. The place of the polarized filters take optical interference filters that perform a frequency division multiplexing of the stereo pair.

Full dome stereo is challenging because of the large audience volume that view the same imagery from completely different viewing angles [HOD93]. If interesting images appear at the top part of the dome and even further back then visitors continue tilting their head backwards to observe those images or they turn their head or they turn their head sideways, consult Figure 1. If polarization passive stereo is used and the head is tilted further than the optical axis of the projectors, the eye-piece filters allow the wrong polarized image to pass through, resulting in cross-eye stereo viewing, which is quite annoying. Wavelength division multiplexing is free of this problem and requires no particularly expensive or fragile glasses.

5.3. Image Distortion

The location of the center of projection (COP) for a dome production is important. The COP is the point inside the Dome around which the content is designed and where the imagery will appear geometrically correct. Usually, COP coincides with the center of the spherical surface. It is considered acceptable that even if no one is seated exactly at the COP, there is a fairly large area in its vicinity where viewing is optimal and distortion-free, like in Figure 3c. As we move further away from the COP, we perceive the intersection of a projected line segment (i.e. a plane) and the curved surface as an arch, due to our oblique relative view direction, as seen in Figure 3a-c. This problem tends to be very noticeable when displaying architectural elements or other shapes with long straight lines and flat surfaces. The effect is further accentuated by fast motion, e.g. navigation through an archway or between pillars.

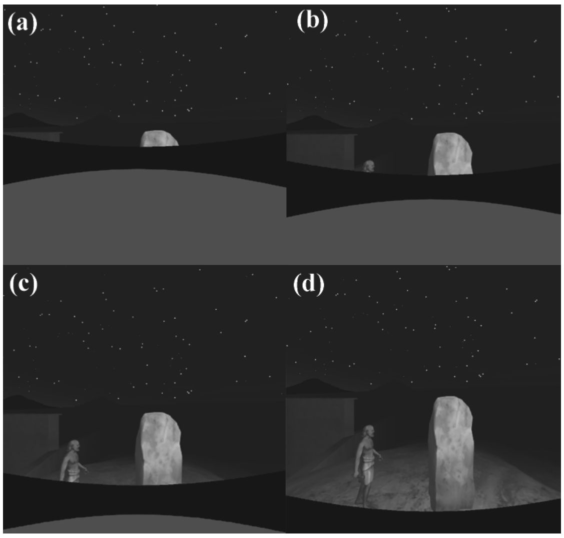

Figure 4: *Vertical Field of View, shows how much of the ground is seen by the visitor. (a) Using no tilting at all. (b) 10° tilt. (c) 20° tilt. (d) 30° tilt.*

5.4. Limited Vertical Field of View

Although a dome display environment has a very large field of view (FOV) (in the case of the FHW Dome, a vertical span of 160 Degrees), it is centered close to the top of the dome. This comes in contrast to the traditional movement and setup of the camera, which points horizontally upfront where the main FOV of our eyes normally is. Existing VR installations such as CAVE-like surround screen environments or curved-wall systems provide a large FOV mainly around the horizontal direction. On the other hand, domes have a very limited FOV at the baseline (physical horizon), which makes scenes with content close to the ground or below the ground horizon difficult to visualize. A technique to alleviate this problem is to virtually shift the FOV vertically, as shown in Figure 4, by slightly tilting the virtual horizon up, applying a rotational transformation on the viewing matrices. For the same reason the dome structure is tilted by design 23 degrees downward. The cumulative effect of the physically tilted dome and the virtually lifted horizon produces an adequate FOV to convincingly visualize objects near the spectators at ground level and have a substantial part of the ground environment in view for better logical reference. A 10° tilt of the virtual horizon is in most cases acceptable but it should not be combined with a fast forward motion into the virtual world as this can cause nausea on visitors further away from the COP [LBV99].

6. Conclusions

The curved surround screen of a dome and the multi-channel display requirements impose many restrictions and problems, such as the ones we have encountered and discussed in this paper. Not all content can be equally successfully ported to a dome VR theater and special care has to be taken to adjust and rearrange the virtual environment to match the physical properties of the dome.

Nevertheless the future for real-time digital dome display looks promising. Standardized/unified interfaces for all the tools from production through to theater automation, have to be specified. Hardware specific arrangements still dominate the way the final production is to be shown. Not every animation/production house has a dome theater for production; therefore general preview tools like the one implemented at FHW for their Dome is essential to open the dome market to more users. Off the shelf 2D/3D rendering packages should adapt to that market and provide the creation of arbitrary/programmable camera projections for real-time WYSIWYG preview.

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Mapping Ancient Mediterranean Trade Networks.

Abstract

Luxury and commodity items widely traversed the Mediterranean Sea during the Bronze Age. However the intricate trading relationships amongst cultures in the region are not clear. Modeling trade-routes by drawing on comparative archaeological evidence uncovered at sites can be assisted by the application of a GIS database. By mapping the quantity of foreign goods at archaeological sites, patterns and insights may be revealed as to the movement, and the extent of trade that was involved in transporting these goods. When this GIS database is created it will be made available on the internet to provide access to material that can be cross-referenced by researchers to related sites they are investigating.

Categories and Subject Descriptors H.1.1Value of information, H.2.8Image databases,H.3.2Information Storage

1. Trade and Mediterranean Bronze Age Societies

That an extensive trade network existed during the Bronze Age in the Mediterranean is attested to by the many finds of foreign goods at sites beyond their immediate area of influence [Bet98]. This is further confirmed by lists of for example Near Eastern commodities that are described in Linear B tablets found mainly at Mycenaean Pylos [She98]. Goods ranged from finished luxury items to exotic raw materials. What is not very clear is the direction of the trade routes that were taken by ancient Mediterranean traders as they exchanged goods throughout various regions [Ast98]. There is no straight forward method to determine how goods moved as they were traded from one area to the next. Land routes most probably were used in conjunction with important sea routes throughout the Mediterranean region. It has been argued that sea routes played a vital role for the broad interaction of local cultures from the time people started sailing [Bas98]. This paper will focus largely on how to determine sea trade routes by using a Geographical Information System (GIS) database to map sites where foreign items were found, and by mapping sites where known export products were being manufactured.

Throughout the Bronze Age traces of cultural interaction in the Mediterranean can be determined by comparing the relevant material culture [Bet98]. Research concerning migrations of peoples, cross-cultural impacts, or trade networks usually focuses on comparative analyses of remains from archaeological sites scattered across a wide area. In order to conduct such comparative analyses access to published material is necessary. However it is proposed that a Mediterranean Archaeology database be established to record finds whereby results of archaeological research across sites in the area are readily accessible over the internet. In order to investigate the movement of goods in this wide area a digital map with the proposed trade networks is of vital importance. Having efficient access to data about where sites and ship-wrecks with distinctive imported artefacts are located can provide a means of spatially analysing the extent and distribution of traded items. This paper proposes that Mediterranean Sea currents and winds throughout the seasons also be incorporated in the database to assist in building models as to the movement of goods by ship throughout the year.

2. Mapping sites with a GIS: Conquests and Challenges

Having access to online GIS databases that contain data necessary for multi-disciplinary archaeological analyses is becoming increasingly essential. GIS databases provide relatively easy access to masses of spatial and attribute or descriptive data, which can include digital images of findings. By providing an online GIS database such analyses across a geographic area can be facilitated more readily. The introduction of GIS on a local scale (i.e. for one site) can be extended to wider areas and hence more sites with essential planning. To implement such a database agreement of terms and the level of data that are to be included have to be determined.

The utilisation of standard terms allow for a "global" database to be implemented. Subsequently standards require to be established that will allow for terms to be set and then be used by archaeologists from different countries. It is proposed that such standards be used to create an online Mediterranean Archaeology GIS database. However one of the greatest challenges is that it is necessary to develop standards in order to effectively use databases. Standards are the key that can be used to unlock and share data amongst colleagues. A conceptual method for arriving at standards is proposed with the need to be further developed and subsequently implemented to ensure that the most appropriate terms are selected in order to effectively utilise such an online GIS database.

Spatial or GIS databases have the ability to store and retrieve spatial and attribute data about every polygon, line, and point on a map. A GIS can allow archaeologists to view the location and have information about their data on interactive maps. In the case of Landscape Archaeology a GIS is applied in order to investigate sites in relation to their environment, significant features in the landscape, and the relationship they may have to each other. For research in this field of archaeology a GIS is used to map sites across a wide region. Inter-site investigations across wide-areas can determine if there are any spatial patterns in site distribution, possibly due to the environment or even cross-cultural impacts.

It is proposed that the methods used for landscape archaeology also be applied for “Seascape Archaeology”. As such the distribution of sites across the Mediterranean and their relation to their immediate seafaring environment can be examined more easily with a GIS. The additional feature that a GIS can allow all images of finds at excavations to be stored in a digital format can facilitate visual comparisons of any distinctive foreign goods. These images allow access to detailed data about possible foreign goods found at the site to be better identified. Archaeologists from other areas can see where a local product ended up in the wide Mediterranean Seascape and try to trace out how the items travelled from one direction to the other [Laf98].

GIS databases facilitate a variety of spatial analyses. At just one site, intra-site investigations can study for example the distribution of particular finds in just one room of a building. In this case a GIS can be used to provide a digital map of all sites where imported luxury items were found. The digitised maps can be used to investigate the distance luxury items travelled. A GIS database can most importantly be used to derive, for example the distance of provenance materials to their original source when known. If data from other sites were available on the internet then comparative analyses could be performed very efficiently to assist provenance studies. In this case material from other sites that have similar features can be found relatively quickly, and may then be used to develop a trade network topology for a particular era or area.

Of course each archaeological site has a unique way of organizing its excavated material. This fact has been a major hurdle for the integration of data so that it can be easily shared amongst colleagues over the internet. However with proper planning and with the application of ontologies and database technology that can provide translating mechanisms for common terms it is possible to establish online GIS databases to facilitate provenance studies. The original intention of the internet was to exchange data and ideas amongst colleagues. By making databases available over the internet Mediterranean archaeologists can now enhance their research. The increasing number of archaeological databases on the Internet demonstrates this. It is hoped by presenting this paper that collaboration amongst colleagues is established in order to coordinate the development of an archaeological Mediterranean trade GIS website.

This paper proposes a plan for a project that could provide a systematic method for recording and then analysing the distribution of foreign goods in the Mediterranean region. Many links have been made for traditional “trading” partners as is seen by papers presented about trade between Egypt and the Aegean [Mer72], [Mer98], and between the Aegean and Anatolia [Mee98]. Provenance studies ranging from techniques based on “potter’s marks” to archaeometric measurements [Leo98] can also be incorporated into this GIS database. A mini-case study will be presented to demonstrate how foreign good finds or locations known for the production of traded raw materials can be included in a GIS database. The location and data about material found at each site can be recorded in a GIS database that can include information about the size, chronology, estimated quantity of production and any other pertinent details. This approach could facilitate an investigation concerning the origins of purple dye production by locating the earliest known murex midden site in the Mediterranean region based on the chronology of the mapped sites.

Apart from tracing the origins of the earliest known murex site, a GIS map of murex middens can also allow for an analysis of the distances covered by the trading networks of this commodity [Ree87]. The density of site distribution within a certain area may also provide a means for determining the extent of territorial or trading boundaries and trading competition. In order to undertake such a project already existing maps can be digitised. However for more precision a Global Positioning System (GPS) would have to be used to firstly record the exact location of known middens into a GIS that can then display the location of all known middens on a map and provide a database for the necessary analyses to be made. For the purposes of this paper Figure 1. illustrates sites that were digitised from an analogue map and a preliminary table that was created to enter the attribute or descriptive data about each of these sites.

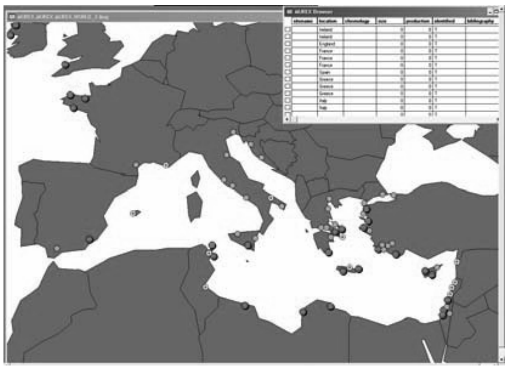

Figure 1: Purple dye production centres.

Mapping murex middens in the Mediterranean with a GIS was an example to illustrate how other known sites with foreign goods can then be incorporated into such types of maps in separate layers of information. These more detailed GIS maps can then be used to model the possible trade routes that were followed for all sorts of goods that were transported by sea throughout the Mediterranean, and perhaps even beyond?

3. Modeling Mediterranean trade routes with a GIS

Continuing on with the murex midden case study described above possible methods of modeling trade networks will now be discussed. With a GIS database that provides data about the spatial distribution of the centers of manufacture and trade of goods ranging from luxury items to raw materials such as purple dye more systematic methods for analysing possible links between areas would be possible. This proposed GIS database could also allow for the spatial analysis of the distribution of for example murex middens to be examined in conjunction with possible exchange networks of other related goods within a given area. Analyses that can be carried out for murex middens can also be performed for example for metal ore sources such as copper mines in the region. By mapping all these interrelated products major sources for raw materials and how they are distributed in a region can be determined.

Linking commodity items with luxury goods may lead to a better understanding of intricate trade networks that included many products distributed over many sites. Relating copper ingots and murex middens could be investigated by determining if copper ingots are found within the locality of murex middens. If so at how many sites in the Mediterranean does this occur at? What is the distance between sites that copper ingots were found at in relation to where murex middens were located? Were trade routes determined by commodities or luxury items? It is proposed that sites in the Mediterranean be re-visited and trade items entered into a GIS database that can then be queried to determine spatial distribution of goods throughout the Mediterranean during the Bronze Age. Including a multiplicity of data in a GIS can lead to proposing possible trade routes, an example of which is tentatively plotted in Figure 2.

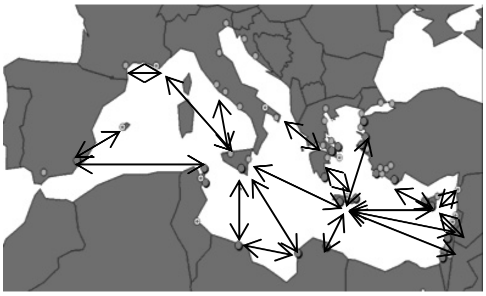

Figure 2: Establishing Trade networks - mapping sea routes.

Establishing trading partners across the Mediterranean Sea can be based on modelling connections between seaports according to the quantity of foreign finds in an area. The identification of the place of origin of the goods can be used to connect a site with an overseas trading partner. These links with the place of origin can be made allowing patterns of interconnection to be displayed on the map. Separate layers of material types could be displayed and by quantifying the frequency of links between any two given areas could lead to establishing more likely trade routes.

That trading links were firmly established between different areas has been debatable given the chance that only one or two foreign items are there because they were one-off gifts [Wat98] and not the result of a strong trading relationship between different regions. Can for example the increased quantity of foreign goods at a site and hence more empirical studies of the remains help to contribute to this area of modelling and then determining trade routes? It can be argued that sites with more foreign goods are more likely to have traded with another area. Therefore by quantifying foreign goods and sites of raw material production on a digitised map can then lead to firmly establishing trading partners by modelling the data available in a more robust GIS database.

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Short Papers

GIS Three-Dimensional Features to Recover City Centers

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Abstract

In the last years, a very rapid evolution of Geographic Information Systems (GISs) involved both implementation techniques and operative paradigms, in order to manage geographic information into digital databases. Particularly, GeoDatabases allow GIS users to intuitively manage very complex structures, such as technological networks, by exploiting the object-oriented representative model in order to describe geographic entities. This evolution makes possible the use of GISs by more and more people; on the other hand, users ask a more rapid evolution of GISs, in terms of technological tools (e.g. software, hardware, internet interfaces) as well as in terms of modeling availability. Loosely speaking, users require to represent situations and models which are hardly describable by actually on-sale general purpose GISs [BZ01]. Equipping GIS software with a 3D support can be a valid solution. In this case, 3D objects could be subjected to queries, without being only mere scenic representations. Aim of this work is the description of a suitable GIS plug-in, compatible with different GIS packages and implemented to extend functionalities of vectorial layers by the addition of a 3D component to existing spatial and alphanumeric ones. Surely, the 3D layer has been conceived in order to be queried as by a metric as by an alphanumeric point of view. Finally, according to GIS specifications, implemented plug-in is provided by data-entry utilities in order to change case-by-case the degree of representative details.

1. Introduction

A GIS is an integrated database which collects, catalogues, analyzes and screens information concerning a territory in terms of maps, altimetric data, GPS coordinates, cadastral data, various technological networks. Initially, 2D systems were implemented with territorial maps and bi-dimensional graphic representations; nowadays GISs integrate a multi-level representation of various data, e.g. architectural communication of territorial existing buildings. Such systems, together with new techniques of data access and analysis, join view and analysis of traditional maps with analysis and management of a specific geographic area. Although the introduction of virtual reality to territorial data improved data representation and communication, description of three-dimensional data shows problem of real-life adherence in terms of graphical depiction of information [Cam93]. It implies a new concept in modeling system, particularly when objects are strongly characterized by three-dimensional data (or four-dimensional data, when it is necessary to include time-evolution of information). The integration of 3D data with a complex set of relationships, i.e. a GIS, involves both methodological and operative problems [KB05] [ZTCC04] partly connected to system querying. Therefore, a GIS has to easily find a model for data-entry, avoiding redundancies among different components representing the same element [ZP05]. Finally, this kind of integration can be able to guarantee a 3D representation of inspected geographic area with a varying representative detail degree. In other words, required information must be strictly necessary to appointed aims, like in a classic GIS. Moreover, 3D GIS must allow a realistic movement into the area to users, and even the sub-parts of the whole datum must be "querying", both in spatial and in a necessary alphanumeric component [GG01]. Structuring 3D data into a GIS without generalizing classical queries during the data processing, implies a GIS implementation with typical 3D functionalities of CADs [MF87], in which data modeling exclusively appears during editing phase. On the other hand, implementation of a 3D GIS general purpose is possible only after the definition of a model capable to represent a "geographic" 3D object as well as to satisfy above-mentioned requirements. Truly, it is necessary to define a so-called Proof of Concept (PoC), not just a mere model. It is a conceptual scheme related to unambiguous and complete rules; its use allows a GIS planner to define his own "model" (i.e. a meta-model), useful to a specific application. Therefore, a plug-in for ArcGis 8.3^{TM} has been implemented by a well-defined PoC, based on 3D extension of classical modeling for geographical features. Particular solutions have been adopted in data-entry level to extend classical geographic 2D model, in order to differentiate a 3D GIS by a classical generic CAD. Proposed plug-in has been evaluated for monitoring buildings in historical centers in order to plan possible renovations. In particular, it is very important to know which materials have been used in a specific building, and if materials selected for renovation phase are compatible with existing structures and surrounding buildings.

2. Description of PoC method

The approached case-of-study is the management of buildings having an high historical-architectonic interest and located into a city center. Exploiting a classical 2D GIS approach, it would be set by using a polygonal-feature layer with specific alphanumeric data, and eventually with relations between features and alphanumeric tables [Zei99] (see Figure 2). In classic GISs, features are essentially implemented by both spatial (generally, shapes are polygonal, poly-lineal or points) and alphanumeric components (constituted by a record for each feature, which is composed by attributes strictly qualifying the modeled element). A one-to-one relationship subsists between the two components; it is valid even if spatial component is represented by many disjoint shapes. Concerning attributes which can assume more than one value for the same object (i.e. building modeled by feature), one-to-many relationships are used. They refer to such tables defined by attributes according to RDBMS databases' rules. Therefore, they cannot be considered as a part of the feature [CDF94]. Moreover, Figure 2 shows two tables carrying out this functionality: Attribute Table Owners stores registry of building's owners, and Attribute Table Materials stores information about necessary renovations. Figure 2 shows implementation of case-of-study by using ArcGis 8.3^{TM}. The most meaningful alphanumeric attributes have a particle identification code (Unique Key) according to the planners' guidelines (Cadastre Code), a system identification code (Primary Key), and the building date. External tables, depicted in Figure 2 as connected to the buildings' features by one-to-many relationships, can be now implemented in ArcGis^{TM} as shown in Figure 2. The names of the two owners are linked to the particle having the cadastral code 456, and to the list of necessary kinds (and amounts) of materials useful for renovation. The exploited model could seem sufficient to manage the problems related to the case-of-study, supposing the presence of other layers and a right completeness databases. Nevertheless, an update, which allows to specify both the building area to renovate and the materials to employ, is hardly implementable by using only the classic tools of 2D GIS [RM92]. Aim of proposed GIS 3D-extension PoC is just solving similar problems with the highest efficiency, architectural elegance and scalability. It is based on redefinition of feature, i.e. the model of reality into a GIS software. In case of 3D GIS, a feature has been considered as the union of an undefined number of elements (Figure 2). They are constituted by:

- a spatial bi-dimensional component (shapes polygon, polyline, points, and so on);
- an alphanumeric component, defined as a set of attributes discriminating a single feature;
- a three-dimensional component, structured as a set of connected and selectable volumes and surfaces;
- a further alphanumeric component, defined as a recordset of attributes related to the different volumes of the 3D component by a one-to-many relationship. Let us remark how number of tables generated by records can vary.

A new characteristic aspect of 3D features is that some constituents could be optional. Therefore, it is possible to have features without 3D components (thus 2D GISs are a particular case of 3D GISs) or features without the classic 2D component, other than the case depicted in Figure 2. Now it is possible to denote how the cited update, in the case of 3D GIS, will have features similar to the ones depicted in Figure 2. Here, various queries can be made on 3D component, such as object identification on established volumes or surfaces. Thus, renovator can know areas of renovation (e.g. roof, attic, front of building) or the kind of renovation to carry out (e.g. crack detected on a front-side of building, having a well-known extension). Other sort of queries can involve measurement of volumes and areas of interest (e.g. it is possible to estimate if amount of material provided for renovations is really sufficient or not).

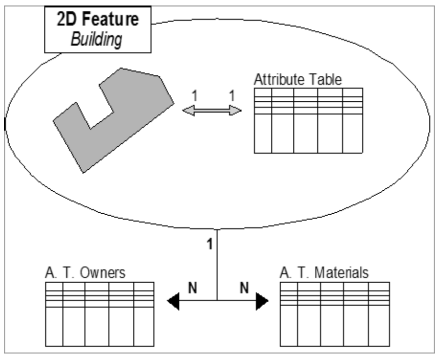

Figure 1: *Classical model of 2D feature.*

3. Implementation of PoC

Implementing the PoC rules into a 2D GIS framework involves a low-level interaction with:

- elements of GIS software (events, libraries, inter-process communications);
- the SQL drivers of an opportune DBMS [Cor97];
- the libraries of the graphic card [WND97].

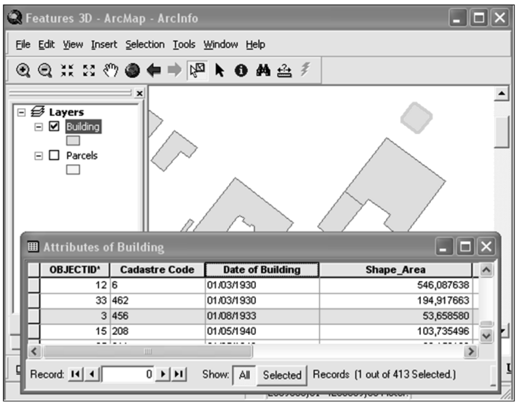

Figure 2: *The case of study.*

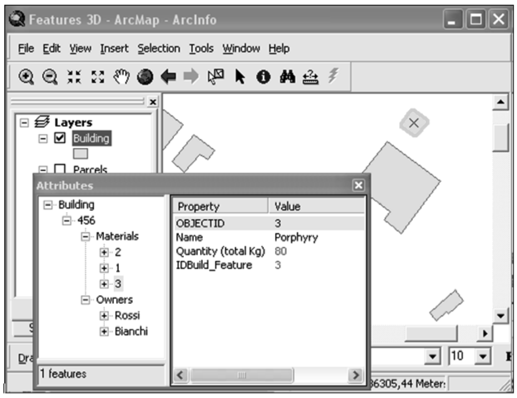

Figure 3: *Match of the feature with external tables.*

The first item has been approached by exploiting the Microsoft COM© technology, used by ArcGis ArcObject^{TM} framework [Zei01]. It gets the inputs coming from ArcGis^{TM} and executes commands if they affect representation and querying of 3D data. Original libraries of ArcObjects^{TM} have been used in order to access to the alphanumeric databases. Finally, the third item did not represent a real problem, since implementation has been carried out into the Irrlicht framework. Iy is an open source, real-time 3D platform for videogames development. In this case, a specific code has been implemented in order to adapt offered functionalities to our aims. Functionalities available into the graphic platform have been used to solve the problem of "collisions" during the implementation of identification procedure for volumes and surfaces, constituting the 3D component of features. Considered method can be resumed as follows: given a direction into the local reference system, a triangle is selected into the mesh used to built the 3D surface and intersecting a straight line with the same direction and passing for a given spatial point. Nevertheless, operation concerning Camera and Texture tools did not require to

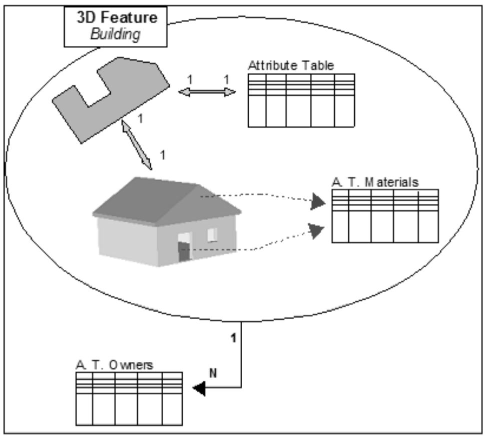

Figure 4: *Sample of 3D-extension of feature.*

implement specific code; in particular, dynamic rendering of scenes is very fluid even if there are several contemporarily viewed 3D features and texture elements correspond to high-resolution digital photos.

4. Implementation of Data-Entry Level

Up to now, a possible conceptual paradigm has been described. It can be adopted for a valid 3D extension of GIS. Let us remark that a practical problem concerning data-entry mode is introduced when the extension needs a redefinition of feature concept using new functionalities and rules. It is evident an exact representation of building shape is prohibitive in terms of costs and time-consuming. In this sense, it could be useful to remember a GIS has to store strictly necessary data. They can satisfy queries and representation into the specific applicative framework. Taking into account this operative principle, 3D components have been stored not by raster or vectorial data, but by using textual keywords referred to previously created geometric templates. Templates are in turn linked as to spatial coordinates into a specific reference system for the related 3D components, as to texture codes extracted by libraries or digital photos. The whole datum is then stored into a XML file [SR01] compatible with Irrlicht's irrXML module. Thus, it is necessary to specify the following items for each building in a typical recording phase (see Figure 4 for details):

- geometrical map of the whole volume (topological superimposition with 2D component is not necessary) with specification of wall number; in this phase, metric precision is due to project requirements since it is not essential;
- floor number;
- roof shape;
- elements which strongly characterize external walls, such as external stairs, entryways, balconies;

- generalized textures for wide surfaces (external walls, roofs, and so on);
- specific textures for narrow and generally irregular parts of surfaces, used for limited renovations (for example with cracks);
- optional definition of such areas which can be used for sublayers generation.

Software implementation, e.g. for palmtop platforms, becomes easy if these representative rules are exploited. Software package has to allow a quick and user-friendly data-entry by using typical templates for the specific application and the area under analysis. Figure 4 shows a snapshot of such Java-implemented software. Layout of main panel is divided into several sub-panels, containing control-buttons or objects used for designing. An example is the canvas in the right side (landscape mode), used to draw external walls or to insert templates (Figure 4 shows Windows and Detachments). The same Figure 4 shows how our implemented plug-in queries and integrates a 3D feature into ArcGIS^{TM}. It is composed by a bi-dimensional polygon, the 3D component and the materials' table of a selected area into the building's wall (highlighted with a red hue). In details, users can exploit a Graphical User Interface (GUI) in order to work with functionalities integrated into the plug-in (Figure 4). It allows to read stored data during the data-entry phase, according to the following procedure:

- first of all, plug-in turns the file containing object description, linked textures, and so on, into a vectorial file compatible with Irrlicht;
- subsequently, a real-time rendering is carried out on the vectorial file by Irrlicht's functions;
- finally, 3D object is related to the other parts constituting the feature.

Figure 4 shows an example of final results for described procedure; here, the 3D components of building 392 is associated with the feature having the same geographical ID (e.g. cadastral code). Therefore, described procedures allow to obtain a 3D feature able to satisfy queries about its 3D component. For example, the classical "identify" query (started by the button with label id3D into our plug-in) allows to remark such materials useful for renovation of the highlighted area into Figure 4. They are listed in a suitable table automatically generated by the plug-in. Alphanumeric values are retrieved by a table belonging to an RDBMS, consulted by using Microsoft Windows© ADO technology. The RDBMS table is spatially indexed with the same analyzed area by a one-to-many relationship. Moreover, the "identify" query has been implemented into the plug-in by using the Irrlicht's algorithms for individuation of spatial collisions. Finally, the plug-in's GUI integrates a particular "Build SubLayers" button. It would start routines able to decompose various portion of the 3D component (e.g. roof coverage) into further objects. They can be mapped into the geometrical plan where layers, containing 2D components of 3D features, lie. Cited routines are not still implemented, but they could extend Geoprocessing operations (Intersect, Union, and so on) to the three-dimensional component of 3D features.

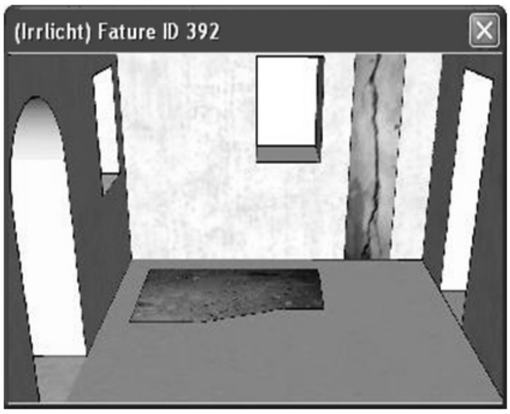

Figure 5: *Texture obtained by a picture of a cleft.*

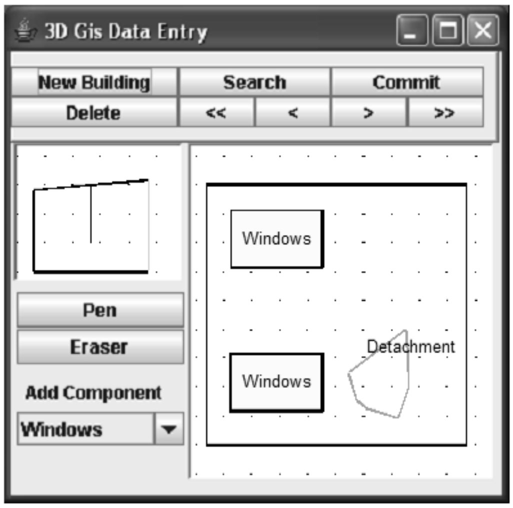

Figure 6: *Data-entry software.*

5. Conclusions and Remarks

The proposed PoC has been conceived in order to offer an easy way of 3D GIS management, since it is based on a coherent evolution of the classical GIS. It is an advantage for training technicians and planners. It would be a complete general purpose "meta-model", able to represent the various and complex problems related to the introduction of a spatial third-dimension in a particular context. Nevertheless, there are a lot of aspects to refine. For example, proposed approach is useful to work in a context similar to the analyzed one, with excellent results. In other dissimilar and unusual frameworks, it is possible to denote structural lacks in

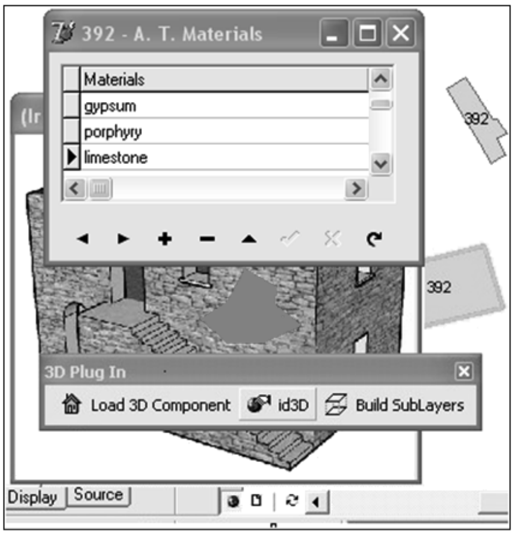

Figure 7: *3D features in ArcGIS.*

modeling phase: it is undoubtedly a limitation of proposed method. Encouraging results have been obtained by using the implemented plug-in. It showed very good performance, usability and versatility. However, for future development, open standards are recommended. In fact, nowadays plug-in is implemented into a copyrighted system, and portability is not allowed.

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Short Papers

VISAGE: An Integrated Environment for Visualization and Study of Archaeological Data Generated by Industrial Computer Tomography

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Abstract

Archaeology studies the past using its material remains such as, objects and artefacts found in excavations. Some of them are in a bad shape, broken, damaged, with missing or changed parts, surfaces, colors, textures etc. Others are well-preserved but so valuable that they cannot be easily studied through traditional invasive investigation methods. That's why, active measurements are often impossible by conventional means. Furthermore, the acquisition of information must be non-destructive and with as less physical contact as possible.
Scientific visualization in general and volume rendering in special develop non-invasive methods for acquiring data from and studying various material objects by representing them visually and extracting useful information about them. Especially interesting are volumetric data sets which contain information about the whole *object, not just its surface. Such volumetric data can be acquired from archaeological objects by means of computed tomography (CT).*
That's why, based on the above ideas and considerations, we started work on a project, in which we want to develop new and employ already-known visualization and evaluation methods for volumetric data sets, implement them in a user-friendly integrated system for archaeologists allowing them to load CT-scanned data sets pertaining to their study objects, analyze them and extract useful object information from the data.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Picture/Image Generation]: Digitizing and scanning J.2 [Archaeology]:

1. Introduction

Archaeology studies the past using its material remains such as, for example, objects and artefacts found in excavations. Some (most) of them are in a bad shape, broken, damaged, with missing or changed parts, surfaces, colors, textures etc. Others are well-preserved but so valuable that they cannot be easily studied through traditional invasive investigation methods. And yet, all of them need to be thoroughly reconstructed and researched in order for them to reveal all the information they carry.

In former times archaeological objects got their value out of aesthetic considerations. So, the collectors and the intellectual elite were most interested in statues of marble and bronze. However, since the 18th century, they have been also engaged in collecting ancient pottery, above all ceramic vessels of the archaic and classical period. Date and provenience of the vases were often misunderstood at that time though. Nowadays, due to the greater number of excavated vessels (often embedded in undisturbed contexts) and research goals that reach beyond aesthetical considerations, the ceramic vessels of Greek and Roman times are a well-analyzed group among the various groups of archaeological artefacts. An especially detailed framework of artists (vase painters and potters) exists for the Archaic and Classical Greek ceramics [Car89], and for the fine ware of Roman times, the so called Terra Sigillata [ea90].

The outlines for dates, artists, potters, and production centres were established mostly by comparing vessels to each other and generating chronological sequences of shape and style. In recent decades, various natural sciences supported the archaeologists in analyzing ancient artefacts: e.g. examination of the raw material (clay) in order to draw a clear dividing line between individual production centres and to locate so far unknown production centres (geology, petrography, neutron activation analysis), comparing great amounts of fragments by statistical methods, and enhancing the documentation process (digital photography, laser-scanning, 3D-modeling). Due to these methods our knowledge increased enormously, even about objects known for a long time. But, new details challenge established ordering systems and further information raises new questions.

As archaeological objects are fragile, frequently incomplete, and unique, active measurements are often impossible by conventional means. Furthermore, the acquisition of information must be non-destructive and with as less physical contact as possible.

On the other hand, scientific visualization in general and volume rendering in special develop non-invasive methods for acquiring data from and studying various material objects by representing them visually and extracting useful information about them. Especially interesting in this respect are volumetric data sets which contain information about the *whole* object, not just its surface. Such volumetric data can be relatively easily, economically, and *non-invasively* acquired from archaeological objects by means of computed tomography (CT). This has the additional advantage over other, surface-based data acquisition methods (surface-scans) of collecting data about the interior and material of the studied objects as well. The acquired volumetric data consist of digitized cross-sectional images (cf. Fig. 1) which when stacked on top of each other form an exact (within the measurement accuracy) three-dimensional model (volumetric data set or VDS) of the studied object.

Hence, CT is a method that allows not only physicians to look into the human body, but gives also engineers and scientists the possibility to see inaccessible parts of objects and to get insight in various materials. Further, the measured cross-sections can be used to recreate virtual object models which can be used for further comprehensive studies, visualizations, measurements, evaluations etc. without touching the originals.

Which are the questions which such an approach could answer easier if not solely?

Based on measurements of Panathenaic prize-amphorae and considerations on function of various popular shapes, the question of standards in antique production processes (Fig. 2(b)) arises more often than before. The capacity of vessels especially is a key issue in the research of ancient pottery since it is essential for establishing ancient measuring systems. Due to the condition and shape (closed forms)

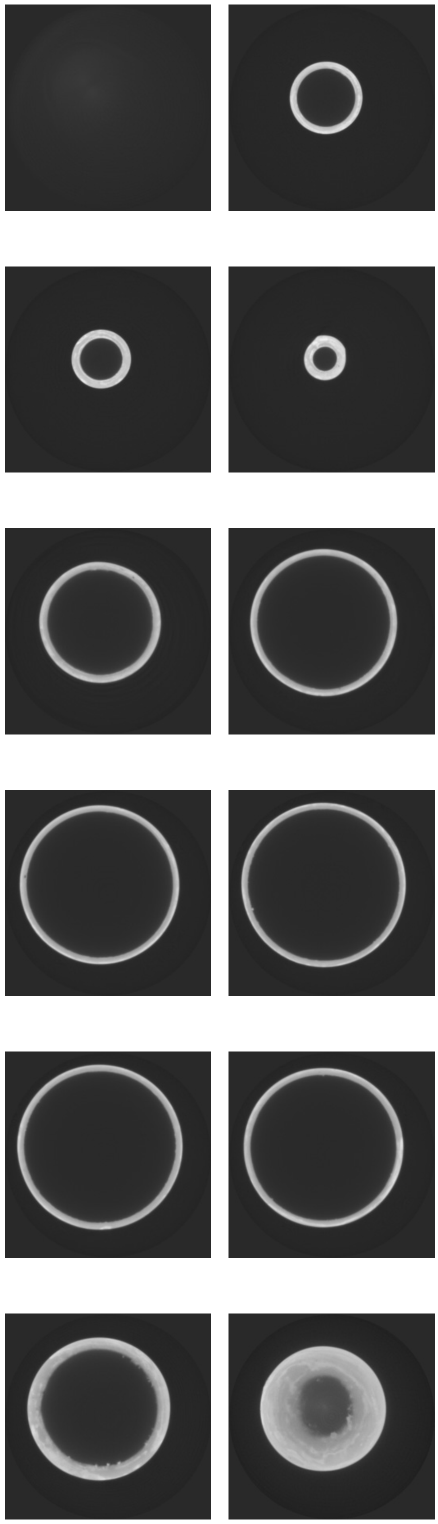


Figure 1: *Cross-sectional CT scans of a lekythos.*

of ancient pottery though, acquiring such data was difficult so far, more often impossible in fact, for fear of destroying or otherwise inadvertently changing the precious originals. However, CT generated models of ancient vases would provide this information without affecting the original substance in any way. Questions dealing with the economical process in antiquity such as: “Is there any difference in the capacity of visually similar pots?”, or “Does an individual workshop use the same amount of clay for similar vessels?” could be answered easily. The amount of used material gives a hint on the production process and on the workshop itself. Moreover, CT gives a detailed plan of the whole surface, too. This model is accurate and objective, whereas a drawing by hand of artefacts with rough surface (Fig. 2(c)) is extremely difficult and often subjective.

Archaeological research is based on visual inspection, but the insight into object interiors and their constituent materials can provide much more information. The insight into the vessels would shed light on the production process: Is a vessel made by hand or on the rotating potter’s wheel? Of how many parts is the vase composed (Fig. 2(a)), was the lip, the neck or the foot made separately? Recognizing individual parts of a vessel makes the development of shapes more plausible. Such and similar questions are of special importance for so-called trick-vases and vases that have false interiors. Volumetric data and 3D-models would be very helpful in the study of the production processes of ancient figurines (Fig. 2(d)), too, regardless of the material they are made of (clay, bronze, precious metal).

A detailed 3D scan of the interior of an object would reveal replaced and additional parts and detect cracks and faults in the material, as well as eventual restoration measures of ancient and modern time (cf. Sec. 3.2). This is especially true, since ancient and modern alterations are often not visible on the surface.

That’s why, based on the above ideas and considerations, we started a project, in which we want to develop new and employ already-known visualization and evaluation methods for volumetric data sets, implement them in a user-friendly integrated system for archaeologists allowing them to load CT-scanned data sets pertaining to their study objects, analyze them and extract useful object information from the data.

2. Project Goal

2.1. Problem Definition

The aim we follow with this project is to develop and implement an integrated program system for visualizing archaeological volumetric data sets, i.e. such acquired through industrial computed tomography of archaeological objects of interest (artefacs, vessels, figures,...), and extracting useful information from them - volumina, profiles, material properties, defects etc.

For this purpose, we intend to perform industrial CT of typical test objects (Fig. 2) from the Archaeological Collection of the Institute for Classical Archaeology in Vienna, chosen in such a way as to represent possibly diverse cases, and to simultaneously test and validate the system using the acquired volumetric data as well as object data collected through conventional means. Finally, the system will be released for further use and field evaluation at the archaeological partner institutions.

2.2. Test Objects

The system we intend to develop needs to be designed in close cooperation with its potential users—the archaeologists, and tailored to their specific demands. We need also a test basis of as diverse as possible typical archaeological objects, around which the system development will evolve taking into account their specifics and possible problems they pose. Such a test base was carefully chosen from the objects kept at the Archaeological Collection of the Institute for Classical Archaeology in Vienna. They were selected in such a way as to represent a very broad spectrum of possible cases, hoping that they will lead to all possible questions and applications and reveal potential pitfalls and problems as early in the system development as possible. In Fig. 2 we present some of the selection of test objects we chose.

3. Concept and Methods

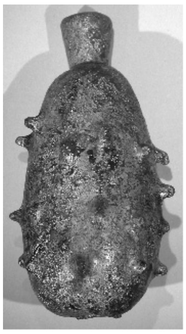
3.1. Previous Work

A few attempts to use computed tomography for investigating archaeological objects were started during the past ten years [IGR97, HST04, JKNS01] (cf. also http://www.uni-wuerzburg.de/museum/Forschung.html and http://www.uba.uva.nl/apm/research.html). While their intentions and research goals were similar to ours, their efforts were hampered by the technological state-of-the-art then. The available computer tomographs at that time were all devised for medical purposes, i.e. their radiation intensity was suitable for the human body, and their resolution was quite low. Besides, all these pioneering studies were one-time shots, similar to our Pilot Study (cf. Sec. 3.2) aimed at solving concrete questions about a specific object, e.g. computerized tomography of medieval metal objects for the purposes of restoration, or material studies at the micro level [IGR97] for the purpose of classification. Nonetheless, their conclusions about the usability and need of CT in the area of archaeology are valid, and we fully agree with them.

An industrial CT as used for testing of materials and machine parts allows for a much higher radiation intensity and duration which leads to higher precision, resolution and quality of the acquired data. And a specifically designed visualization system, tailored to the needs of archaeologists would enable more and faster object studies, with better results and usability.

(a) Attic red figure calyx-krater, clay; 475–450 BC

(b) Attic red figure chous, clay; +/- 430 BC



(c) Alabastron, glass; 4th Century BC

(d) Head of a ram, clay; 3th–1st Century BC

Figure 2: *Test objects.*

3.2. Pilot Study

We conducted a pilot study using a squat lekythos from Southern Italy (Fig. 3), and subjecting it to a CT scan at the *FH OÖ Forschungs- und Entwicklungs GmbH* which owns and runs a state-of-the-art industrial CT scanner.

The collected scan data amounted to ≈1GB and were subsequently used for conducting initial visualization and information extraction studies employing our general-purpose visualization software (ISEG [Š94],VORTEX [Dim98, DH98], F3D [ŠD02]) used hitherto primarily for medical and engineering visualization purposes. The preliminary results were very encouraging in proving the possibility for collecting useful volumetric data from archaeological objects by means of CT, showing the potential of volume rendering for visualizing the objects, and even uncovering unknown facts about them as well as being able to produce and replicate conventional archaeological documentation items (capacities, profiles) on the fly. Some of the (visual) results are shown in Fig. 4.

Fig. 4(a) shows the reconstructed lekythos textured with an artificial texture just for the purpose of demonstrating the potential of the method, while Fig. 4(b) is a serious (first) attempt at extracting object profiles so useful in conventional archaeological object descriptions. Fig. 4(c) shows the hitherto unseen inner surface of the lekythos by means of an imaginary "inside volume object" (blue).

Another interesting and quite unexpected, hitherto unknown result was the constatation that the test lekythos must have been subjected in relatively modern times to somewhat unprofessional restoration works since its neck turned out to be crooked (cf. Fig. 4(b)), and a crack (Fig. 5) was clearly visible in the data set. These findings were and would have remained unknown without the CT scanning and postsequent visualization!

These experiences convinced us and allow us to propose a methodological concept for achieving the project goal described in the following sections.

3.3. Data Acquisition

A few methods for acquiring geometrical and textural information about archaeological objects are conceivable:

1. manual drawing—that is more or less the classical way, which is time-consuming, subjective and imprecise.
2. photography—provides excellent data about surface texture but only from a few directions and provides practically no depth or 3D information.
3. laser scanning, perhaps combined with photography—collects usable surface geometry but no depth information.
4. computed tomography—our method of choice!

While laser scanning is well suited for capturing the outer shape of more-or-less simple objects, and photography de-

Figure 3: *South-Italian lekythos, clay; 4th Century BC.*

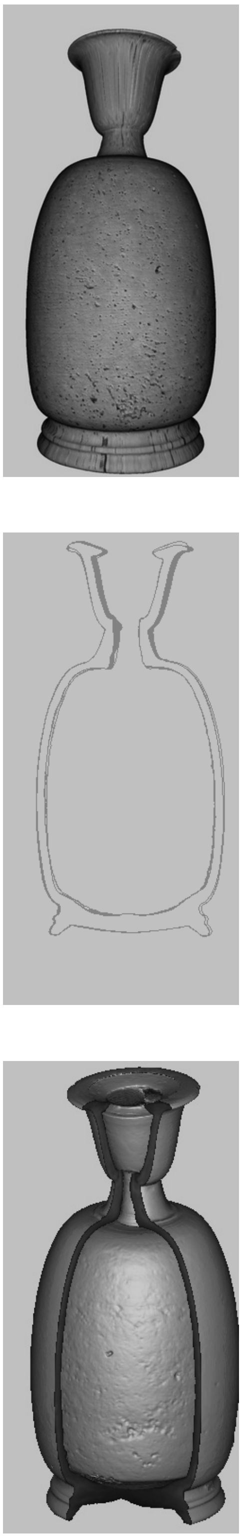
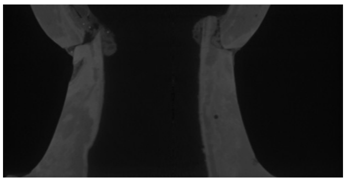
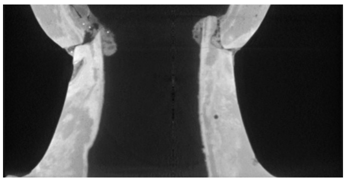


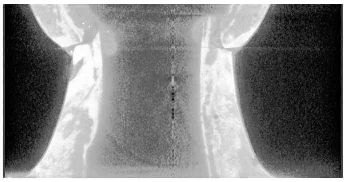
Figure 4: *Pilot study results: a) Pseudo texturing, b) Profiles extraction, c) Arbitrary cut*



(a) Original



(b) Normalized



(c) Equalized

Figure 5: *A vertical cut through the neck of the test lekythos.*

livers excellent texture information, problems and measurement imprecisions may arise with complexly shaped, intertwined or self-intersecting surfaces, eventually further complicated by glossiness or semi-transparency of the materials used. Besides, object materials and interiors remain inaccessible to these methods. And since our goal is to collect, visualize, and evaluate holistic *depth* and *material* information about archaeological objects unattainable by other means there is only the choice of industrial CT left which collects 3D information for object materials and likewise unseen interiors with unsurpassed resolution and quality.

3.4. Preprocessing

The scanned volumetric data as it is provided by the CT scanner is not ideally suited for the kind of processing we intend to perform with it. In general, it is noisy, artefacts-laden, contrast-poor, intensity-uneven. It depends on the kind of objects and scanning parameters/protocols which image processing operations exactly will be needed, but based on our experiences with similar data we daresay that denoising, artefact removal, contrast enhancement, intensity normalization and equalization surely belong to the group of potential candidates. Finding out which operations exactly and in which particular sequence are needed forms part of the research work, and we will devote project time and resources to it. The final outcome of the project, the integrated program environment will encompass a suite of image processing tools exactly tailored to the pre-processing needs of archaeological CT-scanned objects.

3.5. Visualization

One important part of the project resources will be dedicated to developing suitable visualization tools for the scanned archaeological objects. Based on our previous experiences with visualization of volumetric data, we intend to build the system around following ideas:

1. texture hardware based rendering,
2. segmentation using deformable models,
3. novel lighting and shading methods.

3.6. Knowledge Extraction

The final goal of the development works is to make available to the archaeologists a system which would allow its users to do their work better, faster, and more efficiently. Archaeological work consists in extracting information out of objects. That's why our system should allow them to do exactly that in a better way. In preliminary studies and sessions we found out already a few specific goals of archaeological object studies and we want to implement means to their achievement in our system. These will be provisions for answering questions like:

1. What kind of production process was employed?
2. What kind of and how much material was used?
3. What repair/restoration measures were taken?

We expect further questions and wishes to emerge during the development phase and are fully prepared to cope with them accordingly.

3.7. Classification

An important question concerns the classification of archaeological objects based on the identification of the material they are made of. If the possibility to unambiguously assign the studied object to a known one made of the same material exists, then a lot of questions about the studied object can be answered immediately—such as the ones concerning its authenticity, origin, age, etc. This can be done by microscopic and/or chemical investigations, but to the best of our knowledge, it has not yet been thoroughly studied concerning industrial CT, despite efforts in this direction [IGR97]. If the scanned materials (clay, glass, metal, plaster etc.) exhibit enough distinguishing criteria, this would be of great use for archaeologists. The data acquired by CT show a large variation of grey values (cf. Fig. 5. This is due to the different particles of clay and additives absorbing different amounts of radiation. Perhaps, the shades of grey may be assigned to distinct compounds? In this way, a histogram could be produced indicating the chemical (physical) composition of the used material. This would be one of the possible distinguishing criteria. We want to study this problem using the test objects and extract a set of such distinguishing criteria based on statistical considerations, unify them, and propose a classification procedure for archaeological materials.

4. Conclusions

In this work, we presented a project under development, whose main goal is to specify, implement and verify a prototype visualization and evaluation system for archaeological object studies, subject to further improvements, but working and useful in an archaeological environment. Aside from the main methodological problems to solve, a multitude of secondary, purely technological problems will most certainly appear and will have to be solved concerning implementation, portability and efficiency issues thus furthering the development in the area of accelerated hardware-based volume rendering and its applications.

Promising first test results were achieved using a CT scan of a lekythos from Southern Italy (Fig. 3) and our standard visualization software `VORTEX`.

We intend to publish the achieved scientific results in the appropriate forums and make them available to the academic community for evaluation and criticism in their entirety since we consider this the only way how scientific research can function and produce reliable, trustworthy results. By doing so, we hope to sparkle and further additional research in the area which we regard as interesting, timely and rewarding.

Provided a successful development and fulfillment of the project goals is achieved—what we firmly believe, a later addition of design features necessary in a commercial-world production system, like pleasing interfaces, online help system, maintenance programs and contracts, could be achieved better together with a suitable industry partner within a commercial set-up, or even subcontracted to one. This would constitute a positive example of a successful academic-industrial cooperation and of a fruitful knowledge transfer.

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Short Papers

Documenting Events in Metadata

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Abstract

In this paper we outline the importance of event-centric documentation for structuring cultural metadata and historical context. Historical analysis can be seen as an analysis of events involving participation of people and things, meeting each other and thus creating history. Event modeling is so abstract that it can be used to describe cultural items and documentations of scientific observations. This work aims to show how event modeling provides more accurate information about life histories, relates and aggregates relevant information, and so helps to a more effective search and retrieval than currently achieved with Dublin Core and VRA.

Categories and Subject Descriptors (according to ACM CCS): J.2 [Computer Applications]: Archaeology

1. Introduction

Event modeling is a major aspect for cultural – historical analysis because it is an essential part of the complex knowledge required for historical and cultural information; unfortunately, very few approaches focus on event documentation about cultural objects. They usually focus on detailed documentation about the objects and their particular features.

Documentation is an interpretation of cultural materials in relation to a historical context, which can be described in terms of events and processes. Historical context can be abstracted as things, people and ideas meeting in space-time [SAC*06]. For example, a type of an artifact, a style, results from a production event. Historical analysis can be seen as an analysis of events involving occurrences of agents/participants, presence of people and things (material or immaterial), meeting each other and thus creating history as a "network".

The abstraction of all the different kinds of events into simple meetings is a very powerful simplification for core documentation of cultural items and documentations of scientific observations.

Event-centric documentation provides a more accurate view of the past or current life history of a cultural object. Focus on factual information representation in contrast to categorization interprets more effectively history and especially, heterogeneous and complex information resources that are lost, not accurate or unrelated and need to be linked and interpreted in order to capture knowledge. It provides access to information about research and interpretation of the past, relates information sources and helps to a more effective search and retrieval.

Modeling of events can be used for the representation of metadata and content relationships as well, such as participation in an event, part-whole relation, reference information and classification [DIL*05] which are the most fundamental relationships that connect things, concepts, people, time and place. Modeling changes of state (based on criteria such as when, where, who etc.) provides more accurate information about life histories and also relating and aggregating relevant information and knowledge.

Even a description of cultural material is an observation which can be documented as an event. Events enable the construction of related information networks about history of things from the past.

2. Related Work

Event –modeling and documentation is not a common practice for the majority of the standards used in cultural documentation.

Only CIDOC CRM [DOE03] proposes a structure based on documentation of events and processes.

CIDOC CRM (ISO/FDIS 21127) is a standard for the semantic integration of cultural information. CIDOC CRM develops a general ontology [GUA98] about cultural documentation. It doesn't define terms (vocabularies) but relationships between entities. It is a model of 80 classes and 130

relationships, suitable to capture the underlying semantics and metadata of cultural documentation. It is based on the modeling of events and so it can be used both for the representation of metadata and complex content summarization as well. Its approach to event modeling is simple, generic and abstract in order to describe not only cultural materials but also scientific observations.
CRM uses four fundamental principles:

1. Participation in an event (e.g. creator, contributor, publisher, birth date, birth place, creation date, place of find, designer, project leader etc.
2. Part-whole relation.
3. Reference (e.g. subject, "aboutness", representation)
4. Classification.

The basic idea is that historical context can be represented by things, people and ideas meeting in space-time. CRM proposes a simple schema for summarization of historical facts. The past is formulated as events involving "persistent items", presence of things creating, in this way, a history of lifelines of things (meeting in discrete events). This general principle based on events definition can be used to model a variety of relationships.

It is a model which emphasizes on relationships rather than individual concepts or vocabularies; CIDOC CRM is an ontology, which allows for creating global networks of related knowledge.

CRM Core, on the other hand, is a metadata schema. It differs from CIDOC CRM in the following respect: CRM Core is a unit of documentation dedicated to a description of a specific item and not a semantic network of correlated knowledge; it is not ontology. It is made so that information from multiple instances of CRM Core about diverse items can be merged univocally into a knowledge network which instantiates CIDOC CRM. In other words, it is a means to manage the knowledge in the units in which it is produced by the experts.

The VRA Core [VRA02] standard provides a set of elements to describe works (inter alia, objects of material culture) of visual culture (and images that document them). It also defines vocabularies used for annotation. However, it fails to capture complex contexts of creation, use and generally, events and relationships (resulting from events), because information related to event context such as date, place and participants are disassociated.

The same practice is used in CCO - Cataloguing Cultural Objects [CCO05]. CCO is a guide used to describe cultural works and their images. It focuses on data content standards with emphasis on descriptive metadata. It relates, in a selective way, elements sets from VRA Core and Categories for the Description of Works of Art (CDWA).

Dublin Core [WKLW98] on the other hand, is a metadata standard, which defines a limited set of elements to describe general resources. It fails to capture complex historical material and context. It can not describe relationships, processes or phases, such as observations or research activities that can be related to a cultural object.
All the above indicated are schemata and not ontologies.

It appears that most standards focus on modeling categorical data in order to describe individual concepts rather than relationships. However, this practice cannot integrate or connect rich historical information.

3. Events as meetings

Ontologies describe possible *state of affairs,* a specific distribution of *potentially* observable *items,* i.e. material items, conceptual items and events, as well as their associated *relations* and *qualities*, over space and time [DPKB04]. Events can be seen as *particular states of affairs*, in which historical and archaeological phenomena are connected as a network of *persistent items* that meet in space and time.

Events consist of interactions [JLT*05] of participants, consist of "meetings". *Meetings* are interactions of living or dead items that bring about changes of state.

History is a sequence of meetings. An event may cause or be caused by another event. Events order provides relative chronology by a relative order of creation and destruction events of participants (such as strata, finds, buildings etc.). These entities were present ("participated in") at those events (deposition events, historical/ archaeological/architectural events - events of use and production, events- processes of information exchange). Primary evidence for the existence of past events are either their products, permanent traces, placement of objects or reports in written or oral historical records (information). Even immaterial items are regarded to participate in event via their carrier that necessarily reside on, such as human mind, paper, rock carving etc. - see fig.1 :transfer of information [DPKB04].

The action of observing/describing an event is part of the event (a meeting). Events are processes relevant to each other; specifically, are *non-instantaneous, finite* processes of a potentially *complex* nature.
Events cover the reality of archaeological evidence appropriately from the ontological, epistemological and mathematical point of view.

4. Example

Examples implementing DC, VRA and CRM Core schema show different approaches in representing the required, relevant historical information. Our aim is to prove that examples that are not based on event documentation may yield wrong or insufficient conclusions during information search and retrieval.

"Monument to Balzac" is a characteristic example [TAN76]. It was commissioned to Rodin in order to honor one of France's greatest novelists. Rodin spent seven years preparing for "Monument to Balzac" on several preparatory studies (showing different versions of Balzac). The final version (in plaster) was exhibited in Paris in 1898 (and it was

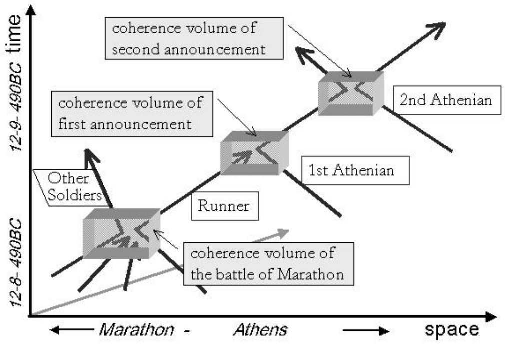

Figure 1: *Information exchange: Marathon runner "carries" a message*

then rejected by the conservative critics as an unfinished sketch). Only years after Rodin's death, his "Balzac" was cast in bronze (this is not an unusual practice; some works were even casts of early works that the artist never executed in bronze).

So, here we have a time-series (fig.3) presenting a construction of a work of art, "Monument to Balzac". It is a production event, a "meeting" based on our knowledge of a monument that was created. The "meeting" of the producer "Rodin" and his work "Balzac" happened in 1898 in France. Participation and presence is represented by the superproperty "P12 occurred in the presence of" which summarizes the roles of the participation of the actor and a thing, such as the role of a "producer" in case of Rodin and his product, "Monument to Balzac".

Since, biography (artist's dates) and sometimes locus of activity is useful information required to the art-historians, we also keep details about Rodin's life, such as when he was born, when he died, etc. This information can be represented in details by a birth and a death event.

Although, this biographical information about the artist seems to be unlinked to the production event, in fact it is related to the work and the date of the creation (independent descriptions can be part of the same event or linked through event description).

Information becomes more complex when it is required to represent our knowledge of the post humus bronze casting of the "Monument". This can be modeled as another production event, which continued the original production event of the work (a time-line for a production process) and occurred after Rodin's death (event). If we do not model this link/network of events and we attempt to search information about a post humus Rodin's work, we will probably find wrong information.

The same example implementing DC, VRA and CCO (fig.4,2), fails to show all the required related information because date, place and participants are described separately and are not related through their participation in discrete events. They can not show the relation between creator, date of creation, place and the object (which was created on a specific date and place, by a specific actor having a specific role and using a particular material). This approach fails to describe a history of processes/activities related to the cultural item.

Even structural and name changes, such as those of "Creator" in VRA Core 3.0 into the more generic term "Agent" in VRA Core 4.0 Version, can not solve the problem; (still, there is no connection to an event description). Moreover, they are characterized by inconsistency in proposing categories: for example, VRA Core 3.0 includes "Location. Discovery Site" and doesn't correspondingly include a "Date.Discovered".

5. Conclusions

Example (CCO)

Record type = item **Class**= sculpture
Work type = statue
Title = Monument to Balzac
Material and Techniques= bronze, plaster
Creator Display= Auguste Rodin (French, 1840-1917); Rudier (Vve Alexis) et Fils.
Role [link]=sculptor [link]: Rodin, Auguste
Role [link]=casters [link]: Rudier (Vve Alexis) et Fils
Creation Date = designed and produced in 1898, cast in 1925
Qualifier: design **Start**: 1898 **End**: 1898
Qualifier: casting **Start:** 1925 **End**: 1925
Subject = Balzac
Culture= French
Description = Commissioned to honor one of France's greatest novelists, Rodin spent seven years preparing for *Monument to Balzac*. When the plaster original was exhibited in Paris in 1898, it was widely attacked. Rodin retired the plaster model to his home in the Paris suburbs. It was not cast in bronze until years after his death.

Figure 2: *"Monument to Balzac" implementing CCO*

In this work we emphasize the importance of event modeling for historical analysis. Structures that are not based on event documentation fail to support meaningful information integration.

So, we propose a new metadata schema (CRM Core), which has comparable complexity with DC, VRA and higher generality; however it is capable to capture knowledge networks. It has the power to provide more effective information integration and reasoning across resources based on more relevant information closer to historical/research information.

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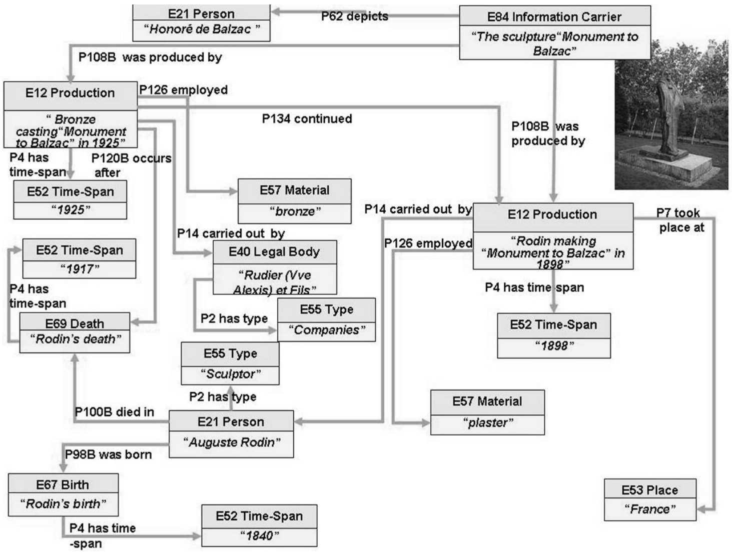

Figure 3: *A graphical representation of "Monument to Balzac" using CIDOC CRM Core*

Example (VRA Core Categories, Version 3.0).
Record Type = work
Type = sculpture
Title = Monument to Balzac
Material.Medium = bronze
Material.Medium = plaster
Date.Creation = 1898
Date.Completion ? = 1925
no connection
Creator = Auguste Rodin
Creator.Role =sculptor
Creator ?= Rudier (Vve Alexis) et Fils
Creator.Role =Casters
Subject = Balzac
Description = Commissioned to honor one of France's greatest novelists, Rodin spent seven years preparing for *Monument to Balzac*. When the plaster original was exhibited in Paris in 1898, it was widely attacked. Rodin retired the plaster model to his home in the Paris suburbs. It was not cast in bronze until years after his death.

Example (Dublin Core)
Type = work
Type = sculpture
Title = Monument to Balzac
Format= bronze
Format= plaster
Date.Created = 1898
Date ....? = 1925
Creator = Auguste Rodin
Creator =sculptor
Creator/Contributor?=Rudier (Vve Alexis) et Fils
Subject = Balzac
Description = Commissioned to honor one of France's greatest novelists, Rodin spent seven years preparing for *Monument to Balzac*. When the plaster original was exhibited in Paris in 1898, it was widely attacked. Rodin retired the plaster model to his home in the Paris suburbs. It was not cast in bronze until years after his death.

Figure 4: *"Monument to Balzac" implementing VRA and Dublin Core*

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Short Papers

A Toolbox For Movable Books Digitization

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Abstract

Scanning and diffusing fac-similes are well studied and known tasks. However digitizing movable books addresses new issues. In this paper, we describe preliminary results about a software that eases the rebuilding of moving systems of such books. This tool computes, in a semi-automatic way, the reassembling of the system's texture, the detection of the system's shape, its rebuilding into a 3D object and its final texturing. Such 3D object can then be imported and animated in a 3D reading environment.

Categories and Subject Descriptors (according to ACM CCS): I.7.5 [Document and Text Processing]: Graphics recognition and interpretation, Scanning H.3.7 [Information Storage and Retrieval]: User Issues

1. Motivations and Background

The first movable books were scientific books [Hai79] in which moving parts made of paper were added in order to illustrate authors' theories. Such books are very fragile and are often damaged and weakened by time and repeated handling. They are also usually forbidden for general public because they are kept in private places where only some researchers can have access. Generally, the digitization of ancient books allows, on one hand, to increase their accessibility towards all kind of public and, on the other hand, to ensure their conservation via an un-damageable medium. The digitization of classic (i.e. flat) books is well known and allows nowadays to ensure their accessibility and their safeguarding. But this process is limited to books with usual dimensions and characteristics. The specificities of movable books make them impossible to be digitized with traditional methods.

Digitization must take into account that a page of a movable book is a volume whereas a page of a traditional book is a surface. The digitization of a three dimensional (3D) object is not a simple task [CHT04]. It is even more difficult when the object's configuration changes with time. In addition to the usual textual and graphical contents, a movable book proposes to the reader an interactive experience by the handling of the moving parts on its pages [CDT05]. Some parts of some pages are thus hidden by moving systems and require a special handling to be acquired at the digitization step.

Our aim is to obtain a virtual reconstruction of a movable book that an user can manipulate and read in a 3D environment. We use as model of book the one proposed in [CST02]. The environment is based on a 3D scene specified with a set of OpenGL functions. We identified three stages in the digitization process: the texture reconstitution, the mesh building and its texturing. These various stages will be detailed in this order in the next sections. For each, we will describe the corresponding functionalities of the application that we have developed.

2. The Digitization Step

The main problem comes from the texture occlusions. It mainly happens with rotating systems (discs, indexes). Depending on the position in which they are, the occlusion will concern a more or less wide area of systems located below. The image of these partially hidden systems cannot thus be obtained directly. We developed a tool which allows to recompose with a set of images, a single image without hidden parts. For a given system, the user must take snapshots, each of them showing a different position of the moving part (i.e. showing a previously hidden area). The idea is to obtain with this set of pictures all data needed to recompose the final picture of the system. For the various pictures, shooting conditions must be very stable in terms of lighting and framing. This last condition makes it possible to obtain better results. Fig.1 shows a set of 2 pictures. There is no limitation for the number of pictures in the starting set. The implemented algorithm uses all pictures and processes them by couple in the following way.

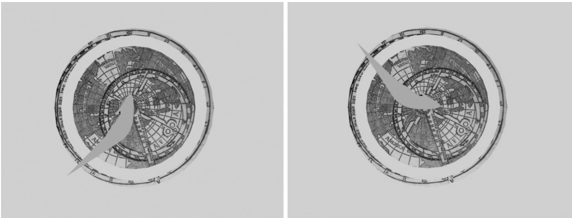

Figure 1: *The initial set of 2 pictures. The mobile part occupies two different positions*

First, the user must manually select two points (by their coordinates) on the mobile part on an image and give the corresponding points on the second image. Then the images are converted into greyscale pictures. The application will then try to identify the moving part by analysing differences between both images. In the case of a perfect point of view (no movement from one image to another), the corresponding pixels will be drawn in black. But in facts, two pictures are never taken without an even small displacement of the camera. In this case, the system has to determine the quantity of this motion, in order to compare the right corresponding pixels. Then, the homography between the two points of view is computed and is included for the computation of the mask building. We have implemented the RANSAC resolution for the homography computation [FB81]. We use a RANSAC because our images are nearly the same but a part (usually the centre) is very different due to the movement of the mobile. The resulting non black part is the area where there is difference between the two images. This stage leads to the creation of a single greyscale image, in which all the non black points belong to the moving part, in one or the other of its initial positions (Fig.2).

Figure 2: *The two computed masks*

We know that the mobile part moves with a geometrical transformation. In our case, it will necessary be a rotation or a translation. It is computed by the application by using the points given previously by the user. This is the reason why only two pairs of points are enough. From the mask obtained previously, there is a set of points likely to belong to the mobile in the first image. By applying the identified transformation to this set of points, one can determine which part of the mask corresponds to the part of the system on the first image. Indeed, the points that belong to the mobile in this image will have as an image a non black point in the preceding mask. The black points or those that have a black image are ignored (Fig.2) The remaining points are replaced by those of the second picture (Fig.3).

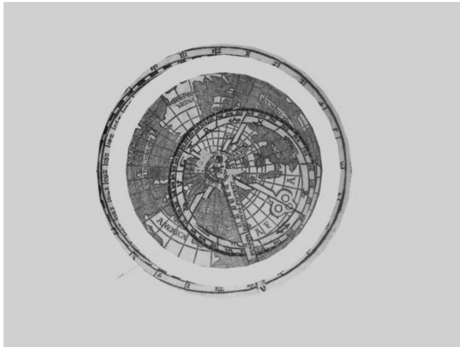

Figure 3: *The reconstructed texture for a 2 pictures initial set*

3. The Modelisation Step

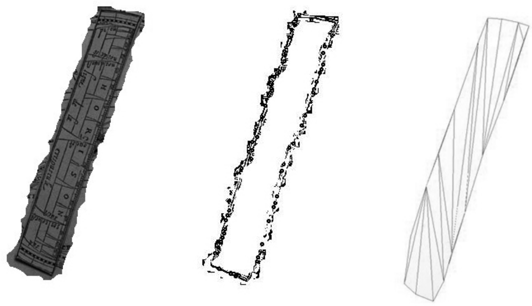

Figure 4: *The initial mobile part(a), the contour detection stage(b) and the 3D mesh(c)*

Once the image of the system recomposed, the application builds a virtual model. With our 3D book model, it is not necessary to have a thickness. For that reason, a simple 2D surface is created. In some particular cases, the simplest ones, the mobiles have basic geometrical forms (circular or rectangular). It is then easy, using a 3D modeler, to recreate the corresponding part. However, two arguments led us to develop our system. The first came from realizing that the majority of the encountered systems have very particular forms. The second came from a librarian, seen as a potential user, who couldn't imagine herself using a 3D modeler. Both motivated us to improve the automation of this process. Our software thus takes as an input the picture of the system to be modelled. It must be prepared in a image-editing software (like imaging or the gimp): the user has to coarsely erase the picture's areas which do not belong to the mobile.

Once done, the application will detect the contour of the mobile part using the Sobel method [Sob70]. It can be divided into two steps: firstly, we compute the picture gradient and secondly, we can extract the interest points by a thresholding. This spline is carried out by a genetic algorithm which gives the contour segmentation. Once this perimeter defined, we rebuild a 2D surface (i.e. the triangles inside the curve). This stage is carried out automatically thanks to Delaunay's triangulation [Che93] applied to a set of points taken from the previous contour. This stage ends with the surface texturing. We can directly make it from the input picture because we modified neither the scale, nor the positions of the points at the time of the re-creation of the shape. The textured object is shown on Fig.5.

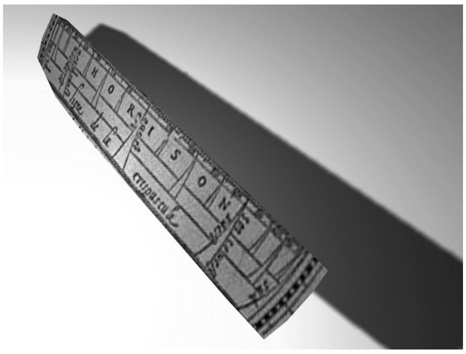

Figure 5: *The textured mesh in a 3D scene*

4. The Assembling Step

Once all the parts are build as 3D models, we can rebuild the hierarchy of the system. We have developped a WYSYWIG application in which a user can build a complete virtual book, from the book metadata, like the author or the book dimensions, to the specification of the hierachy of a system on a page. All these informations are saved into a XML compliant file. This file is used by another application which allows a reader to handle the virtual book. The XML file drives the real-time building of the virtual book and allows the program to know what kind of displacement each system can perform, in response to a user action (e.g. rotation or translation, amplitude, angular limits, etc.). Both of the application (i.e. the building interface and the visualization one) are using a open source real time 3D engine, *Irrlicht*.

5. Conclusion and Future Work

We presented a system for the automation of the various stages of the digitization of a movable book system. It makes it possible to reconstitute a single image of a system starting from partial pictures of it. It rebuilds the corresponding 3D model, by performing the contour detection, the spline computation and the surface generation, based on a Delaunay triangulation. The model texturing finishes this digitization. Some aspects still need to be improved. We will optimize our texture rebuilding algorithm that can be, for the dense textured systems, more effective. We would like to exempt the user of any intervention in the process and automating at least the designation of the pairs of points on the mobile. A good start would be to look at the landmark matching algorithms developed in the computer vision domain. Lastly, the integration of this tool in a more global environment for rebuilding digital models of books is in hand. Finally, we would like to develop tools for the digitization of pop-up's books. They are usually more complex than the movable ones and we will certainly need to use a physic engine for that.

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Short Papers

VR applications, new devices and museums: visitors's feedback and learning. A preliminary report

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Abstract

Between the 15th of September 2005 and the 15th of November 2005, an exhibit on virtual and Roman archaeology was organized in Rome inside the Trajan's Market Museum. The event, "Building Virtual Rome" ("Immaginare Roma Antica"), was a great opportunity to show, inside an ancient monument, and for the first time together, many different projects, applications and installations about VR and Cultural Heritage. The uniqueness of the event was at the same time an occasion both for visitors and organizers to live a new experience, and to face some problematic aspects due, mainly to the meeting of high technological projects (some of them still at research level), cultural contents and also archaeological "containers". During the exhibit we tried to observe visitors and make some interviews, aimed at understanding their expectations at the beginning, their experience during their visit and finally their satisfaction/ dissatisfaction, learning, feedback, and interaction level during and after the visit. The preliminary results of this analysis are showing that the embodiment and the diverse difficulties to use different devices and software depend on many factors and that "communicating" the virtual is not a technological issue, but an epistemological question.

Categories and Subject Descriptors: J.5 [Arts and Humanities]; J.4 [SOCIAL AND BEHAVIORAL SCIENCES]; H.5 [INFORMATION INTERFACES AND PRESENTATION]

1. *Building Virtual Rome* Exhibition

The organisation of the exhibition *Building Virtual Rome*, was aimed at calling for a collective and global effort from diverse sectors that have already broached the subjects of ancient Rome and technology, discussing and examining the international projects, scientifically selecting the best examples from each sector, and offering to a general audience a chance to view and comment them. This international exhibition: "Building Virtual Rome" was the first world initiative dedicated to ancient Rome and its Empire, in terms of virtual archaeology.

1.1 Trajan's Markets, Rome

The exhibition took place inside an archaeological monument, Trajan's Markets, which is not only a place of extreme beauty and a highly suggestive setting for Italians and the millions of international tourists that Rome hosts, but it is also an archaeological site of international monumental and historical importance and value, which link past and future (figure 1).

1.2 - The Exhibition Itinerary and Sections

The exhibition itinerary was separated into four sections, based on different technological and cultural themes.

Figure 1. *Trajan's Markets: the exhibition place*

Section 1. The ancient city of Rome

This section offered applications related to the proto-historical, republican and imperial age of ancient Rome in its topographical, architectural and urban contexts.

Section 2. The Roman Empire

This section offered applications concerning the topography and Roman architecture in the rest of areas in the Roman Empire.

Section 3. Research and Experimentation

This section devoted to particularly innovative projects that are not necessarily linked to the theme of ancient Rome, but involve all the themes of virtual archaeology, interfaces, software development, advanced visualisation solutions, artificial intelligence, mobile systems, avatars, robotics, motion capture, and virtual sets - to name just a few.

Section 4. Special Guests

Different kind of technological solutions and applications were hosted, from the “traditional” computer-graphics movie, with no interaction at all for visitors, to complex VR applications which used common or high-tech devices (mouse, joystick, joy pad, haptic devices, etc.). (Figure 2)

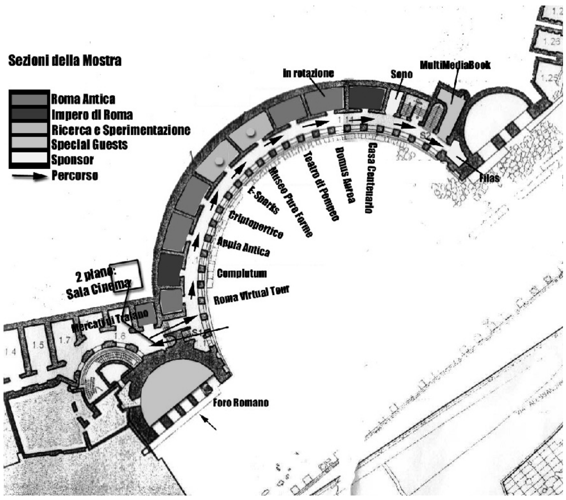

Figure 2. *The exhibition itinerary and types of tech solutions*

1.3 Selection Criteria

Many research institutes, private companies, freelance professionals, public/private authorities and professional studios applied to the call for projects that was published over the web (www.buildingvirtualrome.org). The Scientific Committee used the following criteria to select the projects for the exhibition:

- Cultural content
- Innovation and experimental technology
- Graphic quality
- Congruity of treated themes
- Quality of didactics and communication
- Ability to create involvement in the narrative
- Interaction and edutainment
- Impact of knowledge and learning dynamics

More than 50 projects were selected and were displayed in a “Cinema” room, as movies. For 14 of them an interactive installation was created in the small rooms which, during Roman times, had been shops of a big market (*tabernae*). Visitors could find outside each *taberna* an explanative panel in Italian and English, while at the entrance they could have a short leaflet with general explanations about the exhibit, a short introduction of each installation and the suggestion of three different tours.

2. The VR installations

Table 1 shows a complete list of the interactive installations available. For further information the public web site is still available: http://www.itabc.cnr.it/buildingvirtualrome/.

NAME	TYPE OF APPLICA-TION	INTER-FACE	CONTENT
Gladiators	Audiovisual	Screen, 3d glasses	Gladiators fight at Colosseum
Virtual Roman Forum by Virginia Univ: B. Fricher	Audiovisual	Screen, Speakers	Pre-recorded movie of real-time navigation of reconstructed Roman forum
Trajan's Markets by Trajan's Markets Museum	Audiovisual	Screen, Speakers	Audiovisuals on different projects of the Markets
Cinema room	Multimedia	Screen, trackball	Movies on participating applications
Ancient Rome Tour by Altair4	Multimedia	Screen, Speakers, trackball	Spatio-temporal navigation of Rome with texts, images and VR reconstructions.
Complutum by TEAR	Multimedia	Screen, Speakers, trackball	Images, text audio explan-ations and VR re-constructions of the site
Appia Antica (figure 3) by CNR ITABC	Virtual Reality	Screen, Anaglyph glasses, Speakers, mouse, Joystick.	VR real time navigation inside the archaeological park of Appia Antica with avatars, audios, movies.
Diocletian's Baths Criptoportic by ACS	Virtual Reality-Audiovisual	Screen, Speakers, Mouse, numerical keyboard	VR navigation in the reconstructed city depicted on a wall in Diocletian's baths, with free navigation or pre-recorded visit.
E-Sparks (figure 4) By Plancton Art Studio	Artificial Intelligence	Screen, Speakers, camera and microph.	Artificial creatures living in underwater environment that learn and organize themselves through interaction with visitors.
Pure Forme Museum By PERCRO	Virtual Reality	Screen, Haptic device, passive stereo Glasses	Ancient statues inside a VR museum that can be “touched” through 3D visual - haptic devices
Theater of Pompej by King's Visualis. Lab	Multimedia, VR interactive environment	Screen, Mouse Numerical keyboard	VR reconstructions of Roman sites, and web based explanations ton them.
Mausoleum of	Multimedia	Screen,	Text, drawings and

NAME	TYPE OF APPLICA-TION	INTER-FACE	CONTENT
Arrigo VII (figure 6) by CNR ISTI		Mouse	interactive 3D scanned images of VR statues in mausoleum of Arrigo VII (Pisa)
House of Centenario, Pompeii by CINECA	Virtual Reality	Screen, Joypad	VR navigation (free or automatic) in the House of Centenario; switching possibilities between nowadays and original state.
Multimedia Book (figure 5) by Fabricators	Virtual Reality	Screen, passive stereo Glasses, joystick	VR stereo navigation on an artistic reconstruction of Florence and its culture.
Cave Fruition - CNR ISSIA	Robots	Robots PC to guide them	Robots used for ancient cave investigation
Domus Aurea By La Sapienza	Multimedia	Monitor, mouse	Reconstruction of Roman Domus Aurea with information on it

Figure 3. *Appia Park Narrative Museum (CNR ITABC)*

Figure 4. *E-Sparks (Plancton Art Studio)*

3. The visitors survey: goals and methodology

Rome exhibit offered the great opportunity to undertake an evaluation about the use of ICT, which is becoming more and more a central issue in the Cultural Heritage dissemination field. The special conditions of this exhibition allowed us to concentrate in two different questions: first of all, the perception of ICT use as a communication tool by audiences (because although their utility might be evident to specialists, technology cannot be fully effective without integrating the addressees' points of view and needs); the second question concerned the use and usability of different interfaces.
To that end, and based on on current specific methodology [VHH05], [MCM88], [AP96], we planned four different interviews and observations to be carried out at different moments of the visit. Due to non homogeneity of the applications, it was not easy to have homogeneous results.

Figure 5. *Multimedia Book (Fabricators: F. Fishnaller)*

Figure 6. *Arrigo VII funerary monument (CNR ISTI)*

1) **Initial interview.** At the entrance, a series of questions were asked to visitors. The goal was to analyse their expectations before the real visit and how they had known about the event, in order to understand also how public communication had worked.

2) **Final interview.** At the exit, after the visit, people were asked to answer other questions in order to gather their impressions and opinions about what they have seen. Some specific questions in the final interview were related with:

- the installation the visitor had enjoyed the most;

- the installation which had involved the most the visitor;

- the installation which had allowed more interaction;

- the installation which had allowed a better learning.

3) **Specific interview.** In each *taberna* some visitors were just observed silently in order to see their natural reaction to applications. Other were asked to answer to a short interview on the level of involvement, enjoyment they felt and of knowledge acquired in each *taberna. E*ventual

difficulties in the interaction/comprehension were also annotated.

4) **Time.** The last analysis was meant to calculate the average time a visitor was spending in each *taberna,* both passively and interacting with each application.

4. Some preliminary results

At the end of the exhibition we saw that Saturday and Sunday were most busy days. The average visitor was a man (60% men and 40% women), adult between 20 and 35 years old, mainly teacher or office worker. He was coming from the place where the exhibition took place, in this case Rome, and he was visiting it with his family. He had also some knowledge about archaeology and also, perhaps a bit more, about computers, which he used both at home and for work. Interviewed visitors declared to visit museums or exhibitions fairly often, and as much as 65% of them (all categories of age and both genders, regardless of the previous knowledge about Archaeology) expected to obtain an intellectual benefit from them. The second category of visitors were young people, mainly students, and finally retired people. In terms of general results, the most appreciated *tabernae* were "Ancient Rome tour", "Appia Antica Park" and "Pure Form Museum"; secondly, "E-sparks" was appreciated for enjoyment. The main means of publicity for the exhibition were newspapers and the posters distributed in the city. Only three persons found it out in the Internet.

4.1 Expectations and attitudes towards the use of ICT in Cultural Heritage field

Technology in the CH field is an attraction for people, a good reason to visit an exhibition and particularly to visit the present one. They didn't see it as an aim by itself but as a means of communication, an intellectual benefit needed for a cultural visit; therefore it should not influence the price of the ticket .

When asked about the goals of technology in the cultural field, visitors answered technology should be used in CH field to improve its internal activities (research and preservation) as well as dissemination, and the option was directly related with a highest or lowest knowledge of Archaeology. In any case, technology was seen as a tool that can change practices in the whole field, it is a total flexible tool. Concerning ICT utility for exhibitions, 50% of the interviewed people considered that they are meant for the improvement of dissemination, understanding and learning. In this case, audiences thought multimedia are better than text or images to present Cultural Heritage and requested from ICT applications richness of information and clarity. In other words, they gave them a learning or communicative purpose, far beyond pure entertainment.
Finally, the most disseminated concept of "Virtual Archaeology" combined the goals of Archaeology and some of the properties of Virtual Reality: it was mainly associated with the reconstruction or depiction of the past and not with scientific research or the idea of intangible heritage, which has been introduced in the field. However, all visitors were sure virtual reality cannot substitute real experience or real visit of of a site.

4.2 Use of interfaces and opinions about the exhibition

We considered that the main factors involved in applied digital technologies were enjoyment, immersion, interaction and engagement. From the answers to the "open" questions we deduced that enjoyment was related to novelty and sense of presence. On the other hand, if it was easy and interactive it was appreciated by children but not by adults, who found it funny but useless in the context of a Cultural Heritage settlement.
Elements determining immersion were novelty and richness of information, as well as graphic realism. This means that immersion was understood both as engagement and as a real sensation of presence or, in other words, a combination of physical, emotional and intellectual factors.
Interaction was associated with the system's visible capacity of response, but also the quantity of information was appreciated. This indicates that interactivity is not only physical but also demands an active participation of the user, both physical and cognitive.
Concerning engagement, the main involved factors in positive as well as negative perceptions were: the capacity of exploration or comprehension of the contents, which was totally determinant; the graphic realism (specially in passive applications); and the usability of the interface, for the understanding of which they preferred the help of a human guide and which was critical for the success and the user satisfaction.
These preliminary data showed that just counting the time spent with an exhibit cannot be a good indicator of its effectiveness because many different elements, positive and negative, influence this measure: type of exhibit (audiovisual, VR application or Multimedia), real use of the device, presence of other visitors and problems with the interface [Puj06].

4.3 Learning and understanding of contents

A way to see what people had understood/learned in the exhibits is to ask about its goal. The answers showed that visitors were retaining more the application than the details of the contents and in general, could not tell if or how technology helped them to better understand the contents. Taking into account that the aim of the exhibition was not to foster learning about Ancient Rome but to show different technological solutions related to that topic, we can affirm that it was fulfilled. However, this also demonstrates that if technology has to serve as a learning tool it should be really "invisible", that is, intuitive both from the point of view of the navigation inside the virtual environment (show clearly all the possibilities in the screen) and of the interface operation (only one input device or if possible none at all –use the body as an interface-, put instructions integrated inside the application, etc.), in order not to interfere with the learning of contents.
These preliminary results also demonstrated that VR can

activate a correspondence with iconic skills or mental representations but still some expectations of people are mainly focused on verbal learning and virtual storytelling. Factors involved in learning were the richness of information but also the quality of the reconstructions, specially if they can be related to previous knowledge or experiences. Realism, which is still one of the major concerns for designers, proved to be not decisive for ICT applications' effectiveness from a strictly cognitive point of view. We have to be aware of the fact that there is an ontological gap between the virtual and the real world that technology will never be able to transcend. This is why total realism should not be a goal, but instead Virtual Reality applications should accomplish an epistemological function –in most of the cases better achievable through non-photorealistic rendering– because this is what audiences expect from them [Puj06].

5. Conclusion

In a first preliminary study, it is very difficult to have definitive answers in the field of interaction/relations between virtual environments, virtual content, museums and final users/visitors. In particular we noticed that a wide percentage of projects and applications of virtual heritage are never experimented and monitored with people, but they born and die in digital labs. In fact, in many cases the evaluation of the systems is done by digital content and metaphors and not by the direct users' interaction and behaviours. On the contrary, interaction and feedback determine the virtual embodiment, the empathy factor really crucial for learning and communication. The more the user is immersed in a network of information, the more he/she will be able to have a experience and a knowledge to communicate.

Hence, it is quite obvious that we need more data and information about the sustainability of advanced virtual technologies (VR, multimedia, haptics, computer graphics) in relation with the human factor and dynamic interaction. In the case of the exhibition "Building Virtual Rome", about 90% of the installations of virtual archaeology were presented for the first time to a public audience.

As preliminary conclusions, according to the survey and to the analyses of the virtual projects in relation with the visitors' feedback, it is possible to list the following key points:

- the number of visitors of museums or cultural exhibitions can be *strongly* increased by the use of installations and devices of advanced digital technologies;
- the use of VR systems, in particular, augments the expectations about the exhibition;
- in the case of the Museum of Trajan's Market the number of visitors was increased ten times during the exhibition in comparison with the rest of the year;
- this effect of attraction depends on the curiosity towards the digital technologies and mainly towards virtual environments;
- the feedback of the public is different according to the skills, the age and the interest towards the applications;
- cultural content, software and devices have to be integrated in an interaction system (???) to be successful;
- direct interaction with virtual environments is crucial for the users, but typically they require instructions and training (a difficult approach creates a lack in expectation and a disappointment);
- the "embodiment" factor depends on the quality of interaction and connectivity in the informative space of VR systems;
- virtual contents based on spatial information are able to a better help for dynamic behaviours and users' navigation;
- the example of "Appia Antica" VR application shows that the combination of virtual storytelling with the landscape reconstruction creates a strong "embodiment" between users and a high degree of digital memorization;
- haptics and robotics ("tangible virtual") are appreciated and used by the public, even if the interfaces are not so natural and the behaviours are quite limited.
- Experts or people working in CH field are probably still thinking that Virtual Reality could "threaten" cultural objects, preventing visitors to go, after a virtual visit, to see the real site. In fact no visitor seems to think that virtual can substitute real experiences.

Finally, from this first analyses we can say that virtual heritage applications need to have a more integrated approach between cultural contents, interfaces and technological devices. Interdisciplinary teams need to be created since if an application is developed (and often tends to remain) in a research lab, communication tends to be forgotten. Too many projects are focussed only to enhance a part of the system (for example the digital interface or the computer graphic models) and not to have a holistic vision of the information. Perception, capacity of learning, psychology, emotions, empathy, 3D behaviours, connectivity, dynamic processes of learning, embodiment, are fundamental factors of the virtual communication. Unfortunately, we don't have a deep understanding of the impact and the relationships of advanced digital technologies with the human factor, so the Virtual Museum, or the Virtual Musealization are still a "chimera", at least in epistemological terms.

Agreements

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Short Papers

The Museum's Mind: a cybermap for Cultural Exhibitions

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Abstract

The fruition of artifacts inside a museum is often dramatic because the original connections among objects, sites, territory are removed and the possibility of interpretation depends on the re-contextualization of cultural contents through new maps of relations and meanings. A museum re-creates a new context/alphabet in the topology/ontology of the exhibition. Therefore the "map" becomes the mind of the museum, its communication system. According to this premise, is it possible to identify this ecosystem of relations? Is it possible to understand how a museum or a cultural exhibit communicate? In this paper we try to demonstrate that a VR cybernetic map can be the new code for interpreting virtual heritage's items in museums and cultural exhibitions. VR, as map, can solve problems of conflict between maps and territories. The museum' s mind is actually an ongoing VR design project of cultural communication aimed to analyze the relations between visitors and museum artifacts/items through which it is possible to perceive, to interpret, to storytell the experience, in order to create a self-sense of place. The map is a symbolic environment, a cognitive space, where contents are represented through abstract codes: simple geometries will suggest objects; different colors can be associated to particular properties of items according to their similarities, affinities or correspondences. But this semplified representation can suggest also narrative contents. The cybermap is the metaphor of the 3D space of the museum: the plan of each room is extruded; the walls become transparent and represent "branches" of the spatial relations within the environment. Finally, in order to test the communicative level of artifact, items, features and relations, a multi-avatar environment will be created, where people can meet and interact with cultural contents and change the maps according to new interpretations, relations/affordances, and emotional feedbacks. A first prototype of cybermap was created for the VR project of the Scrovegni Chapel (eContent award Italy); a second one is in progress for the archaeological museum of Castiglion Fiorentino.

1. Museum communication

In a museum, and in particular in an archaeological museum, the artifacts are fragmented, dismembered, de-contextualized and are often juxtaposed to other objects on the base of rules (chronology, typology, taxonomy, shape, stylistic schools) that are absolutely marginal in comparison with their intrinsic significance. This condition favours, in the fruition, an analytic organization of the knowledge that puts in evidence the formal aspects of exhibited objects rather than their thematic contents, compromising the comprehension of the life, the behaviours, the mind of ancient people, in relation with cultural models of the past and of the present [Ant04].

Priority of museum information consists in the contextualization of data and cultural relations. The choice of the connections among objects should define an informative network able to put in evidence cultural and narrative themes. The more the information enhances connectivity the more the possibility for visitors to assimilate and elaborate cultural contents grows up. Every cultural object is a communicative object therefore we have to create the opportunity for visitors to interpret the code expressing its meaning. To make an object readable means to integrate its shape, to perceive it according the correct spatial proportions; subsequently the object has to be integrated in the original context from which it was taken out.

Finally we have to refer about narrative and symbolic themes: what kind of cultural message did ancient people perceived from the object? What kind of message did the artifact's author want to transmit? This is the most interesting level of communication, where in it possible to establish comparisons between different cultures and times.

We have to imagine the communication process like a network, where at the top we find the object/artifact and in the successive deeper levels all the relations connected with its context (psychological, social, philosophical, historical, symbolic, and so on). In order to explain all these connections we need to put in evidence the main key informative concepts and, starting from this base, we can create a communication system. This is possible through two complementary ways: an efficacious arrangement of artifacts inside the museum's space and the support of digital visual technologies in presence of the artifacts. The choice

of technologies, of metaphors of visualization and interaction are in relation to the kinds of cultural contents we want to communicate and to the paths along which public moves. In this way also digital installations become part of the museum's map.
Narrative, educational, evocative metaphors and styles will alternate suggesting to the public different associations and communicative registers.

2. A methodological approach to understand the museum's "mind"

We call the first phase to construct an integrated project of museum communication "anamnesys". We said that the museum is a map, so it is necessary to understand how this map has been conceived and constructed. We'll have to analyze the topology of the exhibition and the typology of the objects, to understand how they are identified and interpreted and if their position is functional to their meaning. Subsequently we can establish categories of evaluation able to help us to build a sort of genetic code (the "mind") of the museum and verify if objects result readable, if they are correctly contextualized and thematized (figure1). We define this "mind" the process of evolution of the cybernetic relations of all artifacts in the space-time. So at the end of this interpretative process we should be able to reconstruct the network of relations in and out the museum. How does the museum face and solve all these relations? On this base we'll be able also to re-create a new integrated project of communication, according to the concept that the museum is an ecosystem.

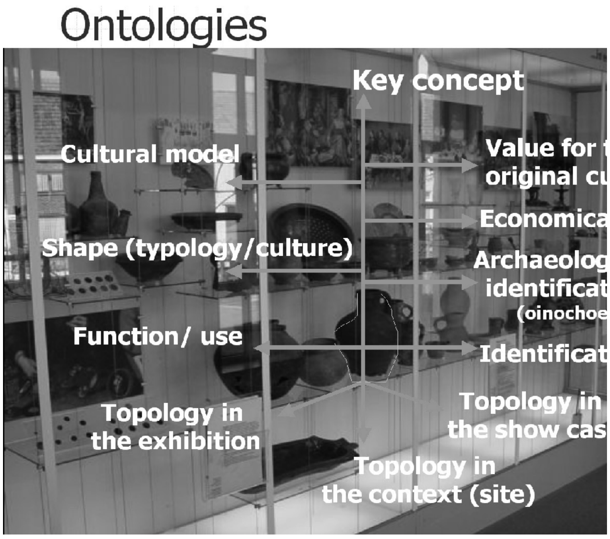

Figure 1: *a simple map showing some categories of evaluation of an exhibited object.*

3. The virtual *museum's mind*

Our idea for the next future is to develop a VR application to create and interact in three dimension with the cybermap of the museum. We believe that this kind of environment could be very useful to project a communicative system. Since two years we have been experimenting the efficaciousness of this approach during some training experiences, (Master of Art and Culture Management in Rovereto, TN, Master in Technology-Enhanced Communication for Cultural Heritage in Lugano) with interesting results. Students analyzed some case-studies, (the Archaeological Museum of Castiglion Fiorentino, in Tuscany, in particular), and realized conceptual maps to decode, deconstruct and reconstruct the museum's information system. The success of the results has convinced us to to go on in the development of a specific virtual reality environment representing the "museum's mind". Our main goal, through this application, is to provide special tools to allow all the operators in the field of museum communication to build their simulations. The cybermap is a symbolic environment, a cognitive space, where contents are represented through an abstract code; simple geometries will suggest objects, different shape and colors can be associated to particular properties of objects according to their similarities, affinities or correspondences (figure 2) [FPR02].

Figure 2: *Cybermap of the virtual museum of the Scrovegni Chapel (CNR-ITABC, 2003)*

At the begin the spatial organization of the cybermap will represent the actual topology of the exhibition, so objects will be grouped and placed in the virtual space according to their real disposition in the rooms and in the show cases of the museum. However it will be possible to switch to new, different maps of relations, following other types of analogies (themes, use, context, material, chronology and so on), and establishing new centres of storytelling according to the key-concepts we want to highlight. The cybermap will be contained in the space of the museum, so the plan of each room will be extruded; the walls will become transparent boundaries between the inside and the outside and the "branches" of the relations extending from the objects will pass through the walls to develop new links with the outside life. Real places of the territorial context are shown by other simple geometries, other colors, according to the identity of the places (sacral, civic, collective, commercial, domestic areas), (figure3).

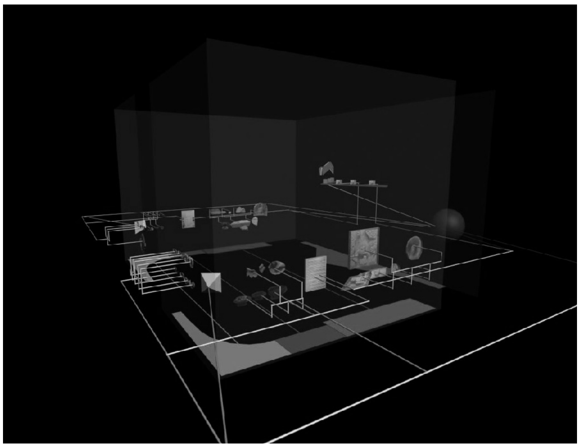

Figure 3: *An initial experiment of cybermap of the Etruscan Archaeological Museum of Castiglion Fiorentino (room of the Temple).*

We can move in real time through the objects of the cybermap, in the three-dimensional virtual space. Objects can be connected by vectors visualizing the relations that can be established among them, and among museum and territory.

Since the scientific community and the museum's operators are the main target of the project, we retain a fundamental rule to maintain the cybermap an open environment. After having modelled the virtual space it is possible to edit and change it again, moving geometries, creating new maps, new associations, new key concepts. The application is not limited to an interactive visualization, its main goal is to provide tools to create and edit conceptual maps. For this reason users will access to a library of symbolic geometries to construct their own map, and they will use some tools of drawing to create vectors, lines, shapes, and so on. Moreover they can link to the 3D space different kinds of metadata (texts, sounds, images, movies, and so on) to suggest the complex informative contents behind the objects. In this way the cybermap acquires a narrative, multimedia informative dimension. In short the application should offer the tools to construct an alphabet, a grammar and a dynamic "rhetoric" of the exhibition.

We are projecting the cybermap as a Multi User Domain (MuD), a collaborative environment. Many users, through their avatar, can interact, meet, change impressions, informations, ideas. The virtual community can be attended by experts and museum's operators, but also by common people. In this way designers will be able to test and simulate the efficacy of their communication projects. When an avatar stops in front of an object, begins to "focalize" it, penetrating progressively into the successive levels of description and content. A sequence of images, dissolving each other, appears from each object. For instance the whole integrated shape emerge from the fragment, the context emerge from the integrated shape and finally the key cultural concept embraces all the sub-levels of information. Moreover objects are interactive and when selected they activate many kinds of metadata as explained just before. Objects are "attractors" of contents and fruition must be a creative process.

We consider the museum's mind like an organism that enters in relation with public [AP05], it modifies behaviours, suggestions, the mind and the rhythms of movement of people interacting with contents. The cybermap (just like the real museum) becomes a new territory, lived, crossed by people: every object or context, and digital installations too, become "sites", with specific and different "energy" of attraction, different times of permanence, different levels of interaction and levels of collective experience. All these aspects could be mapped in the cyberspace, and they could generate, dinamically and in real time, different gradient of colours according to people's behaviours (figure.4).

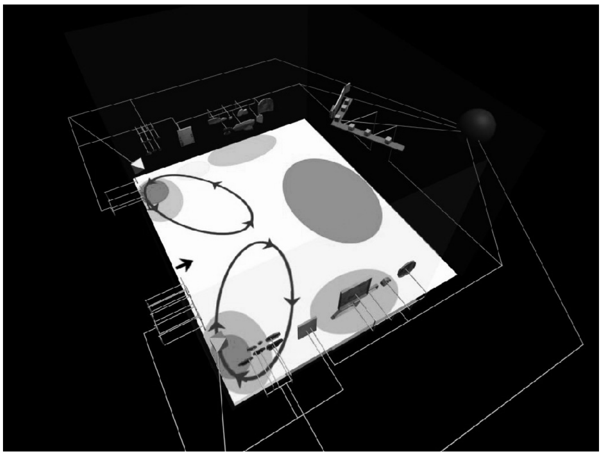

Figure 4: *Cybermap of the temple room (Archaeological museum of Castiglion Fiorentino): gradient of colours represent different levels of attraction.*
Red areas are the most attractive, in correspondence with the video installations (storytelling attractors). The relations are of circular type around video installations, because their communication is possible any time, unlike the fruition of exhibited objects (museum path).

4. Conclusions

In terms of communication, in its origin an archaeological context/object is "autopoietic" (the process whereby an organization produces itself, according F.Varela) [MV80], because it is able to communicate its meaning, in terms of relations with the rest of the environment. The Culture who has produced this context is able to interpret it, to identify its relationships and meanings, because the "map" is in its own territory. The transformation of an ancient context (self-communicating) in an archaeological context (only partially communicating) is dramatic because the original relations/affordances are removed and the interpretation depends on the capacity of reconstructing them. In this case the map is not in its territory, and the archaeological map is not the ancient map. According to this scenario, the museum is a map or a territory? It is a territory (not-coded) because it removes and de-contextualizes artifacts and items from the original context, but it is also a map because it re-creates a new context/alphabet in the topology/ontology of the exhibition. Therefore the "map" becomes the mind of the museum, its communication system able (in theory) to contextualize all the information in new ontologies; it represents the codes of the exhibition in terms of topology, semiotics, relations, and connections. According to this premise, is it possible to identify this ecosystem of relations/affordances?

According to Gibson [Gib79] an affordance is a property of an object, or a feature of the immediate environment, that indicates how to interface with that object or feature. In the case of the Museum, the interpretation of the "map", namely the context of objects/items in the exhibition, depends on the affordance-feedback-perception-interaction-communication with the visitor/user. How does the information circulate? How does the communication system influence the activity of learning?

All these relationships create the capacity to interpret data and artifacts, to communicate meanings, to correlate contexts, to have an experience. The more we create affordances, the more we can contextualize information: when we interact with a museum environment we are not able to validate the activity of experience, learning, communication and, finally, cultural transmission.

This because we don't know codes and alphabet used by the museum system, and because any visitor-stakeholder personalizes his/her visit according his/her own knowledge, curiosity, culture, experience. Form, ontology and spatial connection of the museum information influence the path of learning; so if these factors change, the cultural communication change. Perception and learning use the bottom up approach (from object to mind) and top down behavior (from mind to object), a more symbolic, reflective forms of learning. The integration of bottom up with top-down activities creates the final interpretation, context and content of information.

A simulation VR environment representing a cybermap is able to modify the affordance of the museum objects connecting information in a 3D space, so that to suggest different interpretation and cognitive patterns. Same museum or collection can have multiple ways of reading, according to the affordance we are able to perceive (in fact each visitor personalizes his/her experience).

Therefore the project of creating a VR cybermap is aimed to simulate the experience of cultural fruition within a museum by the affordances created through the interaction between visitors and objects/artefects. Finally the simulation environment should be a MuD (multiuser domain), because of the capacity to stimulated collaborative interaction and shared information. A VR MuD cybermap can embrace in the same time a symbolic-reconstructive and perceptual-motor approach. In a MuD, the interaction and communication shared between virtual avatars-visitors, produces imitative processes, discussions, learning and a strong sense of presence [Sch97]. The combined effect of 3-D behaviours with other users via avatars is greater than the sum of its parts.

In conclusion, the VR cybermap can represent a perfect metaphor of the "museum's mind", a connective space where it is possible to deeply analyze the museum information system in terms of affordances.

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Short Papers

Extraction and mapping of CIDOC-CRM encodings from texts and other digital formats

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Abstract

CIDOC-CRM is a new standard for encoding a wide range of information for Cultural Heritage (CH). At present, existing CH collections are stored using all sorts of formats, sometimes proprietary, often defined roughly, which makes it difficult to share or access heterogeneous information among the CH community. There is a need for a tool to map diverse formats into CIDOC-CRM, assisted by another tool using intelligent language technology to help the mapping whenever fields are underspecified or loosely described, both tools being complementary. In some cases, it may even be better to build fragments of a CIDOC database directly from informal descriptions in natural language only, as the CH community may be reluctant to switch to new formats of data entry. Therefore, this paper focus primarily on the mapping of CH data described in natural language into CIDOC-CRM triples, the building blocks of the full CIDOC-CRM ontology. The methods exploits the propositional nature of CIDOC-CRM triples. Using WordNet as a lexical database and the WEB as corpus, we first extract triples from examples provided in the CIDOC-CRM literature, and then from text describing the medieval city of Wolfenbüttel. We show the strong points of the system and suggest where and how it could be improved. Although the triples extracted automatically from texts do not provide a full picture of the CIDOC-CRM structure buried in the textual description, our results indicate that it provides a sound initial working basis for the mapping/translation process, saving time on what would otherwise have to be done by hand.

Categories and Subject Descriptors (according to ACM CCS): J.5 [Computer Applications]: Arts and Humanities

1. Introduction

Like it or not, the CH community will have to get acquainted to a new ontology for storing databases and collections. The CIDOC-CRM ontology aims at accommodating a wide variety of data from the CH domain, but it sheer complexity may make it difficult for non-expert to learn it quickly, let alone use it efficiently. For others, it may even be simpler to find a way to translate automatically their data from the storage mechanism already in place into CIDOC-CRM. For practitioners unfamiliar with tight formalisms, it may be more natural to describe collections in natural language (e.g. English), and there is already an unprecedented wealth of information available on-line in natural language for almost anything, including CH. Wouldn't it be practical to be able to describe a collection of artifacts in plain English, with little or no knowledge of the CIDOC-CRM formalism, and use language technology take over and produce a CIDOC-CRM database? This paper presents a method to do just that. It is based on the idea that the building blocks of the CIDOC-CRM ontology, the *triples*, have a predicative nature, which is structurally consistent with the way many natural languages are build. According to [CIDb]:

> The domain class is analogous to the grammatical subject of the phrase for which the property is analogous to the verb. Property names in the CRM are designed to be semantically meaningful and grammatically correct when read from domain to range. In addition, the inverse property name, normally given in parentheses, is also designed to be semantically meaningful and grammatically correct when read from range to domain.

A triple is defined as:

DOMAIN PROPERTY RANGE

The domain is the class (or entity) for which a property is formally defined. Subclasses of the domain class inherit that property. The range is the class that comprises all potential values of a property. Through inheritance, subclasses of the range class can also be values for that property. Again from [CIDb], example 1 illustrates how triples can be extracted from natural language.

(1)	Rome	identifies	the capital of Italy.
	DOMAIN E41	PROPERTY P1	RANGE E1
	E48:Place Name	P1:identifies	E53:Place

'Rome identifies the capital of Italy.'

The task of the natural language processing tool is to map relevant parts of texts to entities and properties in such a way that triples can be constructed (also known as *Entity and Relationship Extraction*, see [She03]). In a nutshell, the Noun Clauses (NC) *Rome* and *the capital of Italy* are mapped to *Entity 48* and *Entity 53* respectively, themselves subclasses of the domain E41 and range E1 respectively, while the Verb Clause (VC) *identifies* is mapped to *Property P1*. Sections 2 and 3 introduce the CIDOC-CRM standard and the background necessary for processing natural language respectively. Section 4 presents the methodology used to extract triples from texts. The experiments are explained and discussed in section 5 before concluding in section 6.

2. CIDOC-CRM as the documentation standard for Cultural Heritage

CIDOC-CRM, the ISO21127 International Standard under publication as of 06/06/2006, is a Reference Ontology for the Interchange of Cultural Heritage Information. In other words, it serves as a basis for the management of documentation concerning Cultural Heritage, be it a museum collection, an archaeological site or a database of inscriptions. The universality and completeness of this system is increasingly accepted by heritage professionals, who are becoming aware of the existence of such an international and overarching framework. However, the advantages of using a standard are probably still unclear to them, and the burden of managing legacy systems prevents a wide adoption. Furthermore, the compilers of CIDOC-CRM have rightfully chosen a theoretical and supra-institutional perspective, and do not provide application-specific guidance. This does not facilitate the adoption of the system by heritage practitioners. In fact, only a small number of applications may be presently listed [CIDa]. Since the only way to semantic interoperability is the adoption of a common standard for data description, the EPOCH project [EPO] has undertaken the task of creating a tool – named AMA (see [EPO] under RESEARCH and AMA) – to map compatible data structures to CIDOC-CRM. This approach is in our opinion the only feasible one. Firstly, given *n* heritage management systems, it requires the definition of *n* mappings, while a 1-to-1 mapping among them would have required n*(n-1) asymmetric mappings, and a 1-to-1 mapping to a standard would have required 2n asymmetric mappings. Secondly, since the substance of heritage information is largely the same, the mapping universe AMA will hopefully create will ultimately be a learning system, where new users greatly benefit from the work of previous researchers who already solved most of the problems arising from mapping. It is also possible that in the future, when much information on the mappings will have been acquired, the system may become an intelligent one and suggest solutions basing on the knowledge base accumulated in previous work. Thirdly, this approach solves the problems related to legacy archives, which do not need to be converted to CIDOC-CRM to become interoperable: the data system may remain the same and be used as such for routine work (which in our opinion as yet takes 90% of the time, if not more) and become interoperable via a mapping on-the-fly when this functionality is requested. Still, to achieve full interoperability, there remains the problem of the different language used for data representation: usually data are described and stored in the owner's mother language that creates a barrier to operate with similar databases containing information written in a different language. This obstacle may be circumvented, although not fully eliminated, with the use of multilingual thesauri containing the most significant domain-specific terms. A preliminary expedition in this complex area is being undertaken by EPOCH as well. For the scope of the present paper, the work of AMA is paramount, because it will eventually guarantee the availability of CIDOC-CRM encoded data even when they are stored with a proprietary structure, provided that the task of mapping such a structure to CIDOC-CRM has been accomplished. Conversely, AMA will benefit from the results of the present investigation because it will provide an additional benefit to the list of those deriving from performing the mapping task.

3. Natural Language Processing

Information Extraction (IE) is concerned with the extraction of useful information from text by first using Natural Language Processing (NLP) techniques to get structural information. Figure 1 illustrates the kind of information that can be extracted from example 1. In the remaining of this section we review in turn each element making up the parsed tree of figure 1.

Lemma At the very bottom of the tree we find the lemmas of the words making up example 1, i.e. words which have not been transformed morphologically (e.g. *identify*). Lemmas are more useful for semantic analysis, since they can be looked up directly in a dictionary or thesaurus.

Part-Of-Speech Part-Of-Speeches (POSs) are the grammatical categories of each (inflected) word in a sentence. Some relevant categories for our purpose are IN (preposition or subordinating conjunction), DT (determiner), NN (noun,

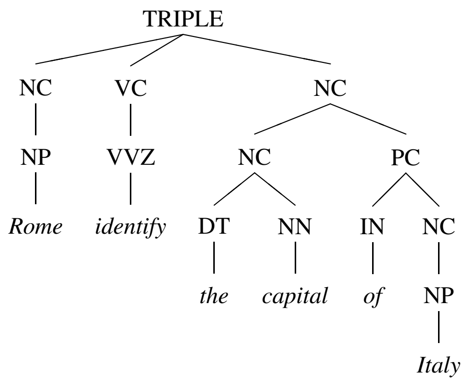

Figure 1: *Linguistic analysis of example 1.*

singular or mass), NNS (noun, plural), NP (proper noun, singular), NPS (proper noun, plural), V_ (verbs).

Clause A clause is a coherent whole of POSs or other clauses. For our purpose, the relevant clauses are NC (noun clause), VC (verbal clause) and PC (prepositional clause). Clauses are built using phrase structure rules, such as:

$$\begin{array}{rcc} NC \rightarrow & DT & NN \\ & [\ The\ ] & [\ capital\ ] \\ VC \rightarrow & VBZ & VVN \\ & [\ is\ ] & [\ identified\ ] \\ PC \rightarrow & IN & NC \\ & [\ by\ ] & [\ Rome\ ] \end{array}$$

Synonymy and Hypernymy Synonyms are words with similar meanings. A hypernym is a word that is more generic than a given word. Only verbs and nouns can have hypernyms. For example, *entity* is an hypernym of the word *person*. This is similar to the notion of subclasses in CIDOC-CRM. In example 1, E41 and E1 are hypernyms (superclasses) for E48 and E53 respectively. WORDNET [WOR] is the lexical database used for that purpose.

Semantic Association When two words (or group of words, i.e. phrase) tend to co-occur in documents, we can assume that they are semantically related. One way of measuring semantic association is called *Pointwise Mutual Information* (PMI) [CH89]. PMI between two phrases is defined as:

$$\log_2 \frac{prob(ph_1 \ is \ near \ ph_2)}{prob(ph_1) * prob(ph_2)} \qquad (2)$$

PMI is positive when two phrases tend to co-occur and negative when they tend to be in a complementary distribution. PMI-IR refers to the fact that, as in Information Retrieval (IR), multiple occurrences in the same document count as just one occurrence: according to [TL03], this seems to yield a better measure of semantic similarity, providing some resistance to noise. Computing probabilities using hit counts from IR, this yields to a value for PMI-IR of:

$$\ln \frac{N * (hits(ph_1 \ NEAR \ ph_2) + 1/N)}{(hits(ph_1) + 1) * (hits(ph_2) + 1)} \qquad (3)$$

where N is the total number of documents in the corpus. Smoothing values (1/N and 1) are chosen so that PMI-IR will be zero for words that are not in the corpus, two phrases are considered *NEAR* if they co-occur within a certain distance of each other, and $\log_2$ has been replaced by ln, since the natural log is more common in the literature for log-odds ratio and this makes no difference for the algorithm.

4. Methodology

Figure 1 suggests that all pairs of NC separated by a VC (and possibly other elements) are potentially valid CIDOC-CRM triples. To validate the triples, we must first make sure that the predicate is relevant by extracting the main verb of the verbal clause (VC) and see if its meaning is similar (synonym) to at least one of the CIDOC-CRM properties. For example, it is possible to use the verb *describe* instead of *identify*. Once a set of possible properties is identified, we must verify if the noun clauses (NC) surrounding the property are related to the DOMAIN and the RANGE of that property. To establish the relation, the first step is to identify the semantics of each NC clause. For English, a good indicator of the NC semantics is the rightmost NN in the clause, excluding any attached PC. The rightmost NN is usually the most significant: for example, in the NC *the museum artifact*, the main focus point is *artifact*, not *museum*. In figure 1 the rightmost NN of *the capital of Italy* is *capital* (excluding the attached PC); this tells us that we are dealing with an object of type *capital*. The second step is to see if the type is a subclass of the DOMAIN or RANGE. Because *entity* (E1) is a hypernym of *capital*, then we conclude that the clause *the capital of Italy* is a subclass of E1:CRM Entity. What if the NC has no NN? This means that the clause is made up of at least one proper noun (*Rome*). To establish the type of a proper noun, we use the Web as corpus and *semantic association* as described previously. We compute how similar the word *Rome* is to each of the CIDOC-CRM classes and choose the most similar as being the type of *Rome* (proper nouns are also looked up in WordNet [WOR]). This gives the following triple:

E41:Appellation		*E1:CRM Entity*
Rome	P1:identifies	*the capital of Italy*

In the remaining of this section we examine the practical details of such a method.

POS tagging and NP chunking POS tagging and NP chunking are combined in one single operation. The method relies on large annotated corpora and statistical machine learning. POS tagging can achieve accuracy as high as 96%. Chunking is the process of grouping POSs in bigger constituents called *clauses*, as previously defined. We have used the freely available and trainable TreeTagger [Sch95], where POS tagging and chunking is available for English and German. We are in the process of creating a tagger and chunker for French.

WordNet: Synonymy and Hypernymy (SH) WordNet is a lexical reference system, developed by the university of Princeton. Its design makes the use of dictionaries more convenient. We have used the Prolog interface. WordNet is based on a concept called *synsets*, also known as synonym sets. A synset is a group of words connected by meaning. Only words of the same part of speech can belong to the same synset. A synset ID is assigned to every word and only words in the same synset have the same synset ID. As one word can have several meanings, it can belong to more than one synset. Then, the word is assigned several entries in the Prolog database, and each entry has a different synset ID assigned. This way we can extract the synonyms of verbs (or properties) and hypernyms of nouns (classes).

PMI: Assigning a class to a proper noun We have used the hit counts provided by the Yahoo [YAH] search engine to compute formula 3, where N is the approximative size of the Yahoo index, hits(ph_1) and hits(ph_2) are simple search while hits(ph_1 NEAR ph_2) is the number of hits returned by Yahoo for a simple conjunctive search ph_1 AND ph_2.

Triple extraction: a walk-through The extraction of CIDOC-CRM triples from text involves mainly the following operations:

1. Text cleaning. The input must be raw text, that is text with no extra tags. Punctuations and special symbols are allowed and, although the system provides some tolerance to grammatical, syntactical and spelling errors, well-formed texts are preferable.
2. Tokenization and POS tagging. Tokenization is the process of splitting the text in individual words or symbols to be POS tagged. POS tagging assigns a POS and a stem (if known) to each token in the form (WORD POS STEM).
3. Clause chunking and pruning. The chunking process assigns clause tags in the form <TAG>...</TAG>, resulting in numerous clauses, which are pruned to the most relevant for our purpose, i.e. NC and PC.
4. NC regrouping. All contiguous NC are regrouped into a single NC ($NC \rightarrow NC$+) and prepositional clauses (PC) following a NC are removed (to get rid of irrelevant subordinate NC clauses).
5. Intermediate triples (IT) creation. Intermediate triples are all *<NC> DOMAIN </NC> PROPERTY <NC> RANGE </NC>* patterns found in the data. The PROPERTY correspond to the rightmost verb between the domain and the range. They are considered intermediate because they may not correspond to any CIDOC-CRM pattern in the end, given the nature of the verb and NCs. The format of the intermediate triples is (D = DOMAIN, P = PROPERTY, R = RANGE): pred('D_WORD', 'D_STEM':'D_POS', 'P_WORD', 'P_STEM':'P_POS', 'R_WORD', 'R_STEM':'R_POS', '[D] P [R]'). The D_WORD and R_WORD are the rightmost NN, NP or PP (in that order) found in the D and R, respectively. The P_WORD is the rightmost verb in P. The _STEM and _POS are the respective stem and part-of-speech of these words. Finally, in the case the DOMAIN or RANGE is a proper noun (NP), the respective stem is replace by one of the CIDOC-CRM classes according to the PMI measure (or hypernyms found in WordNet).
6. Referent resolution. If a DOMAIN or RANGE is a personal pronoun (i.e. POS = PP), it is replaced by the domain or range of the previous intermediate triple.
7. Final triple (FT) creation. Each intermediate triple is processed to see if they can be matched to a valid CIDOC-CRM triple.

For example 1, this translates as:

1. 'Rome identifies the capital of Italy.'
2. (Rome NP Rome) (identifies VVZ identify) (the DT the) (capital NN capital) (of IN of) (Italy NP Italy) (. SENT .)
3. <NC>Rome Rome NP</NC> identifies identify VVZ <NC>the the DT capital capital NN</NC> <PC>of of IN <NC>Italy Italy NP </NC></PC>. . SENT
4. <NC>Rome Rome NP</NC> identifies identify VVZ <NC>the the DT capital capital NN</NC>. . SENT
5. pred('Rome', 'inscription':'NN', 'identifies', 'identify':'VVZ', 'the capital', 'capital':'NN', '[Rome Rome NP] identifies identify VVZ [the the DT capital capital NN]').
6. No referent resolution
7. IT D:[Rome Rome NP]
   IT P:identifies identify VVZ
   IT R:[the the DT, capital capital NN]
   SH D:[rome, location, group, entity, city, appellation]
   SH P:[identify]
   SH R:[capital, entity, location]
   FT D:[e41:Appellation][Rome]
   FT P:p1:identifies
   FT R:[e1:CRM Entity][the capital]
   FT D:[e41:Appellation][Rome]
   FT P:p1:identifies
   FT R:[e53:Place][the capital]

5. Experiments

We have conducted two experiments. In the first experiment (5.1), we collected all one hundred forty-four examples of triples provided in the CIDOC-CRM documentation. In the

the capital of Italy (E53) is identified by (P1) Rome (E48)
www.cidoc.icom.org (E51) has type (P2) URL (E55)
silver cup 232 (E22) consists of (P45) silver (E57)
chess set 233 (E22) has number of parts (P57) 33 (E60)
height of silver cup 232 (E54) has value (P90) 226 (E60)
height of silver cup 232 (E54) has unit (P91) mm (E58)
Mozart's death (E69) was death of (P100) Mozart (E21)
Late Bronze Age (E4) finishes (P115) Bronze Age (E4)
Early Bronze Age (E4) starts (P116) Bronze Age (E4)
Scotland (E53) borders with (P122) England (E53)

Table 1: *Triples from the CIDOC-CRM documentation [CIDb]*

second experiment (5.2), we have extracted triples from a text describing the medieval city of Wolfenbüttel.

5.1. CIDOC-CRM examples

Table 1 shows a few examples provided in the CIDOC-CRM documentation. In these examples, there were 1965 words and 144 sentences. From this we extracted 149 intermediate triples and 184 final triples. The system has generated at least a final triple for 46 sentences, from which:

- 11 represents a suitable match (DOMAIN PROPERTY RANGE), if we consider the selection of a subclass of DOMAIN or RANGE as acceptable, since the system is being more specific than necessary;
- 29 had the right property, although many mismatches were due to the many similar property sharing the verb 'have' and 'be';
- 21 DOMAINs or RANGEs were being less specific (i.e. a superclass) than the true class;
- 15 DOMAINs or RANGEs were more specific (i.e. a subclass) than the true class.

5.2. Extracting triples from free text

The following experiment shows the result of extracting triples from a textual description of the medieval city of Wolfenbüttel. The document was 3922 words long with 173 sentences. The system extracted 197 intermediate triples and 79 final triples. Table 2 shows a few processing steps for the following fragment of text:

> Lange Herzogstrasse is Wolfenbüttel main shopping area. The street's particular charm lies in its broad-faced half-timbered buildings, historic merchant's houses; their central gables still retain the distinctive hatches through which goods could be hoisted up to the attics for storage.

IT	D1	[Lange Herzogstrasse]
IT	P1	is
IT	R1	[Wolfenbüttel's main shopping area]
SH	D1	[herzogstrasse,attribute]
SH	P1	[be]
SH	R1	[area, entity, location]
IT	D2	[The street's particular charm]
IT	P2	lies in
IT	R2	[its broad-faced half-timbered buildings]
SH	D2	[attribute, charm, entity, language, object]
SH	P2	[consist]
SH	R2	[activity, building, creation, creation, entity, event, object]
FT	D2	[e13:Attribute Assignment]
FT	P2	p9:consists of
FT	R2	[e7:Activity]
FT	D2	[e13:Attribute Assignment]
FT	P2	p9:consists of
FT	R2	[e65:Creation Event]
FT	D2	[e13:Attribute Assignment]
FT	P2	p9:consists of
FT	R2	[e5:Event]
IT	D3	[their central gables]
IT	P3	still retain
IT	R3	[the distinctive hatches goods]
SH	D3	gable
SH	P3	retain
SH	R3	good
IT	D4	[the distinctive hatches goods]
IT	P4	could be hoisted up to
IT	R4	[the attics]
SH	D4	good
SH	P4	hoist
SH	R4	attic

Table 2: *A few triples extracted from free text.*

Synonyms and hypernyms are also shown for domains (D), properties (P) and ranges (R). For example, *attribute* is the result of looking for the highest PMI-IR value for the proper noun *Herzogstrasse*, *consist* is a synonym for *lie*, and *entity, location* are hypernyms of *area*. In each case, we extracted from WordNet the synonyms and hypernyms of the three most common uses for each word (verb, noun). In terms of processing speed, steps 1 to 5 (in Perl) take no more than a few seconds, unless we must look proper noun on the Web; using the Yahoo API interface, each PMI-IR computation takes approximately one and a half minute. For steps 6 and 7 (in Prolog), the treatment of intermediate triples, we must allow almost 2 minutes for each intermediate triple to be fully processed.

5.3. Discussion

It is difficult to have a comprehensive evaluation of the system through standard metrics (precision, recall), since there is no benchmark for this type of analysis. A good benchmark would be a CIDOC-CRM human-annotated text. Yet we can give some evidence of the performance of the system. In the first experiment, although there were only 11 perfect matches, many more had at least a suitable property, and a few of these had either a domain or a range which was appropriate. An important cause of mismatch is that many properties are expressed through the verbs *be* or *have*, for which the system cannot make a distinction; extracting more information adjacent to the verbal clause should improve the accuracy of the system. Last but not least, the 149 intermediate triples offer a good fall-back in case the recall of final triples is too low. In the second experiment, we have collected 79 final triples from a 173 sentences long document describing buildings and places of interest in a medieval city. The data was relatively clean, although punctuation was heavily used throughout the document, confusing the chunker. Despite the fact that recall and accuracy appear to be low, there is no doubt that a system like this gives a head start to anyone wishing to build a collection using the CIDOC-CRM ontology. A first pass in the documentation gives a good idea of what the textual documentation is about. However, a fuller interpretation will often involve combining many triples together to form paths. Because of time restriction, we have elected to process the three most common meanings of each word that we looked up in WordNet (avoiding the need to manually pick the right meaning among many); this may have the side effect of lowering accuracy. Speed was not an issue without access to the Web, not an absolute necessity if we have a good thesaurus for proper nouns. Finally, we have tuned the CRM to analyse impressions of a city, which is not a domain for which the CRM is optimally intended. We conjecture that texts about museum catalogues would have yielded better results.

6. Conclusion and Further Work

We have presented a method for extracting CIDOC-CRM triples using language technology. The tool presented exploit the propositional nature of CIDOC-CRM triples and use pattern matching approach based on the output of a phrasal chunker for noun and verbal phrases. The result is a flexible tool that gives a good approximation of the semantic nature of text, from a CIDOC-CRM angle. It can be readily adapted to other languages. The results of the experiments are modest but worth further investigating. The most pressing areas of research includes domain specific thesauri such as [STA, MDA] and discriminatory methods for properties and entities, including common linguistic constructions that do not match the expected [entity, property, entity] pattern. The system can be paired with a more formal mapping method to form a robust translator for diverse digital formats into CIDOC-CRM triples. Finally, let's not underestimate the positive impact of cleaner textual data on the accuracy of our retrieval system.

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Short Papers

DEMOTEC - Development of a Monitoring System for Cultural Heritage through European Co-operation

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Abstract

The DEMOTEC project's aim has been to initiate the development of a European monitoring concept designed to establish links between the various scales of monitoring currently in use. These scales frequently comprise a landscape level, a monument level and a very detailed level (e.g. decorated surfaces). The basic innovative idea behind the project was to develop a better understanding of the ways in which data obtained at different scales relate to each other, and how relevant data from a range of different disciplines can be integrated into a single monitoring system at a reasonable cost. This paper focuses on the different digital tools and techniques used in this system. These include the interpretation and analysis of data obtained from orthophotos based on satellite and aerial photographs, digital photographs and 3-D scanning, as well as from conventional survey and condition assessment methods used in the fields of archaeology, architecture/engineering and conservation, combined with geographic information systems (GIS)

Categories and Subject Descriptors (according to ACM CSS): H.2.8. [Database Applications]: Spatial databases and GIS

1. Introduction

DEMOTEC is a research project initially supported by the European Commission as an Accompanying Measure under the 5th Framework Programme of 2003-2004. It involved the following nations: Norway (co-ordination), Sweden, Estonia, Switzerland and Italy. The project has subsequently continued in the form of a Norwegian project group supported by The Research Council of Norway under the Changing Landscapes Programme and continues until the summer of 2007.

DEMOTEC has aimed to establish a network of experts and users to discuss and outline a concept for a European observation system for large-scale comparative assessment of the state of preservation of cultural heritage. The project encompassed discussions about standards related to techniques, methodology, threshold values and reporting, as well as how to create a communications pathway towards the community in order to create better levels of awareness.
The project approach has been two-sided:
1) The investigation and discussion of management needs and practices
2) The development of a concept for a pilot model based on data from case study areas.

DEMOTEC had an initial case study area in Nemi, Italy, an area which is being influenced by Rome's rapid expansion. The DEMOTEC concept was subsequently applied in two Norwegian case-study areas: the World Heritage site of the town of Røros, and the municipality of Vestre Slidre. Data obtained from these two areas has been used for the demonstration and testing of methodology throughout the project. As is the case for many near-urban areas and areas exposed to tourism, cultural heritage here is suffering from various types of pressure. These include urbanisation, pollution, and degradation due to lack of integration, and decay due to the fact that heritage values are either overexploited or not integrated within modern planning. On the edges of the rural landscape, the cultural heritage environments are subject to natural degradation, overgrowing and loss of meaning, effects also caused by changing agricultural policy. These landscape and social development trends represent serious challenges to cultural heritage management throughout Europe [Ska06].

2. Objectives

DEMOTEC's main objective has been to mobilise European scientific expertise with the aim of developing indicators and a framework for a common European monitoring system for the comparative assessment of the state of preservation of *in situ* cultural heritage sites and landscapes.

Through the exchange of experiences, research results and testing towards selected national pilot models, the intention has been to establish a standardised system capable of reporting the state of cultural heritage preservation to citizens, heritage managers and politicians, as well as providing a tool for facilitating management decisions.

The project is based on the development of a better understanding of how changes and deterioration on the differing scales of landscape, monument and details are linked. The basic innovative idea has been to integrate this interdisciplinary knowledge and data into a single monitoring system which contains a maximum amount of information obtained at a reasonable cost.

The national project has focused on establishing a reference model in order to be able to test, adjust and implement the international monitoring system in the context of Norwegian conditions. The goal is to establish the basic concepts and framework for such a system in a Norwegian environment.

3. Background

Monitoring systems have been developed at national levels and at many different scales in several countries. Although very different in outline and data-output, these systems establish an important basis for further integration, the exchange of experiences, and development. Where monitoring methodology has been developed in Europe, it often applies to specific selected monuments or details of a monument, and not to the site – or the cultural heritage environment - as such.

Large-scale on-site monitoring of cultural heritage is a relatively poorly developed field of research internationally, and no international standards currently exist. This is particularly the case in the field of cultural heritage site monitoring in a landscape context. However, some European nations have developed methodologies and systems for assessing the state of preservation of cultural heritage sites related to selected landscape development factors (cf. http://www.uni.net/aec/riskmap/english.htm, http://www.international.icomos.org/publications/risk.htm).

4. The monitoring system's functionality and indicator development

The scale relationships can be categorised in two different groups:

A) Scale relations with internal dependence (where the underlying phenomenon is constant while the grain of the different observation strategies differs).

B) Scale relations without direct internal dependence (for example, deterioration in paint or carved decoration on a church in relation to the characteristics and processes in the landscape around the church).

Even when direct relationships between the detailed scale levels and the landscape scales are not present, a multi-scale approach will offer advantages for heritage management in a monitoring scheme that favours a high degree of data integration. A multi-scale approach can provide an informative overview for the management of a whole landscape.

In order to construct a monitoring system that covers a wide spectrum of landscape issues that are important in terms of both natural and cultural heritage, it has been necessary to integrate both multidisciplinary and multi-scale approaches. For reasons of cost-efficiency the monitoring had to be done at the highest possible scale – a landscape scale - where remote sensing data could be utilised. The idea behind this was that if the scale-related indicators were chosen correctly, important changes to individual monuments would also be recognised as changes in indicators obtained at the landscape level. The system could thereby be designed to trigger monitoring on finer scales to verify and specify the changes taking place on larger scales.

Indicators specific to the <u>cultural heritage environments (landscape) scale</u> have been linked to the various types of pressure mentioned earlier, such as:

- spatial indicators related to the perception of the cultural environment
- abandonment of agriculture
- agriculture
- reforestation
- infrastructure and building development
- tourism
- erosion caused by traffic

On the <u>medium scale level</u> the main challenge has been to establish an indicator framework with connections to both the detailed scale level and the landscape level. The chosen case study areas contain examples of monuments and buildings built of timber or stone, as well as prehistoric cultural heritage objects that are closely linked to nature, such as grave-mounds, house plots, cairns, and so on. The most important medieval building materials are represented, such as stone and lime-mortar in masonry, and wooden stave and timber structures. Indicators have been linked to effects related to:

- chemical degradation of building materials
- climatic conditions
- moisture content
- vegetation and microbiological processes
- mechanical degradation, such as erosion, decomposition, wear-and-tear from visitors and traffic
- the indirect effects of agricultural activity.

The <u>detailed scale level (decorated surfaces level)</u> is usually defined as individual objects or artefacts, or parts of interiors or exteriors with a specific interest or value.

In addition to monitoring techniques for climate logging, monitoring at this level has mainly been based on data obtained from digital photography, micro-photogrammetry and laser scanning[SE06]. The GIS-analyses used on these datasets are equivalent to the analyses used on satellite and orthophotos on the landscape level [SES04]. The case study areas include a variety of objects and artefacts i.e. mural paintings, paintings on wooden panels and architectural features carved in wood.

In this instance too the main challenge was to establish connections and links with the other levels. It was also considered necessary to expand the set of indicator framework and monitoring techniques in order to detect other forms of degradation, damage and changes to objects and surfaces with high artistic and/or historic value. In addition, emphasis was put on the connections with the other two scale levels in terms of choice of indicators, so that techniques could be integrated into an overall solution. Indicators for the detailed scale level have been linked to:

- small-scale biological interaction and growth
- bio-degradation from bacteria and fungi
- insects and rodents
- air pollution
- fluctuation in temperature and relative humidity
- flooding and water leakage
- mechanical damage caused by mass tourism, vandalism and human handling.

5. Methodological challenges

In order to meet some of the above-mentioned challenges, and drawing on our experiences gained in the Italian part of the project, we selected the Slidre area in Oppland as a Norwegian case study area for DEMOTEC. It is an example of a typical southern Norwegian mountain area, with agricultural core areas in the valley and mountain pasture and summer farms in the mountains. Slidre is situated in the Valdres district approximately 200km northwest of Oslo. The area has a high density of listed and well-preserved monuments and sites, including two stave churches (Lomen and Hegge), two medieval stone churches (Slidredomen and Mo, the latter in ruins) and one secular medieval building (Riderstoga at Leirhol). A selection of cultural heritage sites, archaeological sites (such as the Einang Stone and the associated Iron Age settlement area) and associated villages, farms, mountain farms and pastures and surrounding landscape lay within our case study area.

During the 19th century, European traditional landscapes in so-called marginal agricultural areas underwent major changes in land use as a result of rapid technological, economic and social changes (VISTA 2002). The abandonment or reduction of agriculture, as well as the abandonment of grazing and hay production in Norwegian mountain districts have transformed landscapes from diverse mosaics of land use and grazing intensities to coarser mosaics. Forest regrowth and other changes in vegetation are now taking place, and these changes are apparent on many different spatial scales. These natural processes heavily influence *in situ* cultural heritage preservation on a landscape scale. In the chosen case study area tourism also has an enormous impact on land use, in addition to building and infrastructure development, and the effects of erosion. This is particularly true of the mountain area towards Vaset, where accelerating development that has an adverse affect on cultural heritage preservation can be observed.

The TOV project"Monitoring programme for terrestrial ecosystems", established by The Directorate for Nature Management (DN) in 1989, [BSE99]; [ØBØ*01] has documented ground vegetation changes resulting from changes in grazing intensity at different locations throughout Norway. These investigations have been conducted at a very detailed scale in order to detect changes in species compositions and increases/decreases of single species. Increased knowledge of scale relations has been of great importance when these data were interpreted and extrapolated to indicate changes for entire landscapes. In addition, a landscape scale description of history and future scenarios for land use pattern (including grazing) for study sites which covers aspects such as latitude, altitude and degree of continentality has helped in describing changes found in the course of detailed scale analysis. Data from both the TOV project [BSE99]; [ØBØ*01] and 3Q project [DFF*] have been used in DEMOTEC to establish an understanding of the processes that influence the preservation of cultural environments and monuments. Methodology related to that used in the TOV project has also been useful in establishing a cultural heritage monitoring system based on a scale concept.

To be able to develop comprehensive, long-term and cost-efficient monitoring of natural and cultural parameters, processes and resources it has been vital to combine and use heterogeneous data collected at different scale levels. Knowledge about scale relations is fundamental for understanding the conditions and structures of landscape processes.

An important management-related challenge was to link monitoring systems on a regional level with data from detailed monitoring programmes. We therefore had as our aim to explain relationships between results from intensive (detailed) monitoring and results from extensive monitoring (covering larger areas). DEMOTEC has developed methods for more efficient exploitation of both remote sensing data and monitoring programmes.

Scale-related indicators can be developed by establishing a better understanding of spatial scale between dynamics observed at ground level and remote sensing data. As a result, the use of remote sensing data for monitoring becomes more reliable. Such indicators can be developed by using already existing data derived from monitoring programmes that represent long series linked to dynamics and processes at ground level. The TOV project contains this kind of extensive data regarding vegetation processes, structures and changes in six different mountain pasture landscapes, based on observations conducted since 1990. Data from the 3Q project has also been used to understand processes and effects in the relationship between the preservation of nature and cultural heritage.

6. A GIS-based model: techniques

A cost-effective monitoring system exploits existing spatial datasets containing geographical information, deducing from these the various landscape parameters which are relevant to monitoring at a detailed scale level. By using earth observation data from satellite and/or aerial photographs, it has been possible to integrate earth observation data in the process of developing new landscape indexes. These data could be directly integrated with fine-scale data derived from the sampling of monuments, vegetation or vulnerable surfaces on monuments.

The DEMOTEC pilot system has been based around a geodatabase, constructed in such a way that it can be accessed both through the GIS interface of the ESRI ArcMap [Esr96] products as well as through MS Access database software. This facilitates participation not only by experts, but also enables cultural heritage managers to access the monitoring data for management purposes.
Differing sets of data need different treatment before spatial integration; for instance, remote sensing data need to be geo-referenced. All datasets have been converted to the same projection and datum, and all calculations have taken place in this geographical format.

The analyses conducted at landscape levels were based on grid analyses in a GIS, where classification and re-sampling of spatial entities, as well as comparison with previous monitoring states, constitute a key starting point when monitoring indicators. Analyses that have been conducted at this scale include changes in land use and vegetation, as well as simple area statistics. Working at this level, the pilot system mainly used historic aerial photographs and recent orthophotos and terrain models. The geo-referencing of the aerial photos was performed using the Orthobase module in Erdas Imagine [Erd97], but the potential of the new Stereobase module was also investigated. This could be used to extract relevant information from existing aerial photos, for example. Data collected from fieldwork on the chosen monuments and sites has supplemented the development of indicators and increased the reliability of a monitoring system based on the assessment of data derived from satellites (Ikonos, Envisat, Spot, Landsat, DEMs etc.) where these are available.

The analyses conducted at a medium scale level have utilized a more heterogeneous spatial data set. Orthophotos (both historic and recent) and historical maps have also been important at this level. The geo-referencing of the historical maps was performed in ESRI ArcMap. Some of the analyses conducted at this level were of a more qualitative rather than quantitative nature (such as interpreting changes in traffic patterns over a 150-year period, or interpreting the loss of relationships between areas due to changes in subsistence etc). Terrain models were also used at this level. Photographs taken along visibility lines have been used at this level in order to monitor changes in relationships between entities.

The analyses conducted on the detailed scale level have utilised various types of sensory equipment and data-loggers to monitor parameters such as humidity, air quality etc. In addition, GIS techniques developed for different scale levels have been applied (such as using terrain models on details of building features). Rectified photos and 3-D scanning have also been utilised at this level.

It has been necessary to conduct conventional survey work in order to check that the results from monitoring analyses are correct, and some of the supplementary data could only be collected in this way. The geodatabase is compiled in accordance with an established routine, whereby the field-worker extracts the relevant monitoring data in the geodatabase and transfers these data to a PDA/GPS setup that contains a small GIS software (ESRI ArcPad) [Esr00]. The field-worker records changes on a registration form and transfer the data back into the geodatabase. The new data can then be used - in combination with the existing data - to perform analyses. The results of the analyses then form the basis for a monitoring report.

In addition to the above-mentioned challenges related to linking the scale levels together, there have been further challenges related to compiling the geodatabase's monitoring history (i.e. the history of the different conditions of a specific detail, monument or landscape), as well as challenges in linking information from the national spatial cultural heritage inventory (known as Askeladden) with the monitoring system for the two Norwegian case studies.
Some of these problems have resulted from the fact that the Askeladden database is currently geared towards heritage management, and has only to a limited extent been designed with monitoring tasks in mind.

7. Concluding remarks

The main aim at the outset of the project was to establish a system that can report the state of cultural heritage preservation to citizens, heritage management authorities and politicians in a standardized way which can facilitate future management decisions.

Our solution has been to construct the outline of a monitoring system through the development of a pilot model in a case-study area in Italy, and subsequently apply this pilot model in two Norwegian case-study areas.

The pilot model has survived the methodological challenges of creating a system based on an interdisciplinary multiscale concept, as well as the technical problems relating to developing the model as a geodatabase.

The adaptations that have been implemented in order to create the system open up the prospect of being able to apply this approach on a broader scale.

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Short Papers

New Possibilities in 3D-Documentation Using Digital Stereo Photogrammetry

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Abstract

Stereophotogrammetric recording allows spatial perception and three-dimensional analysis of objects. The integration of digital image processing techniques into a photogrammetric evaluation system offers new possibilities for the process of image orientation and an increase in accuracy for stereoscopic measurements. Object surfaces and profiles can be automaticaly generated from digital images using correlation procedures. With the resulting software, users are able to make stereoscopic recordings and analyses on their own. Data from tacheometry and laserscanning complements the photogrammetric determination of digital object models. In combination with the high resolution stereoscopic image material, point clouds and 3D models with original texture can be generated. In addition to central perspective exposures of analogue or digital metric and amteur cameras, also images from high resolution panoramic cameras can be used for stereoscopic evaluation. So, a technology and software for fast and simple photogrammetric on-site recording and 3D object documentation will be developed applicable especially in architectural surveying, building preservation and archaeology.

1. Introduction

Photogrammetric methods are still fundamental instruments for cultural heritage object documentation. Compared with discrete measurement techniques, like hand measuremts, tacheometry and also laser scanning, photogrammetric object recording offers a continuous, high-resolution rendition of the visible object surface and allows a geometric evaluation also at a later date. Moreover the collected photos are often an important documentation resource for future researches.

While image rectification is a simple but approved technique for documentation and evaluation of plane object surfaces, in many cases the handling of higher level photogrammetric methods for spatial object analysis is too complex for non-photogrammetric users.

Stereophotogrammetric recordings allow three-dimensional documentation and evaluation of uneven objects and freeform object surfaces. Spatial perception at stereoscopic viewing gives users information about condition, quality, and structure of surfaces. The integration of automated image analysis techniques in one user-friendly stereo evaluation software can simplify the stereoscopic measurement procedure and open up this technology for a wider user area.

The use of stereophotogrammetry and image analysis for building history and archaeology is one research focus at the chair of surveying at BTU Cottbus. The introduced workings are based upon a long-term cooperation with fokus GmbH Leipzig and the joint research project "Integriertes 3-D Panoramamesssystem" for combined photogrammetric evaluation of digital panoramic images and laser scanner data between TU Dresden, KST Pirna, and fokus GmbH Leipzig.

2. Image matching techniques

On the manual stereoscopic measurement the user has to superimpose homologous image points with the help of the floating mark. This process of depth determination is often difficult for untrained users and may produce wrong results at stereoscopic evaluation. Due to the substantial similarities of stereoscopic image pairs, correlation techniques are well suitable for integration into a stereo evaluation system. First an automated depth measuring function using image matching was implemented for an easily positioning of the floating mark on the object surface. According to the Vertical Line Locus procedure [CH84] a straight line orthogonal to the current projection plane is defined. For discrete points with a defined interval Δh along this line, image coordinates for the left and right image will be calculated. The intersection point between the line and the object surface can be obtained from the image coordinates with the maximum similarity between the surrounding image matrices using the normalized cross-correlation coefficient for a one-pixel accuracy approach - e.g. [Pie91]. A sub-pixel localisation will be calculated afterwards with least squares matching (LSM) (e.g. [Ack84], [Foe82], [Gru96]) for a geometric and radiometric transformation between both image patches. LSM is the most accurate image matching technique and offers an improved accuracy also for images with larger perspective differences. Moreover the adjustment calculation of LSM affords statistical estimation on the obtained inner accuracy.

3. Image orientation

The orientation of stereoscopic image pairs is organized in a three-step procedure starting on inner orientation for the used cameras, relative orientation between both images and absolute orientation of the model coordinate system. The parameters of inner orientation should be previously determined by a camera calibration based on a reference point-field. On suitable object geometry approximated values for inner orientation can be determined by space resection adjustment separately for each image.

Figure 1: *Simple camera bar for stereoscopic exposures with defined base distances of 30 cm and 60 cm (left) and reference frame for stereo model orientation (right)*

The measuring of homologous image coordinates for relative orientation is supported by integrated correlation techniques. So, natural unmarked tie points can be used to consider an ideal point location within the object space (Fig. 2). Image points with sufficient texture information will be defined in one image. Initially, the search area for the corresponding image points has to be specified interactive. After the first calculation of relative orientation parameters, the search area for the correlation process can be automatically limited to the corresponding epipolar band.

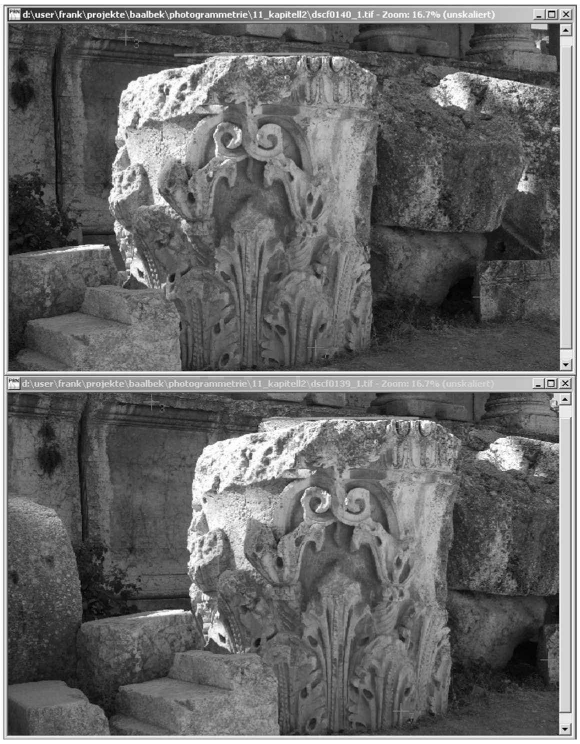

Figure 2: *Relative image orientation using correlation techniques for matching of unmarked object points, (Capitel Baalbek, hight 2 m, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)*

The model coordinate system of relative orientation can be transformed with passpoints into object space or simply scaled with a known object distance. Using a calibrated stereo bar as object distance for scaling (Fig. 1), no other reference information will be needed in the object space and so, full-scale reconstructions of non-reachable objects can be easily generated. Additionally, single image orientation is possible by space resection adjustment. Signalled reference points for an absolute orientation or space resection can be automatically measured with sub-pixel accuracy using centroid calculation for circular targets or adapted methods for cross-shaped patterns [Luh86].

4. Stereoscopic image acquisition

Different approaches for camera modeling allow the use of digital and analog non-metric cameras as well as digital panoramic cameras (Fig. 3) for the creation of stereoscopic models. Digital SLR cameras offer good lens quality, a sufficient geometric stability and the high image resolution is comparable to analog medium format cameras. Several studies have shown the suitability of compact digital zoom cameras for photogrammetric purposes on principle [HLT04], but the use for an exact stereo evaluation is not recommended. Also large format metric or non-metric analog cameras can be used for image recording, but the processes of negative develpment and film scanning may lessen the quality of the correlation results.

Figure 3: *Stereoscopic view of a panoramic image pair (Dresden Trinitatis church, EYESCAN M3D, c_k 35 mm. RGB CCD-line with 10.000 pixels)*

According to stereometric cameras like Zeiss SMK with a calibrated stereo base, a defined distance between both camera positions can be realised with a simple base bar (Fig. 1). This configuration allows the use of just one camera for both exposures according to the advanced normal case of stereophotogrammetry. Scaling of the stereoscopic model system is possible with the known base distance, so that no additional object information is needed. This procedure allows fast and easy stereophotogrammetric documentation of architectural fragments and archaeological findings on site with possibilities for full-scale three-dimensional evaluation at a later time.

With the help of object scale-bars or a reference frame (Fig. 1) with given 3D coordinates within the object space it is possible to transform different stereo views into one uniform object system.

5. Automated stereo measurements

Similar image structures can be automaticaly determined with image matching algorithms. The first step is the calculation of approximated values for the best location of a reference image patch (template) within a predefined area of the search image using normalised cross-correlation coefficient. A sub-pixel localisation follows using least squares matching. Object coordinates are computed from the matched image coordinates with forward intersection using the parameters of inner and outer orientation.

Figure 4: *Matched points of a capitel (see Fig. 2) in the stereoscopic image display (left) and 3D view of the created point cloud (right)*

The generation of 3D point clouds for the processed object surface will be done by applying expansion algorithms on the matching procedure starting from a given object point. The increment for the template translation within the reference image and the size of search area within the stereo partner can be defined by the user, dependent on image resolution and object structure. Furthermore the user can restrict the evaluation area within the stereo model interactive.

Horizontal and vertical profile evaluations of objects (Fig. 5) can be generated similar to surface determination using expansion algorithms for image matching. A profile line for the automated measurements can be defined by a given elevation for horizontal sections or an aligned perpendicular coordinate system for vertical sections.

It is also possible to include 3D laser scanner data into a profile, given in STL format or over a user defined ASCII interface. A coordinate filter imports only points within a defined tolerance range to the profile plane.

With a special separation algorithm it is possible to arrange discrete points into objects or to eliminate outliers [SS06]. The automated measured points of a profile line can be reduced and adjusted for the creation of simple vector geometries using smoothing algorithms [Bie06]. Finally a DXF interface allows the export of profile drawings to CAD systems.

6. Surface triangulation and texturing

Digital surface models can be generated from matched object points and laser scanner data using the Ball Pivoting

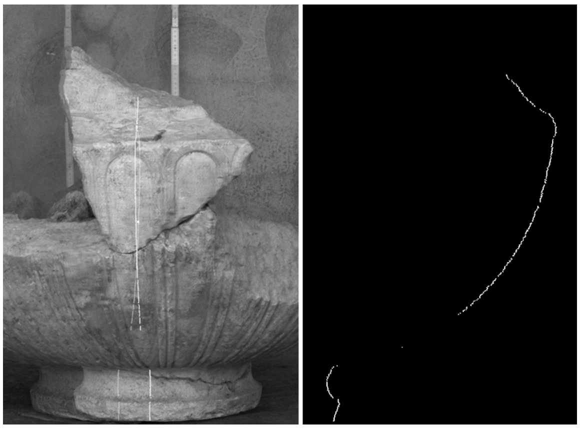

Figure 5: *Automatic measured vertical profile in stereo view (left) and profile plain (right) (Fragment of a Kratér, max. diameter 60 cm, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)*

Algorithm [BMR*99]. The algorithm is comparable with a ball rolling over the point cloud surface. The radius of the ball has to be larg enough, so that it do not fall through the point cloud surface. Starting at a triangle, the ball pivots around the axis between two points until it touches another point, forming another triangle. Thus, the ball rolls over point cloud surface until no new triangles can be found. Because of irregular interspaces between matched or scanned points, it is not possible to triangulate the whole point cloud with just one ball radius. Therefore an adapted algorithm was implemented using several ball radii for such irregular point clouds [Vet05].

Several approaches for the texturing of point clouds and digital surface models (DSM) were implemented in the software. With collinearity equations the color of 3D point clouds can be determined from image information either of oriented stereo or single images. Furthermore distance dependant point coloration can be determined related to a coordinate plane or the laser scanner standpoint.

For triangle texturing using stereoscopic image information the intersection of the current image ray with the DSM, as well as alignment of the directions between triangle normal and camera axes and the triangle neighbourhood have to take into consideration. To eliminate image failures and covered object areas the user has the possibility to define areas within the selected images.

7. Conclusions

The integration of image matching techniques into a stereo evaluation system for close range photogrammetry affords a spatial collection and evaluation of objects especially in the fields of architecture, archaeology, and preservation. The presented system considers the special needs of architectural photogrammetry and allows the use of analog and digital amteur cameras as well as digital panoramic cameras. A simple technique for stereo image acquisition together with first automations in relative image orientation using correlation techniques allows a fast preparation of stereoscopic models without advanced photogrammetric knowledge. The automated stereoscopic measurement procedures offer high accuracy for photogrammetric point determination and simplifie the three-dimensional object reconstruction.

The described functions were implemented in the software metigo STEREO (Fig. 7) of the fokus GmbH Leipzig.

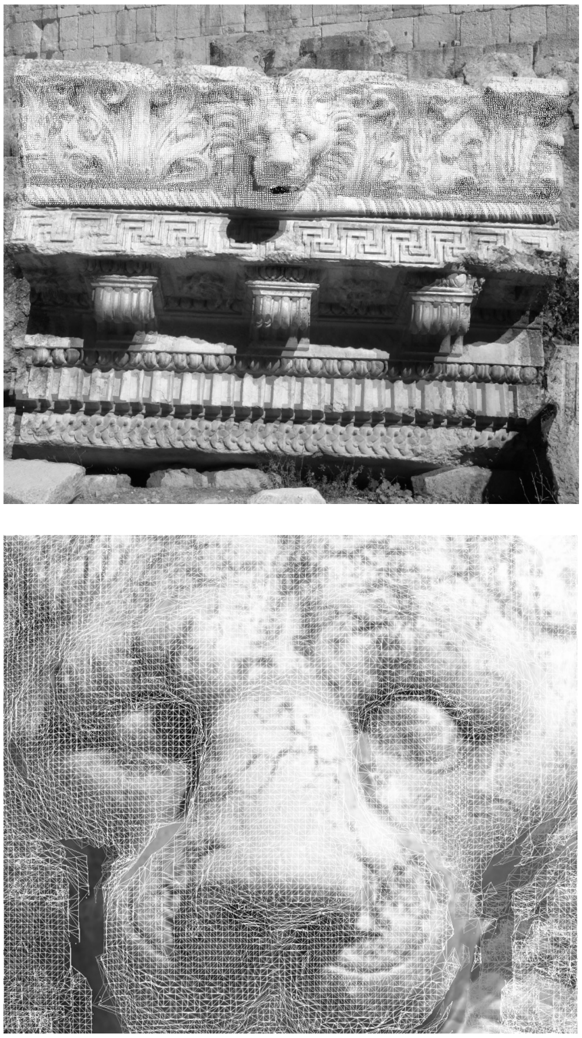

Figure 6: *Triangulated object surface of an architrav block in Baalbek (Object size 3 m x 2 m, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)*

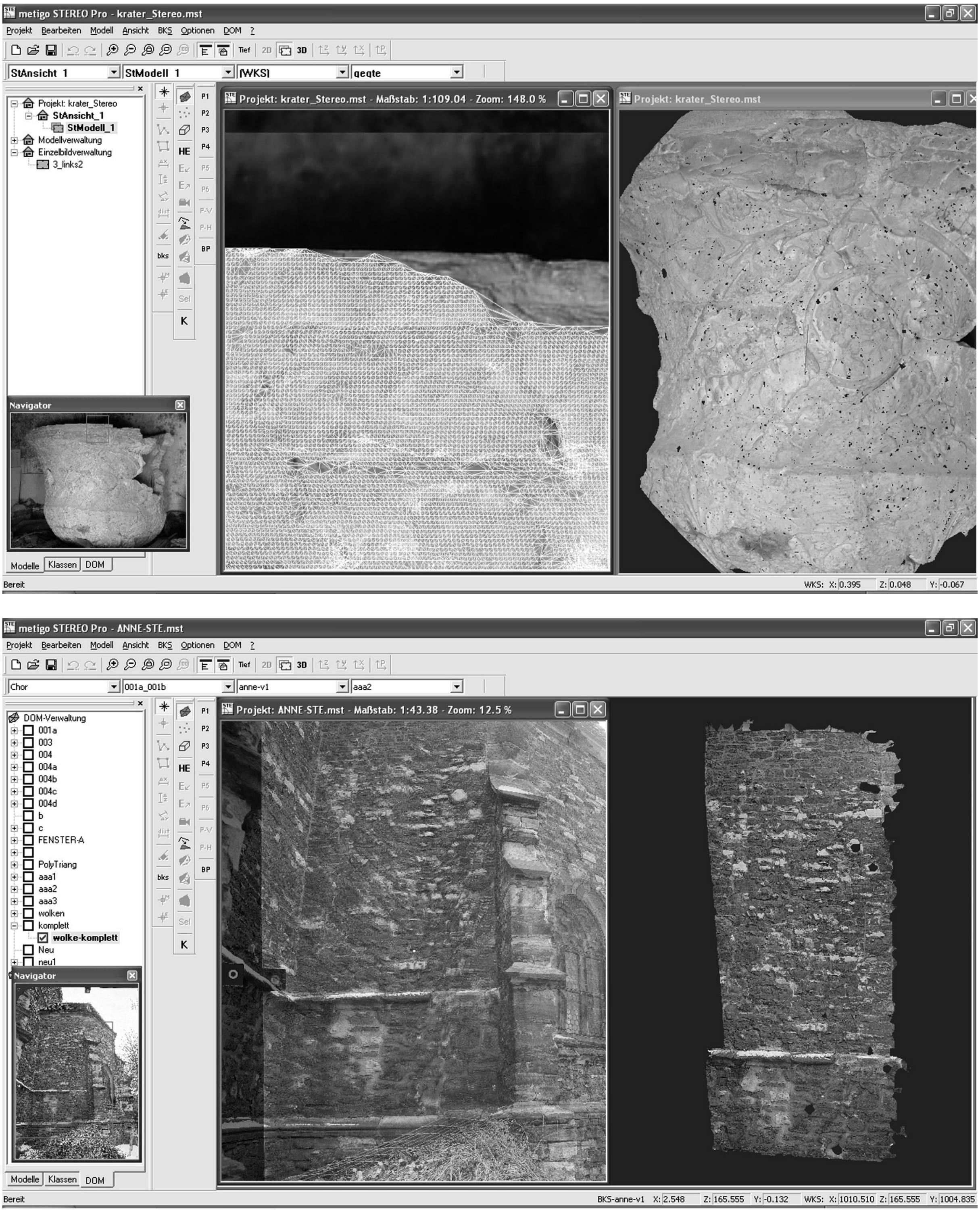

Figure 7: *Evaluation with metigo STEREO: stereoscopic view with overlaid triangulation (left) and textured 3D model (right) (upper figure: Kratér Baalbek, diameter and height 1m, Fuji FinePix S2,* c_k *35 mm, CCD 4256 x 2848 pixels, lower figure: Church St. Annen, Eisleben, facade height 8 m, Zeiss UMK 13 cm x 18 cm,* c_k *100 mm, scan 2500 dpi)*

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Short Papers

A Tourist Guide System for Ancient Cities Case study: BISHAPOUR

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Abstract

Location-based services (LBS), which extend beyond today's use, will play a major role in tourism industry. Information interesting to tourists is location-dependent by nature, and Geoinformation system (GIS) contains many of the components necessary for LBS. GIS can handle spatial and aspatial queries, allowing navigation and wayfinding, deliver relevant information on the mobile device ranging from spoken instructions to 3D visualizations presentation in particular location.
Navigation assistance is one of the fundamental services in a mobile assistant which calculate routes between two locations, with GIS network analysis tools, but it can't guarantee users to receive their goal. Tourists have to find their ways through unfamiliar environment. Wayfinding as the main component of navigation gain importance. Mobile wayfinding that gives turn by turn route direction including landmarks, in both graphical and verbal route instruction representation can prevent them from getting lost or confused. Wayfinding is frequently assumed to take place on the spaces which can be described by network graph theory. But there are environments in which there is no obvious network structure. In tourist interested spaces like ancient cities we frequently encounter with spaces which there is no network of paths to follow, rather there are open spaces between buildings and rooms and other objects. Hence in such spaces using a hierarchical arrangement between existing elements are more reasonable than a network structure.
In this paper we propose a model according to tourist's purposes and non-network structure environment. As a platform of experiment environment BISHAPOUR, as an ancient city, is selected.

Categories and Subject Descriptors (according to ACM CCS): [2D and 3D GIS in CH]: Navigation/Wayfinding model

1. Introduction

Third generation standards of mobile networks like HSCSD (High-Speed Cicuit-Switched Data), UMTS (Universal Mobile Telecommunications System) together with new generation smart phones and PDAs (Personal Digital Assistants) and improvement of localization technology like GPS (Global Positioning System) are increasingly developing location-based services an specially tourism-related applications.
Tourist related tasks, such as sightseeing, wayfindin between destinations, shopping, notifying of events an so on are not highly structured and specific [ZJ05]. I becomes hard for a tourist to effectively plan a trip to a unknown city and to collect the right information i advance. Tourist encounter with changing environmen

and it makes necessary to support this nature of tourist plans by mobile tour guides. Information interesting to tourists is location-dependent by nature, and GISs contain many of the components necessary for LBS (Location-based service). GIS can handle spatial and aspatial queries, allowing navigation and wayfinding, deliver relevant information on the mobile device.
However, the danger exists of investing a lot of money into solutions that tourists will not accept [Zip02]. Usability is one of the most important aspects for the future success of tourist information system. Tourist assistance systems should regard that use of these systems is not the primary goal of the tourist. Parallel tasks such as carrying heavy luggage or answering a phone call and visiting historical building while walking, apply additional pressure on the user, which has to be compensated by guidance systems. Context-awareness plays a major role in Location-based services in order to provide ubiquitous services in the right situation to the customers. [BKS05], [MZ02].
In tourism applications, end users at each particular location, would like to get individual information about it on their devices [HV03], it will be necessary to support planning a schedule to travel multiple destinations efficiency under specified restrictions and user's interests. With respect to tourists often are unfamiliar with environment, receiving turn by turn route direction include landmarks, in both graphical and verbal route instruction are desirable. Among all services that mobile tourist assistant systems provide, we focus on wayfinding/navigation service in this paper.
For provision a mobile adaptive tour guide system with tourist context, investigation in tourist cognitive resources is necessary [Kra03]. Research in cognitive science reveals finding one's way in a street network uses a different set of cognitive abilities than navigating from one room to another in a building [28], moreover tourists often use tours to learn in a structure manner about places visiting rather than strictly follow their suggested path [GM05].
Current GISs data models based on precise geometry of the space are so different from human cognition [RT04], Therefore software design for GISs needs to integrate human spatial reasoning and cognitive concepts of navigation in to the systems. [TF92] In this article we focus on the adaptation strategies need to apply to wayfinding/navigation models.
In this paper we present some of tourists' contextual factors which influence wayfinding task, and we propose a hierarchical wayfinding model convenient to many of tourist visiting sites.

2. Navigation/Wayfinding

Tourists have to find their ways through cities, through buildings, along streets and highways, and environments to be navigated are usually unfamiliar. In many cases people find it difficult to perform wayfinding tasks in an unfamiliar environment, because of deficiency of clues, lack sufficient landmarks or badly designed architecture [Rau01].
Route planning and navigation assistant systems can efficiently calculate routes between two locations. It can be done by current network analysis exists in current GIS software but it can not guarantee users reach to their goals. Mobile wayfinding assistance is one of the fundamental services in a mobile information system. The adaptation strategies need to apply to wayfinding services. The navigational instructions can be adjusted to the current situation using knowledge about the user's preferences, familiarity with the environment, their current goal and the environment that navigation takes place [BC03], [Kra03].

2.1 Adaptation with purposes

Investigations on cognitive aspects of wayfinding for a tourist reveal their preferences for route instructions are different from other purposes (a person in a hurry or a driver). The tourist as a user who wants to use the system for entertainment and on vacation, without knowing where they were exactly going, they believed to find something interesting in a particular area [BKW02]. They are able to spend the most of his attention to the space when finding a way. They often tend to follow a rather estimated direction, Instead of following a specific route [GM05]. They often don't like to find their way with metrical distances and turn angles while they walking [RT04].
Other than the role of purposes in wayfinding task, configuration of spaces also needs adaptation strategy.

2.2 Adaptation with spaces

GIS navigation functions use network analysis for finding optimal route, they assume wayfinding takes place on networks, therefore graphs are an appropriate formalism for these spaces, but there are environments in which there is no obvious network structure, we encounter with open spaces which there is often no network of paths to follow. Ruetschi [RT04] called them scene space, Hence in such spaces the models are used, must not assume a network when there is not.
The network spaces have a well defined structure and a route in a network can be described as a sequence of decision points [Kli05]. Decision points in scene space are not so obvious, therefore wayfinding hardly depends on the precise distance between the elements of spaces and detailed metrical representations [RT04].

Because of the current models used in GISs can not adapt with tourists' contextual factors we work on a model based on Ruetschi's models for structuring wayfinding in a transportation node [RT04]. Indeed, we design an object oriented map for wayfinding in a part of my case study, Bishapour.

3. Case study

We selected Bishapour city as a platform of experiment environment. Bishapour is a city that remains of Persian ancient which existed 1700 years ago. Bishapour city is located in Kazeroun, a city of Fars province in Iran. Bishapour was the most important city in the Sassanid era, which was built during the reign of Shapour I. Design of Bishapour is not circular. Streets and roads cross each other in the center. The state buildings were constructed in the center of the old castle, north of the city. Each building in this complex had its own specifications and peculiarities, like Anahita Temple, Formalities Hall, Walerin Palace, Memorial columns. After the Arabs entered Iran the city was decorated by some Islamic architecture features.
In Bishapour scene spaces are seen more than network spaces, we chose a part of this city including northern complex, Tang-e-Chogan and columns that depicted in figure1 for implementation.

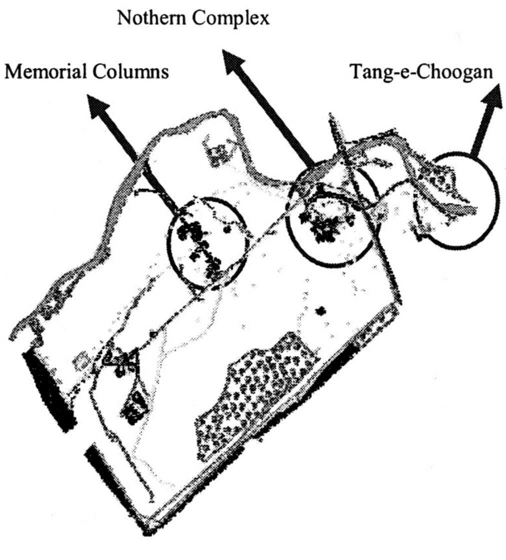

Figure ۱: *Bishapour*

4. Implementation

We implemented a model called schematic geometry in a part of Bishapour city, Figure.2. This model is based on image schemata and partial order, configures scene space and models wayfinding task.
Using partial orders is in accordance with the common belief that human memory is hierarchically organized, human beings use hierarchies extensively to simplify their conceptual models of reality and to structure spaces [RT004], [TF92], [Car96], and image schemata provide a grounding of the formalism in human cognition [RT04]. According to properties of wayfinding in different situation which mentioned above, Instead of using wayfinding based on metrical distances and turn angles, we propose use of knowledge in the world for wayfinding guidance systems. Due to formalize human concepts of spatial knowledge, image schemata include instances for elements in real world to mean space are useful for spatial configurations.
Image schemata originated in philosophy and linguistics, Johnson [Jon87] defined image schemata as recurrent patterns consisting of some parts and relations that help us structure our perceptions and actions.

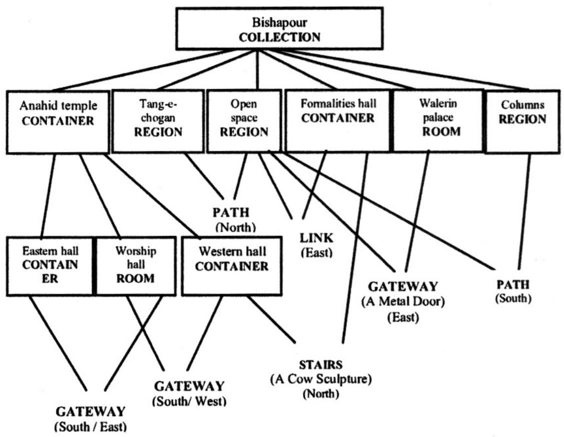

Figure 2: *Schematic geometry for Bishapour*

By an investigation of each application and each special space (an Iranian ancient city) and based on Johnson's image schemata, we can define required cognitive schemata.
- A building instantiates the CONTAINER schema, the concept of containment, defining an inside and an outside, divided by a boundary and thus can contain other instances. We use also REGION and ROOM schemata include containment relationship in our model.

- A door as a GATEWAY schema, the concept of connectivity, which entities are connected through it. LINK, ULINK, PATH are used in model are instances of a connections

When a tourist is standing at a worship hall is located on the Anahid temple, then she is also standing in the Anahid temple. This model allows deduction that there is a way for reaching Walerin palace. But she should be able to recognize which connection is one that reach her to Walerin palace among existing connections, therefore the connections schemata should have attributes for introduction landmarks if there are, and qualitative spatial relation definition for determination their relative position in their CONTAINER. Figure2 shows schematic geometry equipped with this information for wayfinding, we introduce landmarks [Kli05] (a cow sculpture) and simple topological relations.

Although identification most of connections is possible without these topological relations,(e.g. STAIRS which are distinguishable easily), with elements' positions with respect to one CONTAINER, determination of approximation distance (near/far) between them and their neighborhood relationship are feasible.

5. Conclusions and future work

Emerging new technologies such as handheld mobile devices with wireless connections provide requirements for eCommerce and eTourism development.

Context-awareness plays a major role in Location-based services in order to provide ubiquitous services in the right situation to the customers. We focused on tourist's contextual factors which should be taken into account in delivering information.

We implemented a model in Bishapour, according to tourist's context and scene spaces available in this city.

This model that is more adaptive with tourist cognition and dose not work based on precise geometry, decreases navigation service correlation to positioning with high precision. And we intend to complete this model with topological relationship that has expressed to some extent in this paper, and design such model for wayfinding in street network.

In Bishapour we have a combined space of scene and network, and for tour planning we will need to use dual graph [Win02]. Because loops and route segmentations that should be walked in two directional, have not been assumed in Traveling Salesman Problem, while we encounter with this problem in Bishapour for tour planning. We intend to solve loops and bidirectional segments in combined space of Bishapour.

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Historical Archive of the Aegean 'Ergani': Visualising the Archival Experience, a Museum Multimedia Application

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[1] Historical Archive of the Aegean 'Ergani'

Abstract

Historical Archive of the Aegean 'Ergani' is a civil, non profit organisation based in Mytilene, Greece, aiming to collect, preserve, document and exhibit archival material of the 19th and 20th centuries. 'Ergani' has undertaken the creation and installation of a multimedia application to be displayed as an integral exhibit of the Museum of Olive Oil Industry of Lesvos, (member of the Network of Thematic Museums of the Piraeus Bank Group Cultural Foundation). The installation is a multimedia exhibit presenting and exploring entrepreneurial and innovative aspects of olive culture and olive oil industry in Lesvos during the period 1890-1960.

The multimedia application draws its content and makes use of the digitised archival material of the Kourtzis Archive, as well as the related archival and historical documentation information which situates and describes this archival material. The design and implementation methodologies of the application, aim to simulate the experience of searching in an archive (the archival experience) as integral to the experience of a visit to the museum (museum experience).

The visualisation of this archival experience is achieved through the use of two, synchronized touch-screens. The first screen is used for the visualisation of the archival content's semantic web in the form of an interactive hypergraph. The second one, uses the digitized archival material as an interactive interface which reproduces the hypertextual relationship which characterizes the archival material and the production of historical knowledge.

1. Introduction

Historical Archive of the Aegean 'Ergani' is a civil non profit organisation based on Lesvos island, Greece, aiming to collect, preserve, document and exhibit archival material related to the 19th and 20th centuries[His06]. 'Ergani' has undertaken the development of a multimedia installation to be displayed as an integral exhibit at the Museum of Olive Oil Industry of Lesvos, (member of the Network of Thematic Museums of the Piraeus Bank Group Cultural Foundation); the installation presents various entrepreneurial and innovative aspects of olive culture and olive oil industry in Lesvos during the period 1890-1960.

This multimedia installation explores and refers to the industrial heritage of Lesvos, in relation to the unique gift of this island's land, the olive tree and olive oil. It is based on and utilises the archive of the Kourtzis family and the related entrepreneurial activities of its members in the field of olive cultivation and olive oil extraction with particular emphasis put on the organisational and technological innovations and inventions which supported them. Our central motive and focus point is 'Ergani', an internationally recognised and patented invention of Mitsas Kourtzis (1924), which has been warmly greeted, not only in Greece but also in the other olive oil producing Mediterranean countries and was presented in various international conferences and international journals of its time. The archive material utilised for this multimedia installation, includes rare documents, photographs, amateur films from the period 1924-1927, diaries, books, magazines, drawings, scientific reports, etc.

2. An Archive inside a Museum

The specific multimedia installation is about the cooperation between two different organisations which are both active in the domain of cultural heritage, a Museum and an Archive. The first, tells the story of olive oil extraction through the display of various related artefacts, while the second, holds a valuable archive which is made available thus enabling a better sense of understanding of the nature and history of olive oil production in Lesvos.

From the perspective of the users, the cooperation between these two different organisations is in a sense natural, since it gives them access to complementary and unified cultural content on this particular issue.

These forms of cooperation are not novel if one considers the 'cabinets of curiosity' which were created during the 17th and the 18th centuries and can be said to constitute the ancestors of both Museums and Archives. These 'cabinets of curiosity' did not distinguish between objects and works of art, between books, documents, manuscripts and maps but contained all of them in an attempt to understand the world through unified collections of its various artefacts.

However, during the 19th century, these unified collections were gradually transformed into separate organisations, following the different material nature of their holdings. This change was compatible with the newly emerging forms of work the administration of knowledge which were compatible to the new realities of the emerging nation state.

Today, it seems that an increasing number of people tend to agree with the intellectuals of the 17th and 18th centuries rather than those of the 19th and 20th. They want to have access to the contents of Archives, Museums and Libraries without necessarily accepting or understanding their internal differences in terms of their politics, their distinct classificatory boundaries or the different methods for accessing their collections.

Thus, the strengthening of the cooperation between these different organisations becomes very important, if our aim is to satisfy the emerging needs of today's users. In our own case, this cooperation takes the form of a multimedia installation utilising the contents of an Archive which is installed as a permanent exhibit inside a museum, thus enabling the visitors to come into contact with both a museum and an archive which are quite far from each other in physical terms.

3. Weaving Cultural Content

The multimedia installation draws its content and makes use of the digitised archival material of the Kourtzis Archive which contains archival material of the period 1840-1970, as well as the related archival and historical documentation information which situates and describes this archival material. This digitised cultural content utilises the results of the national project entitled "Development and exploitation of a thematic digital collection regarding the modern economic and social history of the North Aegean region (1870-1930) which is funded under Information Society Action Line 1.3 "Documentation, Exploitation and Promotion of Hellenic Culture" [Inf06].

'Ergani' has undertaken the archival and historical documentation of the Kourtzis Archive according to a methodology following all the internationally accepted standards. Thus, archival documentation at document level produces ISAAD [Int01] descriptions, which are then encoded in XML following the EAD DTD and RLG recommendations for interoperability. Further study of the material - historiographic or otherwise- and documentation work spanning multiple parts of the archive is semantically supported by the CIDOC CRM ontology [MSK05]. The process of digitising the historical material has generally followed the most widely accepted international standards and best practices[DT03][Web03].

More specifically, the methodology applied in the case of the Kourtzis Archive aimed at:

i. ensuring the optimal coverage and accessibility of documentary evidence by detailing an initial structured and authoritative view of the archive through complete and native application of archival description and interoperability standards, extensive use of thesauri and normalized signalling of personal, temporal and geographical information (Getty AAT and TGN, Library of Congress TGM I and II, and the UNESCO Thesaurus)[AAT06][TGN06][TGM06]; ii. open documentary evidence to historical analysis and materialise and creatively visualise the resulting discursive structures by interconnecting documentary evidence through the instantiation of a central knowledge model (CIDOC-CRM).

The semantic weaving of the archival web used for the production of this particular exhibit is furthermore supported through the annotation of the digitised historical material and also, annotation of the relevant historical texts produced by historians who have examined and analysed the contents of the archive. This annotation process is guided by the principles of Grounded Theory and sets out to examine, administer and connect in a meaningful way, a large and diverse body of evidence by the use of concept-codes which signal their relationships[GS67]. The capacity to conceptualise these concept-codes and their subsequent relationships, is based on the theoretical sensitivities of the researcher and is influenced by the subjective ability of 'reading the data', but also, by the capabilities of the software tools designed to assist this sensitivity.

In our case, our data includes texts, pictures, sound and video files and the application of Atlas.ti software, gave us the ability to create a series of concept-codes around which our multimedia content was organised semantically. These basic concept-codes were, 'Ergani', 'Ergani, inspiration and creation', 'Ergani, construction and function', 'Ergani, promotion' etc.

The 'gathering together' of digitised archival material under these concept-codes and the relationships between the concept-codes themselves, create our 'semantic web' or, to put it differently, our "clusters of meaning"[Ifv89].

The innovative aspect of this multimedia installation refers to the ways through which the human and social sciences are integrated (through the assistance of software technologies) into the weaving of the content of the application. By using the rich methodological tradition of the humanities and of the social sciences, we can develop better ways and methodologies for representation and semantic construction of multimedia data. Not only access to this content is organised and structured, but also, is visualised in such way that it is adaptable to the specific needs of different visitors of the museum.

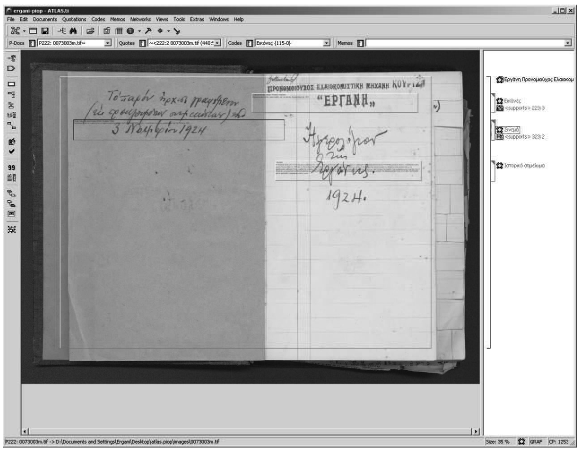

Figure 1: *Example of annotation through the use of Altas.ti software. Here, we can see the use of the code "Ergani, inspiration and creation" and the way in which the digitized archival material is annotated and interrelated semantically.*

4. Visualizing Cultural Content

When designing this museum installation the aim was to achieve an innovative visualisation of the digitised cultural content. Two different applications were created so that the user has the choice of navigating into this digital cultural collection through two interactive entry points: a) an interactive display of the digitised cultural content, its corresponding archival description, and additional historical documentation data -always related with concept-codes- and b) a navigating tool representing the content's semantic structure visually displayed in the form of a hypergraph.

The first application was developed using Macromedia Director. It 'exhibits' the most important archival items while a series of tools (see Figure 3) assist the user in further exploring these items and discover their interconnections with other related material and data (picture, text, sound or moving image), enriching thus, his/her experience of the exhibit. The tools' symbols were chosen to correspond specifically to the relevant thematic categories as well as to the applications functions (choice of colours and functions/utilities).

The second application was implemented with the use of ThinkMap SDK. The nodes of the hypergraph show the concept codes related to the installation's cultural content and their interrelations. Explanation of each node displayed at each moment is presented at the side of the hypergraph.

The physical infrastructure of this installation consists of two touchscreens each connected to a video projector so that more museum visitors can watch the effect on the information displayed as the user interacts with the installation. The left part presents the interactive display of the digital collection items and the right one the content's semantic hypergraph (see Figure 4). Interacting with one part of the installation affects the other. Clicking on a node of the Thinkmap SDK hypergraph will change the thematic category presented in the Macromedia Director multimedia application.

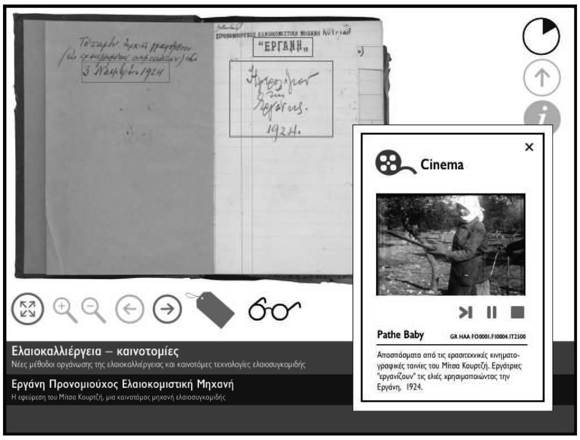

Figure 2: *Example of a Screenshot from the left screen of the application where a part of the digitized material is presented (Ergani diary, IT.0073). The user can retrieve information (text, sound, image, or video) by activating a series of hyperlinks. All information contained has been designed so as to be displayed in a pop-up box, thus allowing the image of the digitized content 'to speak for itself'. Additionally, on a second level, the user can examine each archival evidence in greater detail by using the relevant preview tools (full screen view - zoom in - zoom out).*

5. The Museum Experience

The physical room where the multimedia installation is exhibited is 4x14m and is organically integrated into the main exhibition hall of the Communal Olive Press of Ayia Paraskevi. The installation takes into consideration three basic parameters which are signaled out in the relevant literature in relation to the experience of the visitor who visits the museum: the personal dimension, the social dimension and the physical dimension.

The personal dimension refers to the initial combination

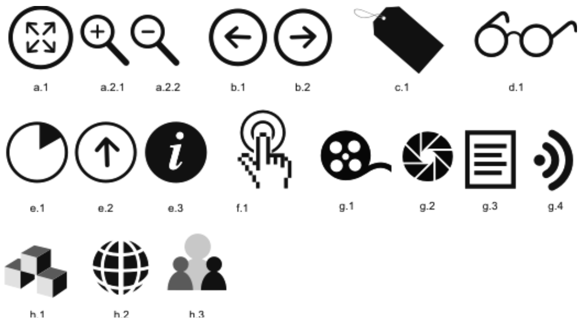

Figure 3: *Series of overviewing symbols used: group a: overview tools (full screen view - zoom in - zoom out), group b: navigating tools to-from archival items, symbol c: initializes a pop-up box which displays the archival description of each item, symbol d: initializes access hyperlinks to further information for each item, group e: navigating tools to the thematic categories of the application, symbol f: initial access hyperlink, symbol group g: series of symbols representing the form of information which is displayed to the user (video (g.1), picture (g.2), text (g.3), sound (g.4), symbol group h: overview symbols representing concepts for the application of Think Map: terms (h.1), locations (h.2), names (h.3).*

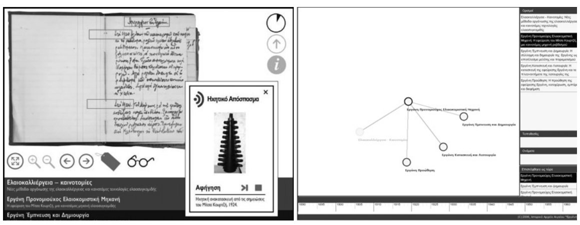

Figure 4: *Screenshot of the application (left and right screen). On the right screen, we can see the visualisation of Thinkmap software which is capable of handling cultural content by visualising it in various representational models (hypergraph, hierarchical, chronological, by name, other). On the left, and depending on the navigation of the user and his/her interaction with the application, the archival material is presented in its various forms, sound, video, text and pictures or a combination of these.*

of experiences, knowledge and use of each visitor. In our case, an initial sample questionnaire research was conducted which focused in registering the different needs expressed by different user groups. The results of this research were then integrated into the installation's design and the selection of texts and of the thematic clusters which were adopted.

The second dimension which was taken into account, was the social dimension. The technologies (overview projectors) and software used in this installation were specifically designed to suit the needs of groups of 15 viewers, thus stimulating a sense of collective engagement with the content. Also, we took in mind the needs of viewers of different height, thus, it was decided to use adjustable projectors to suit small children.

In addition, we organized the structure of this installation around 3 levels of entry on the basis of temporal, geographical, age and knowledge criteria according to the main social categories of visitors. The first level offers a brief but sufficient first acquaintance with the Kourtzis Archive and focuses on the educational efficiency of its use, mainly for Greek and foreign visitors, families with children, organized elementary school visits etc. The second level offers a more open approach which can be adjusted to the particular needs of the users, mainly for people with specific interests, relevant background and returning visitors. The third level offers full access to the content and is designed for users who want to deepen their historical knowledge, for example, academics, researchers, students etc.

The third dimension which was taken into consideration was the physical dimension of the exhibition room, since the fact that the installation was placed into a separate room, independent of the main exhibition hall but also related and integrated with it, gave us the opportunity to attempt to simulate to the visitors, the experience of visiting an Archive containing material related to the general thematic of the museum. This experience refers to the overall atmosphere of the room which tries to emanate a sense of an archive 'reading-room' as well as the sense of looking through the contents of an archive. To achieve this, we chose the usual "silent noises" of reading rooms which are used as a permanent background of the installation. To achieve the second, we used the appropriate tools to reproduce as closely as possible, the experience of the researcher who constructs historical knowledge through the use of archival material.

As it has been said,

"the Archive has a flavour, a beauty which calls on the desire of all, who because of culture or training, insist of being constantly surprised by the past. The hard work of archival search has a beauty, it attracts by promising the emotional sensitiveness which causes a 'remnant', a 'surplus' of life, by the countless traces and fragments of the past. Finally, in a metaphorical sense, the archive stimulates taste, because by touching the material, all our senses our stimulated. You touch it with your hands, you examine it by sight, breathe the old dust left on the leather and paper, you become oversensitive to the sounds heard in the silence of the reading room which break the rustling of the turning pages"[Far89].

6. Simulating the Archival Experience

The main aim of this multimedia installation is to simulate as closely as possible our "experience of the archive" and its framing into the "experience of the museum"[AT01][SA03]. The possibilities to use an independent space outside the main museum display hall, has given us the opportunity to attempt to simulate the experience or the 'atmosphere' of an Archive 'reading room' and what it might be like to experience searching into an archive with the aim of reconstructing our relationship with the past.

According to the relevant literature, simulation is defined as the model of the 'real' world which users utilize in order to research and understand a system, energy or a phenomenon and is divided into two categories according to its educational aim: the accumulation of knowledge of a particular item-content, and the accumulation of knowledge of a process[AT01][SA03]. The first category distinguishes between physical and iterative simulation where the first refers to an object and its treatment in the real environment or on a screen, and the second category, which distinguishes between procedural simulation (the way something is achieved) and situational simulation (where is achieved). Regarding this installation, physical simulation aims to enable the user to comprehend the object on display (design, creation, function, importance) and procedural simulation which aims to enable the user to feel the experience of constructing historical knowledge by searching or going through different archival material.

7. Evaluations

The international literature regarding multimedia attempts aiming to integrate the experience of an Archive with the experience of visiting a Museum, is not rich, since in modern times, the tendency has been to view the Museum and the Archive as two separate and distinguished spaces, neglecting the traditions of the 17th and 18th centuries which refused to distinguish between them and neglected the politics, the boundaries and the different approaches to knowledge which came to be associated with them during the 19th century[HK03].

The application remains faithful to a 'look and feel' approach to the primary material itself without the introduction of virtual reality, 3d graphics or animation. On the contrary, it offers into digital form, access to a reservoir of knowledge which has been constructed by the geopolitical space which surrounds it, by using new technologies and tools.

The evaluation which was conducted refers to the process of data collection and their linking and interpretation, so as to arrive at a comprehensive critical overview of the way this installation corresponds to the predetermined qualitative criteria that were initially set.

A two level provisional evaluation has been carried out; the first level of evaluation included the use of a 'mental map' which was presented to selective samples of user groups with the aim to enable us to assess the level of comprehension of the title of the application as well as the comprehension of the main parameters related to our subject. These terms and mental contexts which were singled out from the answers collected, were juxtaposed to the semantic web and the codes which were produced during the process of creating the semantic web of the content. The second level of evaluation included the use of the template of the application by selective groups of users so as to assess the degree to which the application succeeds in meeting the initial aims related to user interface, the degree of interaction and its educational effectiveness.

The results of this provisional two-step evaluation were integrated into the application but the final evaluation will take place at the end of October 2006.

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Virtual Reality and Stereo Visualization in Artistic Heritage Reproduction

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Abstract
The use of different media from photography to virtual reality may provide a user with an extraordinary tool for appreciation and exploration of artistic heritage. This is especially important in case when direct perceptual experience is denied by distance to museums or prohibition of manipulating exhibits, and in case when a specific media may provide a user with extra functionalities. The use of a specific media such as virtual reality is very important in case of time-spatial work-of-art where the problem of functionalities presentation becomes much more demanding. The goal of the presented work is to contribute in assessing the role of different visualization technologies in work-of-art reproduction focusing on the use of virtual reality and stereoscopic viewing. Our main testing application reproduces a time-spatial work-of-art which contains multi-level mirror reflections and where gravity is also accounted for in the physical simulation. This application has been chosen because it inherently calls for user interaction, which challenges reproduction fidelity and real-time response. The resulting visual reproduction is analyzed for different display technologies and stereo viewing approaches. Results from sets of test trials ran on five different virtual reality systems, from 3D Laptop to Head Mounted Display and large Panorama, confirmed benefits of stereo viewing and emphasized few aspects which represent a base for further investigation as well as a guide when designing specific systems for telepresence related to virtual museum applications and interactive space installations.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism I.3.5 [Computational Geometry and Object Modeling]: I.3.4 [Graphic Utilities]: Virtual device interfaces J.5 [Arts and Humanities]: Fine arts I.4 [Image Processing and Computer Vision]: general

1. Introduction

There is nothing better than perceptual experience with pieces of art. Museums are still noticeable attractions to visit. Whereas for paintings the visual experience can provide the viewer with all aspects the author intended to express, artistic heritage, especially contemporarily, goes beyond traditional paintings and very often comprises interactive, time changeable installations or sculptures (time-spatial works-of-art). These types of artworks call for fully interactive and preferably immersive environments, to reproduce object potential meaning and interpretation. Lack of sufficient exhibition conditions (e.g. lack of space for presenting all of pieces, installations which can not be touched in the museum) quite often makes experimenting with pieces-of-art unavailable to people. A kind of remedy to the problem is making a sophisticated multi-media multimodal presentation being a substitute of a real object and providing user with wide variety of experiences. Among main media employed in artwork presentation: paper descriptions, photographs, films, computer animation, virtual reality (VR). The role of the chosen media depends on the object characteristics and the experience wished to be provided to a user. Assessing the role of different media in artwork presentation would clearly represent an important activity, which provides useful knowledge to be considered when designing cultural heritage reproduction. In the presented work we intend to contribute in assessing the role of different visualization technologies in work-of-art reproduction. The focus is also on the use of virtual reality in artistic heritage, which is under-represented in the literature, with the objective of analyzing the main 3 tasks to consider when creating a virtual museum applications: photorealistic reproduction, physical simulation, interaction with objects. A special attention is eventually paid to analyze user sense of presence and viewing experience for different VR systems, an aspect strongly related to display technology and stereo visualization. Time-spatial works-of-art are especially discussed and used as main testing application because they inherently call for user interaction, which challenges reproduction fidelity and real-time response.

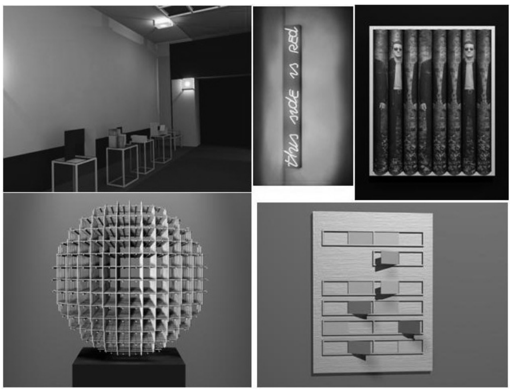

Figure 1: *The different contemporary pieces of artistic heritage which were considered.*

2. Multi-Media Presentation of Work-of-Art

Different media may be used for visual presentation of real work of art. In our analysis we consider: photography, film (motion-picture), computer animation, virtual reality. In case of photographs the 3rd dimension becomes reduced and so spatial features can be just imagined. By multiplying the number of photos connected with different viewpoints, more information can be revealed. Unfortunately such mean of presentation is incomplete due to its discontinuity and lack of thorough object observation possibility. Nevertheless, interesting efforts to overcome this limitation can be found in recent literature, [SSS06]. Another form of presentation is through motion capture and computer animations. Films and animations can more thoroughly retrieve time and spatial object features but at the same time they limit perspective and duration of the presentation. The user can not much influence presentation chronology except for stopping it, rewinding, pausing, or playing it slower. The captured images should be high-quality and entertaining. In case of virtual animation this means graphical appeal and high-quality rendering. Computer animation provides much more possibilities, but in comparison with a film it has still not acceptable image sterility. The use of virtual reality can well complement other media and it is especially important in case of time-spatial works-of-art because of the need for interaction. Even though the most advanced virtual reality simulation can not create fully photo-realistic copy of the original, digital reproductions let the user fully experience object functionality and it could become an introductory step towards real object perception. That is why reproductions play an important role in art propagation, and it is in particular the "exploration layer", [WKP02], which provides a user with an illusion of interaction with a real object by means of its reproduction. Interactive applications usually render less accurate graphics, finding the best trade-offs between image quality and real-time performance. The user will be given the instruments to change the configuration of the object of interest at his/her will, without breaking object's physical constraints. The user should be able to interact with the object with a simple and intuitive use of common input peripherals as the mouse or the keyboard, and change the viewpoint.

3. Interactive Works-of-Art

The works of art express internal author's attitude stimulate, shake and strike the spectator's interest and creativity giving him/her satisfaction. In case of time-spatial works-of-art, the aesthetical experience is not only connected with external appearance but with internal functionalities conceptualization as well. The role of VR representation as a media for artwork functionalities presentation becomes then very relevant and demanding. In fact, virtual world presentation can be treated as object simulation rather then object reproduction. Different contemporary pieces of artistic heritage were considered (figure 1). We have then chosen the Mirror-Cube as our main testing application because it inherently calls for user interaction in order to be appreciated, which challenges reproduction fidelity and real-time response. Furthermore, the chosen object poses some challenges for what concerns photo-realistic reproduction and physical simulation, it appears suitable for VR systems comparison, and it emphasizes the VR technology added value. The Mirror-Cube is a 6-sided parallelogram, a cube, which contains six mirrors, such that each mirror fully covers the internal part of each cube side, (figure 2). This transformable installation provides a viewer with different operational and interpretational possibilities. Simple element joints assure wide spatial transformation possibilities. The usage of the mirrors for object's construction leads to a specific game between real elements of the installations (mirrors, wooden stick fixed to the mirror surface, lines painted on the external side of mirrors) and their reflections. There has been an interest in the recent time among researchers in the thematic related to time-spatial works of art [MP02], [WKP02]. P. Patyra [Pat05] investigates the J. Robakowski "Mirror's Ball". The object consists of two elements: the spherical mirror and the ball. There could be observed the distorted reflection of the ball in the mirror, together with reflected surroundings. The ball is covered by the photos. The viewer can move the ball, (which rolls on the mirror surface following an elliptic path), so changing the reflection in the mirror. Even though mentioned authors discussed problem of works-of-art presentation quite thoroughly, none of them tackle the problem of multi-level

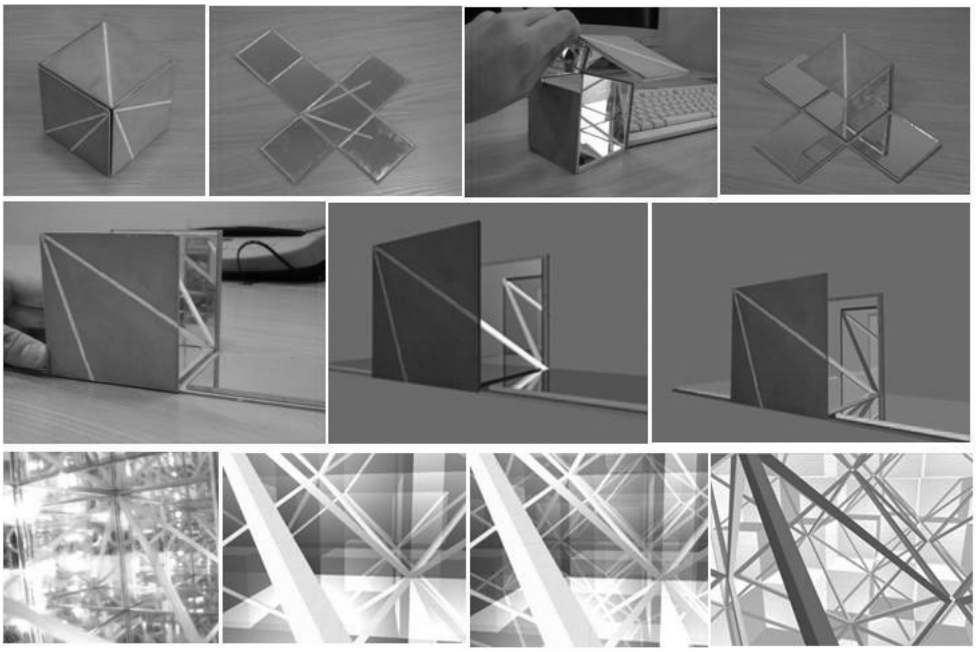

Figure 2: *The Mirror-Cube: exterior appearance and functionality (top-row), artistic nature (center row), infinite reflections (bottom-row). Center-row from left: photograph, raytraced with Mental Ray, rendered with OpenGL. Bottom-row shows multiple reflections. From left: photograph, raytraced with reflection limit 5, limit 8, rendered with OpenGL and 8 levels of reflections.*

reflections. None solve the problem of interaction with installations comprising mirrors at high satisfactory level. This paper presents complementary attitude towards presentation of artworks in which reflections play a main role and considerably influence installation perception.

4. Stereoscopic Visualization and Display Systems

The media mentioned in section 2 may be displayed in stereo called as 3D photograph, 3D movie, 3D animation, 3D interaction. The possibility for stereo visualization represents an important aspects which is lately receiving greater interests. This due to the spread of VR applications, improved visualization performance and more powerful graphic hardware at lower cost. Stereoscopic visualization is closer to the way we naturally see the world, which tells us about its great potential in VR applications. Stereoscopy is about the eyes seeing 2 slightly different images. Different technologies have then been developed to separate the images seen by the eyes. Main approaches may be classified as:

- *Passive Stereo*. Multiplex images in space and can be subdivided in: "Anaglyph" (separation based on color filters); "Polarized" (separation based on polarized filters); "Separated Displays" (separation based on the use of different displays very close to user eye, as in HMD systems).
- *Active Stereo*. Multiplex images in time typically based on "Shutter Glasses".
- *Autostereoscopic Stereo*. Separates images based on special reflecting sheets laying on the display, or other methods. Do not require users to wear goggles.

Different stereoscopic approaches can be used coupled to different display systems, [LP06]. The latter responsible for the provided degree of immersion, interactivity level, isolation from surrounding world, etc. Researchers in the literature have investigated the benefits of stereoscopy for different application aspects and depth cues. The literature works can be classified as either application specific, or abstract test, (abstract tasks and content with general performance criteria), [DJK*06]. In literature test trials often deal with assessing the role of most dominant depth cues, e.g. interposition, binocular disparity, movement parallax, [NM06], and their consequence to user adaptation to new context (user learning capabilities). The parameters through which assess stereoscopy benefits typically are: item difficulty and user experience, accuracy and performance speed, [NM06], [Dra91]. Everybody seems to agree that stereoscopic visualization presents the necessary information in a more natural form than monoscopic visualization, which facilitates all human-machine interaction [Dra91], and improve the possibilities of visualization offered by common 2D graphics workstations, [GB01]. In particular, stereoscopy improves: comprehension and appreciation of presented visual input, perception of structure in visually complex scenes, spatial localization, motion judgement, concentration on different

Figure 3: *Virtual reality facilities at the Aalborg University VR Media Lab and Medialogy Copenhagen. Top-row from left: 160 deg. Panorama, the structure of the CAVE, and a representative view it. Bottom-row from left: 3D Desktop, 3D Laptop, Head Mounted Display, 3D photo-cameras setup.*

depth planes, perception of surface materials. The main drawback with stereoscopic visualization, which have yet prevented large application, is that users are called to make some sacrifices, [SS99], [LP06].

5. Comparison of 3D Technologies

We have chosen among well known VR systems adopting different stereo approaches and display systems. At the Aalborg University we have a large variety of VR facilities, which represents a very suitable testing ground for our investigation (Figure 3 shows the VR facilities). In particular:

- *3D Laptop*. 15in high-res LCD display, passive anaglyph.
- *3D Desktop*. 21in CRT high-res monitor, both passive anaglyph and active shutters.
- *1-sided CAVE*. 2.5x2.5m rear-projected screens, high-res high-freq projectors, both passive anaglyph and active shutters. This facility is part of a pre-existing 6-sided CAVE (see fig. 4 top-left), so including head-tracking, etc.
- *Head Mounted Display*. 2x 0.59in OLED LCDs (800x600), separated displays stereo.
- *160 deg. Panorama*. 3x8m front-projected curved screen. High-res. projectors, active shutters.

In order to assess support of different VR systems in time-spatial works-of-art reproduction a series of comparative user studies are proposed to be run on the above mentioned facilities. The resulting visual reproduction is also compared with a typical outcome experienced with 3D photographs and 3D movies. Figure 3 shows the stereo photo-camera setup. A similar setup was used for 3D movies capture. With this study we assess systems capabilities for different display technologies. While performing comparative tests the users are asked to report about their experience through questionnaires. Questions are grouped into 5 judgement categories: *adequacy to application*, *realism*, *presence*, *3D impression*, *viewing comfort*.

6. Testing

6.1. Implementation, Image Quality and Speed

Over 160 pictures were taken with cameras with different resolutions. The pictures were grouped into 4 sets according to the following concepts: exterior appearance, functionality, artistic nature, infinite reflections. Figure 2 illustrates the above concepts. The animated video sequences of the object are modeled with Maya and rendered with Mental Ray. The resulting pictures are elaborated in Adobe Photoshop while animation sequences are converted with Adobe Premiere into movie files. Final presentation was based on a well defined storyboard. The interactive application is implemented in OpenGL which also simulates mirror reflections by the use of the stencil buffer. Multiple mirror reflections are added by means of recursive approach. The Mirror Cube modeled with Maya is imported into OpenGL and then interactively rendered. Object faces' physical simulation provides gravity acceleration of rotating mirror faces. The Stencil buffer which is now popular in commercial graphics cards, solves the reflection problem up to a relatively small number of nested reflections, and all mirrors ac-

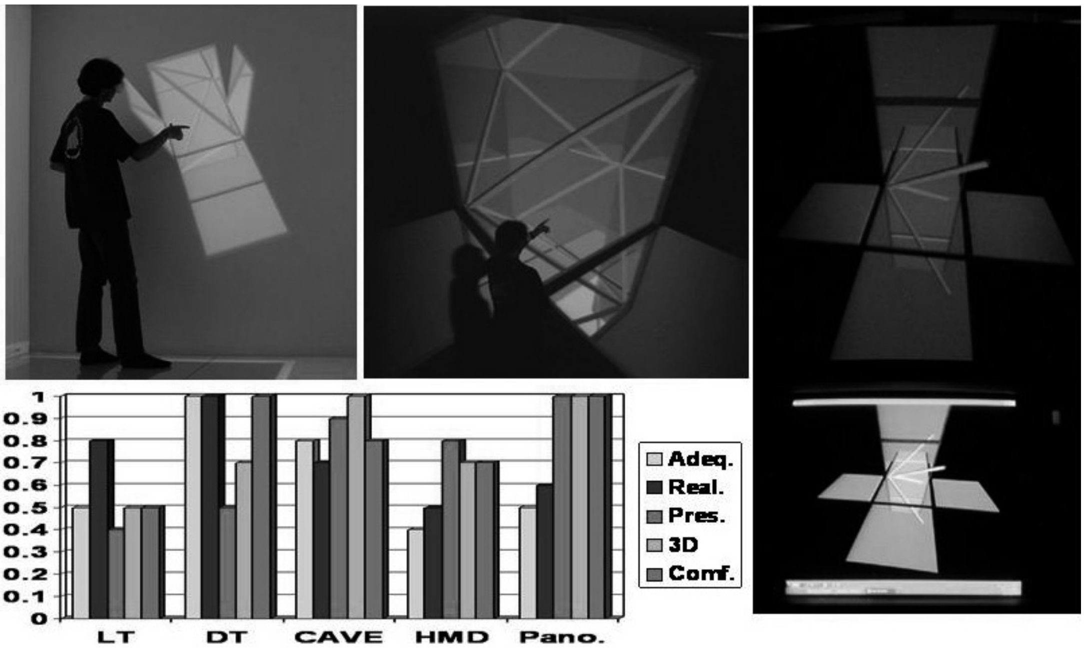

Figure 4: *The simulated Mirror-Cube in the CAVE environment (top-left) and Panorama (top-center). The left-picture shows a setup for concurrent comparison of Panorama and 3D Desktop images. The table summarizes comparative test results. The horizontal axis represents system considered: (LT) 3D Laptop with passive anaglyph, (DT) 3D Desktop with active shutters, (CAVE) CAVE system, (HMD) HMD, (Pano.) Panorama. The vertical axis summarizes users response on 5 different categories.*

curately reflect the scene and the other mirrors image. The use of the Stencil buffer in OpenGL allows for fast rendering being both stencil and depth test hardware implemented. The use of the Stencil buffer approach increases the illumination level in the scene as consequence of the mirror reflection, [Kil99], (a problem not present when using raytracing). The quality of the rendered images is observed by comparing real and computer-generated images, (figure 2). Surprisingly, the general quality of the images rendered in OpenGL (by polygonal verteces interpolation) is not far from that of the images generated in Maya (per-pixel raytracing). Concerning the rendering of the reflections, these are correctly drawn for both rendering techniques, however a more accurate light calculation makes a greater difference. Interesting, in case of screen-shots taken inside the closed cube, the reflections are identical. The responsiveness of the application to input commands changes for different platforms. There is a maximum level of reflection above which response speed is unacceptable (8 reflections on our Laptop). Concerning the gravity simulation the use of a friction was necessary.

6.2. Testing Displays Technologies

The results of the Comparative tests based on extensive testing trials related to the virtual interaction, ran by 5 VR experienced users, are summarized in figure 4.

Adequacy to application. The CAVE seemed very suitable as interactive gallery. In fact, already by moving around head and body a user can "play" with the artwork. The Panorama also offers good feedback but mostly for an expert user (interaction is through 3D mouse). The 3D Desktop provides a different type of interaction, and it was believed the most suitable for low cost remote-user interaction, and still better than 3D Laptop because of the possibility for using active shutters.

Realism. Large visualization screens provide higher Realism when passive anaglyph is not adopted. High realism with the Panorama, but better with CAVE thanks to the head-couple tracking. Details are difficult to catch when user stays very close to big screens. In case of Panorama the above effect diminishes being that user sitting at predefined distances. If we focus on comparing the rendered visual effect with the real one (when having object in hand) the 3D desktop gives the best result. This goes along with theories in [DJK*06], being this a "looking-in" task, i.e. when the user sees the world from outside-in.

Presence. The larger screen VR facilities provides the best result in relation to sense of presence, (as expected). Interestingly, the user involvment decreases in the case of the passive stereo anaglyph. This seems to be mostly justified by eye-strain arising from rear-projection (screen alters colors causing high ghosting). Passive anaglyph performs slightly better on real images, mostly due to a higher level of Realism.

3D Impression. It may surprise the reader that some users claim a high 3D Impression with 3D Desktop. Confirmation of 3D Desktop perceived 3D Impression can be found in [JLHE00], showing how the range of depth tolerated before loss of stereo fusion can be quite large. The CAVE and Panorama gives best impression for negative parallax (in front of display), which is very important in case the considered testing object is small. The 3D desktop also gives great performance. In case when the user exploits the VR added functionalities (not available in reality), e.g. object displayed in big dimension, or a virtual navigation inside the object, the CAVE and Panorama gives best performance.

Viewing Comfort. The highest Comfort judgement is assigned to 3D desktop with shutters and the Panorama, as confirmation of the benefits of front-projection in terms of image quality. Head-tracked displays may produce some disturbing effect (nausea). The passive anaglyph technology strongly affects viewing comfort. It is acceptable in case of 3D Desktop and Laptop, but it calls for high brightness, and unacceptable in the CAVE where high crosstalk arises from rear-projection.

The above results for the virtual interaction can be compared with general test-user impressions related to virtual animation, 3D movies, and 3D Photographs.

Virtual Animation. The Adequacy to application is generally much lower is case of animation due to the interactive nature of the object which is not represented. A higher level of Realism is always provided by the 3D Animation (compared to virtual interaction). This due to the raytracing based rendering. Still, the realism is lower than films or photographs. The viewing comfort is generally higher with animations than with interaction.

3D Movies. The impressions gathered when users were looking at 3D movies of various type showed a general improvement in user judgement in terms of (photo)-realism (as expected). The 3D films were highly appreciated in the CAVE, (as much as the synthetic images), then on the HMD, (which provided bright images and good color reproduction), and then on the 3D Desktop in case of active stereo. Passive anaglyph both on the 3D Desktop and CAVE lower image quality which is claimed to provide less realism. The 3D Impression were judged best in the CAVE in case of negative parallax, and the performance on the 3D Desktop was very good (particularly negative parallax). The HMD provided strong depth impression.

3D Photographs. When using high-quality photo-cameras and dias and separated display stereo for visualization, the Realism is the highest. This due to high-definition photo-realistic textures. 3D Impression can be very high for close objects. Viewing Comfort is also very high if active stereo is adopted or in case of separated displays. Naturally, 3D Photographs lack dynamics, which lower the sense of presence. A sensitive parameter affecting Realism is the distance between camera (baseline) which may cause the visualized object to appear "cartoon-like". The same aspect may however contribute in providing a stronger 3D impression.

A more thorough comparison is a work in progress.

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Short Papers

AN ETHICAL OVERVIEW OF LONG-TERM PERSPECTIVISM Experiences from an Archaeological Survey on Jebel Bishri in Syria

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Abstract

Jebel Bishri forms a table-like mountain in the Palmyride range of Central Syria. The area belongs to the arid zones and consists of desert–steppe and steppe limited with the Euphrates irrigated agricultural valley to the north and the Syrian Desert to the south. The datings of the archaeological traces of mobile sites in the area reach from ca. 500,000 years to recently abandoned Bedouin sites. Nowadays nomadic pastoralists form the major population in the area, partly leading semi-sedentary way of life on the fringes of wadis and on the piedmonts of the mountain. Since the year 2000 the Finnish archaeological survey and mapping project SYGIS (Syrian Geographic Information Systems) has been working towards a basic inventory of ancient sites in this archaeologically largely unexplored as well as environmentally endangered area. This paper tries to emphasize the ethical importance of building a basic inventory of sites in archaeologically unexplored and endangered areas before any surveys concentrating on a single period/culture/site type or focusing on another particular phenomenon will be carried out. Basic general survey which gives objective and balanced value for each archaeological period and site is the best one to protect the area and preserve its cultural development and diversity throughout the ages from a long-term perspective. This is scientifically justified for the future research and protection as well as preservation of the sites. As the area of Jebel Bishri covers ca. 1 million hectares remote-sensing methods have been vital in covering such a large region which is endangered by looting and rapid environmental change. Environmental change is taking place through expanding desertification caused both by global warming and direct human impact. Beside looting and traffic heavy winds causing erosion increase the disappearance of ancient sites in the area.

Categories and Subject Description: Miscellaneous

1. A Long-Term Perspective from Jebel Bishri

Jebel Bishri forms a northeast plunging block in the Palmyride mountain range limited with the Euphrates river to the north and the Syrian Desert to the south (Fig.1.). [BBBS01] The annual precipitation of the region hardly reaches 150 mm. Environmentally the area belongs to the arid zones offering different ecotones consisting of desert–steppe, steppe and fluvial terraces dating from the Pleistocene and the Holocene [BS81]. Archaeological finds vary from hunter-gatherer sites of the Lower Palaeolithic dating ca. 500,000 years back to recently abandoned Bedouin compounds [see L06].

Compared to prehistory 5000 years of the historical time only consists 1 % of the archaeological time scale. From the gathered archaeological evidence it has become clear that nomadism has played a central role in the subsistence economy of the people in the region during the past 9000 years. Even if there is evidence of the earliest endeavours of agriculture in the neighbourhood, the settled

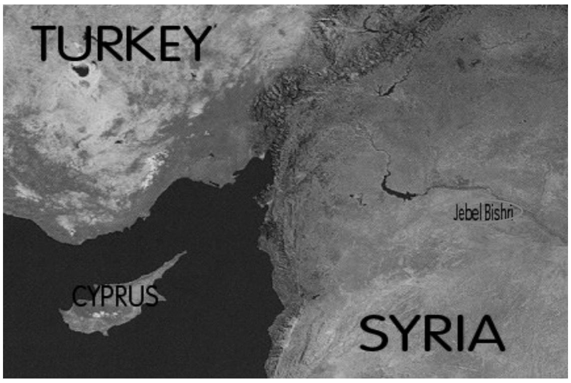

Figure 1. *The location of Jebel Bishri in Central Syria seen from a satellite.*

life has never completely rooted into the area of Jebel Bishri.

F. Braudel has especially provided us with different scales to study human past either from a *long-term* or *short-term* perspectives. In archaeology, in particular, one encounters long-term phenomena and is able to study how humans have coped with different situations and adapted to different environments throughout the ages. However, often in archaeology it has been thought that climatic and environmental conditions as well as changes are long-term phenomena in their nature compared to changes in structures of human subsistence economy, social groups and types of cultures.

Unfortunately apart from general global warming currently humans are directly working as speeding agents in the change of the environments. The phenomena such as deforestation, desertification, river channel changes and land degradation are acting as environmental short-term agents affecting quickly and drastically the subsistence economy and culture. One of the rapidly speeding phenomena is desertification in the area of the Bishri mountain taking over the grazing lands of pastoralists, whose structures of life are of long-term origin on the Syro-Arabian desert fringes and steppe areas. ACSAD (The Arab Centre for the Studies of Arid Zones and Dry Lands) is currently combating desertification in the region of Jebel Bishri. Currently the constant expansion of a desert line affects the ranging land of the nomads making their subsistence economy vulnerable. (See Fig. 2.)

Figure 2. *A widespread sand cover implying desertification of the Jebel Bishri region in the year 1999 displayed through a classification and analysis of Landsat-7 ETM image. Classification by Markus Törmä 2003, © Eurimage.*

Jebel Bishri forms not only an environmentally but also an archaeologically endangered area. Archaeology can help in understanding long-term changes in environment and human behaviour in the past for planning the sustainable development for the region. In turn the present speedily increasing harmful changes in environment can be studied for the sake of archaeology to understand the stress and adaptation of humans from a telescoped perspective. Ethnoarchaeological questions also open new ways for understanding different solutions which humans have chosen in different environmental circumstances.

2. Towards a Regional Inventory of Archaeological Sites

Jebel Bishri has formed a meeting point of different subsistence economies, cultures and civilizations throughout the past. Archaeologically the area is also endangered by human agents such as looting and traffic. [HG97, LT04] The looting of the archaeological remains on Jebel Bishri is widespread, and also therefore the archaeological work primarily needs to aim for protecting and preserving the cultural heritage of the region. [LT03, LT04]

From the experiences received in the Finnish archaeological survey and mapping project SYGIS working on Jebel Bishri since the year 2000 the project wishes to emphasize the importance of general multi-period archaeological surveying in the area which has not earlier been under systematic archaeological studies and is threatened by environmental deterioration and looting (see Fig. 3.).

Figure 3. *A looted Bronze Age tumulus comprising a cist situated along the Euphrates on the northeastern piedmont of Jebel Bishri. Photo from SW, Michael Herles 2005.*

Therefore we agree with F. Hole's statement that the surveys that aim for the basic inventory of sites are most rational, especially in the areas where the archaeological heritage is endangered by different endeavours of humans or threats caused by nature [Hol80].

GIS is a modern way to build a regional inventory for storing and displaying location information and distribution of sites. As generally known, GIS constitutes of geographic information systems to store and represent different layers of data either in a vector or in a raster form. The themes of the layers vary: they can be cartographic, environmental or cultural data layers connected with geographic information of the location. [AM96]. The coordinates of culturally important sites in an archaeologically endangered area are primary parameters to be collected and used in the protection work, and they are the parameters in GIS functions. However, where looting is widespread and protection work difficult, it is not advisable to make exact location information public, for example, through an accessible GIS website in the world wide web to facilitate the looters way to unstudied and unprotected sites.

3. Prospecting, Surveying and Mapping with Remote-Sensing

Using remote-sensing methods in prospecting, surveying and mapping the large area of Jebel Bishri is the best way to preliminarily approach and grasp the geographical features and environment of the area with its different topographical boundaries. Remote-sensing methods, especially when high resolution aerial photographs or satellite images are available, also help in identifying sites. Satellite images are a valuable source for building predictive models for archaeological sites through classifications, but with high spatial resolution photographs and images sites can be detected with a naked eye as well.

Remote-sensed data such as satellite images have provided a basis on which field survey has been planned also defining the transect limits on the ground by geographical (longitudes/latitudes, coordinates) and environmental parameters such as different contours and edges visible in the environment and landscape. The contours have consisted of such features as river drainages, desert fringes and mountain edges, i.e., natural boundaries and some man-made limits such as roads. The Finnish project has used rectangular study areas divided and spaced according to topographical features so that the survey edges have reached maximum lengths.

The intensity of a field survey covering large areas on the ground is often dependent on budgets. The site/ structure tracing and recognition by remote sensing methods can never reach the total amount of sites even with high resolution photographs and images or by the recognition of geophysical anomalies. Open accumulated sites with low stratification and cave dwellings, for example, are those which can be predicted with different kinds of GIS models but not usually identified with remote-sensing. The only way to identify them is surveying on the ground. Defining the spacing of the transect lines between field-walkers naturally affects the accuracy of recognizing sites. But also walking the same area backwards in different day time and light conditions exposes more sites and adds the probability of recognizing as many sites as possible.

As mentioned, the aim of the Finnish project is to build a regional GIS for Jebel Bishri. Therefore location information for archaeological sites is vital mainly collected with GPSs and in prospecting with rectified satellite images. Control points are collected on the ground with a GPS for image rectification and for 'signatures' to identify different materials in images.

4. A General Survey and the Depth of Cultural Time

An ethic consists of statements about what you should do, what makes an action right and situation just…an ethic consists of standards that apply to members of certain groups. [Wyl03] From our experience it has become clear that a single period / culture/ site type/ structure surveys, i.e., those that concentrate on searching only specific kinds of remains [see the goals of archaeological survey Ban02] are ethically highly questionable in archaeologically largely unexplored areas, like Jebel Bishri.

The surveys concentrating on a single period, a single remain type, social or economical structure often execute documentation and recording standards for their own interests and may distort contexts and the evidence of cultural development in particular regions. While picking only certain types of finds such surveys change the find contexts creating unbalanced information and databases in areas from which basic cultural data is lacking. Therefore they distort the find contexts for the future archaeological research. In addition, such surveys do neither sufficiently take into account the evidence of the variety of past processes in the region nor elucidate how certain phenomena have emerged and developed in the area. They do not reveal the spatial distribution of sites in relation to their different contexts.

The damage of the surveys with a sole goal in an area lacking a site inventory and mapping is in its extreme comparable to "treasure hunting" masked into a scientific research design in which individual researchers are not altruistically working for the best of the whole area and for the study of its past. Finds and sites gathered with a single period or phenomenon in mind in endangered areas may become *like museum pieces without proper information of the provenience. The state and nature of the context in the sequences of cultures of the region and the related finds/sites in the time of the discovery are ignored.* The recording of the contexts and existing neighbouring sites in the time of discovery are important. A single-period or single-type/subject survey is particularly harmful in the areas where looting is taking place in the neighbourhood before proper general survey has been carried out. Because of the looting the contextual information can disappear very quickly without later possibility of reconstructing the situation of the original discovery.

At least indicative finds representative of all the periods, cultures and types of the sites and regions are needed. Sampling with different statistical approaches should be also designed so that it will not avoid certain types of remains or areas, e.g., spaced regularly outside a transect, a quadrant or slopes. The basic survey that takes into account all the possible locations of past human activities in the chosen study area provides objective and balanced information of the region. It opens the only way to understand the cultural development of the region from a long-term perspective.

Because Jebel Bishri covers ca. 1 million hectares we have so far carried out field work in experimental plots choosing different environmental zones. Pedestrial survey is carried out in 15 m interval field walking on the ground. Our survey and mapping has revealed differences in the archaeological remains according to the environmental zones also reflecting differences in subsistence economy adapted to the environment and the amount of precipitation. Hunter-gatherer sites are more numerous in the desert–steppe areas while nomadic and semi-sedentary sites are exceeding in number in steppic regions offering evidence of some seasonal agriculture, springs, water harvesting and wells. As mentioned, only the Euphrates side of the mountain associated with the fluvial terraces provides evidence of sedentary sites and agriculture associated with the evolution of writing and civilization. [Lön06, LT06]

5. Rapid Environmental Changes Affecting Cultural Remains

The archaeological evidence indicates that during the Pleistocene, when hunter-gatherer economy was prevailing, the environment of Jebel Bishri was more of the savannah type. As mentioned above, that is the longest archaeological time-frame covering ca. 500,000 years and offering a peak in the frequency of the cultural material of the region.

Rectified satellite images as well as geophysical examinations laid in a coordination system have been used as environmental data sources creating layers for GIS. The Finnish project has also used satellite images for prospecting, field mapping and displaying distribution of the archaeological sites and their types in space (see Fig. 4.).

The climate has affected the condition of the soils. Jebel Bishri belongs to the region of aridsoils which cover 50% of the total soils of Syria. In those the Jebel Bishri region consists of gypsiorthids which constitute 20% of the soils in Syria. In the lack of proper drainage systems the type of soils increases salination in the irrigated river valley. If some woodlands have earlier existed at Jebel Bishri, they - apart from a few trees - have completely disappeared. Erosion is caused by lack of trees, shrubs,

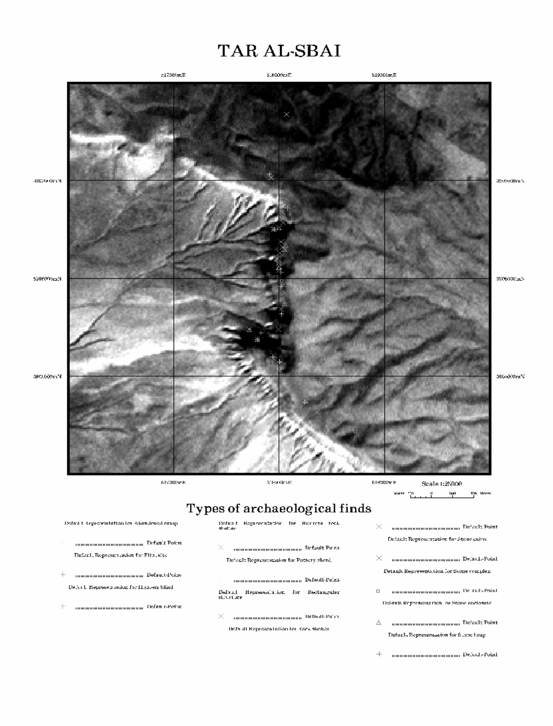

Figure 4. *Distribution of all the site types at Tar al-Sbai, the southwestern edge of Jebel Bishri, displayed on a panchromatic channel of a Landsat-7 ETM image. Mapping by Markus Törmä 2005, © Eurimage.*

Figure 5. *A Palaeolithic abri, rock-shelter, collapsed due to erosion at the western edge of Jebel Bishri. Photo from W, Margot Stout Whiting 2000.*

cultivation, plucking the roots of pastoral shrubs, overgrazing and not using appropriate agricultural techniques. The heavy erosion is also affecting the soils and causing the collapse of rock-shelters of soft limestone and sandstone (Fig. 5.). [Nap06]

On Jebel Bishri the desertification exemplified by expanding sand cover has conquered much of the ranging land in a few decades from the 1960s to 2000 [LT04, LT06]. The high speed winds accompanied with the human impact have been moving the edge of the sand cover also dislocating archaeological finds from their original sites.

6. An Ethnoarchaeological Approach for Understanding Past Situations

In the survey of nomadic environment and changes in its equilibrium ethnoarchaeological approaches have been integrated into the project design of the Finnish project. The purpose is to provide information and possible analogies for human behaviour in the past through surveying, recording and documenting present-day Bedouin compounds. Informants typical of ethnographic interviews have been used in receiving background data of the social structures of the tribal life, subsistence economy of the nomads and semi-sedentary people in the region. Also the yearly cycles and decision mechanisms while facing seasonal stress and adaptation to droughts have been recorded.

In ethnoarchaeology there exist particular questions which can be posed in studying, for example, hunter-gatherer as well as nomadic life, the seasonal cycles and to trace long-lived structures of life in the region [GB91]. Our interest has especially been to understand the site abandonment processes as a part of seasonal life as well as final and total abandoning of sites and regions for environmental, social or political reasons. [CT93, LT06] Abandonments affect the structure of the site and its site inventories.

The human responses to different impulses in present whether environmental, social, cultural or political may cast light on reasons why certain sites have been abandoned in the past. Instability of the settlement life is apparent in the semi-arid regions that are dependent on yearly changing precipitation. As mentioned above, the area of Jebel Bishri nowadays hardly receives 150 mm a year, and once in ten years the rainfall can reach to 200-250 mm to provide opportunity to rain-fed agriculture. However, tanks of water were earlier provided by government and water-harvesting was carried out to ensure cultivation. In 1995 the legislation banned all agricultural activities in the endangered *badiyah*, steppe, as agriculture was increasing the desertification. [LT06] Especially on Jebel Bishri desertification seems to have caused abandonment of semi-sedentary villages such as in the areas of Ash-Shujiri and Nadra (see Fig. 6.) in the centre of the mountain and on its eastern piedmont. But obviously governmental policy has played a central part through legislation as well. [LT06]

Figure 6. *A permanently abandoned ruined semi-sedentary pastoral village at Nadra in the eastern piedmont of Jebel Bishri. Photo Gullög Nordquist 2004.*

7. Conclusions

From the experiences of SYGIS, the Finnish archaeological survey and mapping project of Jebel Bishri in Syria, it has become clear that in previously largely archaeologically unexplored and currently endangered areas a basic general survey and mapping for recording and documenting the cultural heritage is ethically vital. The aim of our archaeological survey and mapping project in the Jebel Bishri region has been to build a balanced inventory of sites not giving preference to certain periods, site types, structures and cultures. Each recognized site has been equally recorded.

Recording location data with GPSs on the ground and remote-sensing methods primarily serve a regional inventory that can be stored and displayed in GIS. The attached information of the types and sizes of the sites can be recorded and documented on the ground to be associated with the location information. It has to be emphasized that without precise location information in longitudes/latitudes or/and coordinates the further protection and preservation work is hampered.

The general survey will preserve and protect sites from different periods in an objective and balanced way offering spatial and scientific contexts for future archaeological studies in the region. If the goal of the survey is a single period/ culture/site type/structure or other individual phenomena in practically unexplored regions the work while, for example, collecting finds will distort the balance and fails in understanding the long-term development and change of the human life in the region for its future preservation and protection work.

8. Acknowledgements

The Finnish mission wishes to thank the Syrian Department of Antiquities and its former and present General Directors, S. Muhesen, H. Moaz, T. Fakouch and B. Jamous for their kind co-operation through the years. We are especially grateful to Dr. M. al-Maqdissi director of the archaeological excavations in Syria, and Dr. A. Abdulrahman, director of scientific affairs in Syria, for their support and help during the work of our project. We are especially grateful to GIS-prof. Kirsi Virrantaus for her support over the years. The Jebel Bishri survey groups including Prof. Martti Nissinen, the NorFA scientific course members including Prof. Gullög Nordquist, Prof. Christian Meyer and Theol. Cand. Helena Riihiaho as well as Dr. Michael Herles and Mr. Marcus Königsdörfer are to be mentioned with gratitude. Last but not least we wish to express our thanks to the Academy of Finland and NorFA for funding and Nokia Co. for sponsoring the project.

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The 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage
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Short Papers

Presentation of an Integrated System for the Recording and Documentation of the Cultural Heritage of a Historic City. Digital Registry for the Historic Centre City of Nafplion

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Abstract

The aim of the present paper is to present a project regarding the recording, classification, digitation, access and presentation of the cultural heritage of a historic city, for the creation of a database that can be accessed through the Internet.

The way the data is organized and accessed, follows the territorial standards logic and is directly connected with their contents. It is a concrete – not theoretical – open and evolving model, aiming to the wide-spreading and learning of the tangible and intangible elements that constitute the cultural heritage of a city.

The above system will also serve as an important tool for all those entities involved in the preservation, protection and management of historic cities.

1. Introduction

The object of this paper is to present a project regarding the recording, classification, digitation, access and presentation of those elements that constitute the cultural heritage of the historic city of Nafplion, with the aim to create a database that can be accessed through the Internet. The system is implemented within the framework of the project «Recording, Digitation and Correlation of existing material for the preservation and conservation of the historic center of Nafplion – KOITIDA» and is funded by the 3rd CSF under the measure "Information Society". The Municipal Society for the Cultural Development of Nafplion is the implementation agency and user of the program.

The system contains information that illustrates the cultural heritage of the city through time.

The way the data are organized and accessed follows the territorial standards logic and is directly connected with their contents. It is a concrete – not theoretical – open and evolving model. The objectives of the system are:

The documentation of the identity and the high value of the historic city,

The gathering and preservation of historic evidence that are scattered in public and private archives and are deteriorating as time goes by,

The recording and monitoring of the changes that occur in the historic city through time and the management of its evolution,

The conveying of the findings and the data to the international academic community, the competent authorities, the local society, the city's student population and to the visitors of the city, as well as

The development of a digital platform for the recording and documentation of the cultural heritage in historic city centers.

The presentation of the full project aims to promote the discussion on the way we record, classify and present the multiple elements –tangible and intangible– that constitute the physical configuration and context of historic cities, as well as those elements that illustrate their evolution and change made through time.

The implementation of the above project was greatly contributed by the long, hard work of a multidisciplinary academic team, as well as, by the vision of Nafplion city officials, who have devoted their time to the protection and promotion of the city's cultural heritage.

2. Definition of the elemements that constitute the cultural heritage of historic cities.

The concept of cultural heritage, as has been ideologically defined by the end of 20th century, covers much more than the built environment. It covers the whole of tangible and intangible elements, which express the historic, social, and cultural identity of each historic city, as well as its aesthetic qualities.

Beyond the space defining elements of the heritage -landscape, natural environment, urban form, monuments, archaeological remains, historic buildings and elements, as well as historic urban patterns that are more easily recorded, the analysis of the intangible elements and values, that comprise a historic city such as the history and the collective memory, the social content, the cultural context, and the functional character of the city, are equally important parameters that comprise the city's cultural identity, constitute a part of its intimate meaning and should also be recorded and identified.

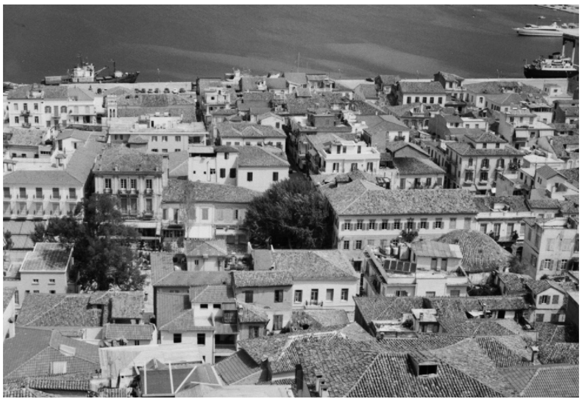


figure 1: Eye bird view of the historic centre of the city of Nafplio

2.1. The phases of the recording and documentation project.

The first recording of the cultural heritage of the city of Nafplion dates back 20 years and was performed within the framework of a greater project. That recording included the following:

Study of the historic evolution of the city and the individual city districts as they are defined by the topography of the area, the geometric characteristics of the urban web, the typology of the structures and the monumental fortifications that surround the city.

Identification of the architectural quality of historic buildings and the development of registers, which included an analysis of their typology, age, number of floors, structural condition and the degree of alteration from the original building form.

Study of the historic patterns and the geometric attributes of the city web, their function and their degree of conservation.

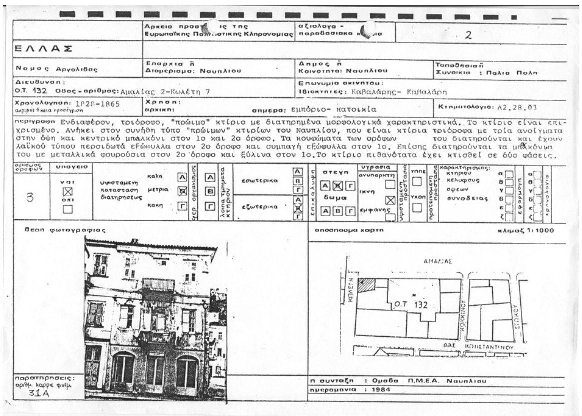
Identification of the city's functions through the recording of the land uses, the social and cultural equipment, the traffic and parking system and the evaluation of the city's technical infrastructure networks.

Research of the existing regulations on construction and protection and identification of the ownership status.

A second recording was performed last year with the double aim to complete the evidence that constitute the architectural characteristics of the structures –as interior elements and decoration, construction elements e.t.c– and to illustrate the changes that have occurred in the form and function of the historic buildings. There was also a recording, through a questionnaire, of the profiles of owners and tenants of the buildings in the historic center, the mobility of residents and professionals and the functional problems of the buildings.

Beyond the in-situ recordings, a major source of information were the building permit archives of the Ministry of Culture, which is responsible for the protection of the historic buildings of the city and inspects every building permit that is issued, as well as the archives of the local City Planning Office.

Historic maps, engravings, old photographs and post cards, as well as special bibliography on the city, its buildings and monuments were gathered from public libraries and archives and from private collections, for the historic documentation of the city. Further data on historic figures and intellectuals who lived in the city, as well as on literature and art that promotes the city was collected for the recording of the city's intangible cultural heritage.



ΕΛΛΑΣ
Νομος Αργολιδας | Επαρχια ή Διαμερισμα: Ναυπλιου | Δημος ή Κοινοτητα: Ναυπλιου | Τοποθεσια ή Συνοικια : Παλια Πολη
Διευθυνση: Ο.Τ. 132 Οδος - αριθμος: Αμαλίας 2-Κωλέτη 7 | Επωνυμια ακινητου: Ιδιοκτητες: Καβαλάρης- Καβαλάρη
Χρονολογηση: 1828-1865 | Χρηση: αρχικη: σημερα: εμπόριο- κατοικία | Κτηματολογιο: Α2.28.03
περιγραφη Ενδιαφέρον, τριόροφο, "πρώιμο" κτίριο με διατηρημένα μορφολογικά χαρακτηριστικά. Το κτίριο είναι επιχρισμένο. Ανήκει στον συνήθη τύπο "πρώιμων" κτιρίων του Ναυπλίου, που είναι κτίρια τριόροφα με τρία ανοίγματα στην όψη και κεντρικό μπαλκόνι στον 1ο και 2ο όροφο. Τα κουφώματα των ορόφων του διατηρούνται και έχουν λαϊκού τύπου περσιδωτά εξώφυλλα στον 2ο όροφο και συμπαγή εξώφυλλα στον 1ο. Επίσης διατηρούνται τα μπαλκόνια του με μεταλλικά φουρούσια στον 2ο όροφο και ξύλινα στον 1ο. Το κτίριο πιθανότατα έχει κτισθεί σε δύο φάσεις.
αριθμος οροφων: 3 | υπογειο: ναι / οχι | υφισταμενη κατασταση διατηρησεως: καλη / μετρια / κακη | εσωτερικα | εξωτερικα | στεγη | δωμα | υγρασια: ανυπαρκτη / ιχνη / εμφανης | χαρακτηρισμος: κτηριου / κελυφους / οψεων / συνοδειας
θεση φωτογραφιας | αποσπασμα χαρτη κλιμαξ 1:1000
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παρατηρησεις: αριθμ. καρρε φιλμ 31Α
η συνταξη : Ομαδα Π.Μ.Ε.Α. Ναυπλιου
ημερομηνια : 1984

figure 2: Card of the first recording, 1985

During both recordings, there were discussion meetings held with the city residents with the aim for them to participate actively in the recording and to express their opinion on the objectives of the project. The promotion of the city's cultural importance and the organization of educational programs through the integrated recording and documentation system that is to be created have met with positive reactions from the city's residents. It should be noted, however, that there were many suggestions for the need to take advantage of the system towards the development of protection projects for the city.

2.2. Data classification, information classification and design of the database

For the design of the database has been taken into account the fact that the contents of the database are information concerning both space in the city scale as well as the individual elements of the city (historic buildings or public spaces). Therefore, the arrangement and classification of the data was performed at two different levels:

- General information material, which includes: General imaging of the city, general and special bibliography, literary and ethnographic texts, old maps and drawings, engravings and post cards, paintings and films.

- Special information material, which includes maps, drawings, pictures, and writings that refers to:

a. The characteristic elements of the city's historic center (buildings, public spaces, monuments, cultural buildings, demolished historic buildings, local social and economic data)

b. The historic elements of the greater city area, (buildings, public spaces, monuments, cultural buildings, demolished historic buildings)

c. The fortifications of the city

In particular, the information and data regarding the city's historic center was organized in the following Sections and Sub-sections.

a. Historic – Architectural elements.

Historical information, general description of architectural characteristics, existing protection laws and regulations, time of construction, typology, roofing system, architectural alterations.

b. Special construction and morphology characteristics

Vertical outer shell, internal bearing and non-bearing systems, floors, doors, openings, external decorative items, terraces, interior elements of special interest.

c. Social – Economic data.

Detailed data on the owners and users of the buildings (name, age, date of purchase and/or occupation).

Use per floor, conservation conditions, time of repairs, functional problems.

d. Imaging

Characteristic black and white picture of each building (1985)

General and special colour pictures of all sides of each building and of its special details (2006)

Building plans (layouts, elevations, sections) based on published information.

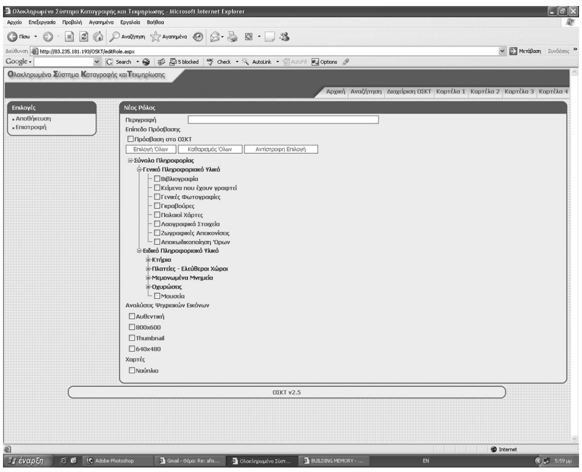

figure 3: Screen of online database

2.3. The use of the system

All historic evidence for which there will be recorded information in the system (monuments, buildings, public spaces), were identified by a unique reference number which relates to the number of the building block in which they are located and were depicted in the city map as "active elements".

The users of the system responsible for data entry are: the scientific personnel of the City, who will be responsible for entering information into the database, as weel as other special users

Users of the system with access to the information are: local public and private agencies looking for certain information, scientists and researchers from Greece and abroad, residents and professionals of the city and the student population.

2.4. Updating – monitoring

The information that is entered into the database is divided into specific time periods that may be – or will be in the future – expressly defined (i.e. 1985, 2006, 2010, etc.) or not (i.e. old photographs and drawings without exact date of production).

The above information material is today being recorded into a server located in the City of Nafplion. This information will be continuously updated and its retrieval can be performed using many different criteria. This way, it will be possible to constantly monitor the development of the activities within the city and to plan the city's evolution.

Access to the database through the Internet allows the updating of the material by special users from distant locations thus making it a "live" instrument.

2.5. Ways to retrieve and present the data - interface – access

The principles of the interface design took into account: the general objectives of the integrated recording and documentation system -as they are presented in the introduction-, the users profile, which was determined from the beginning and the content of the information which is directly correlated with the territorial standards

The retrieval of information has been designed to be performed through the city map, by selecting a random or specific building, or through thematic maps (typology and age of buildings) as well as by street names.

Attached there is an sample presentation of the above functions.

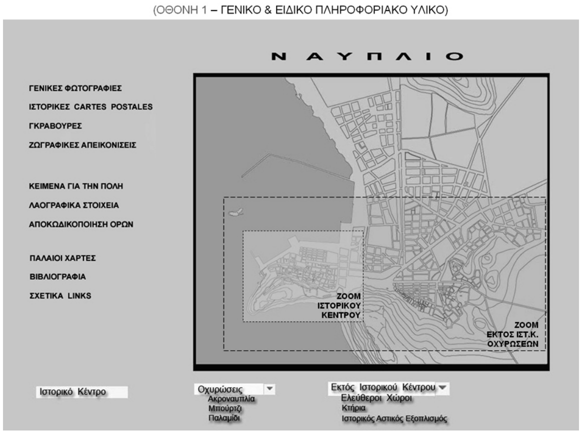

figure 4: General and special information material, A sample presentation of the data base function, version_01

figure 5: List of buildings per road, A sample presentation of the data base function, version_01

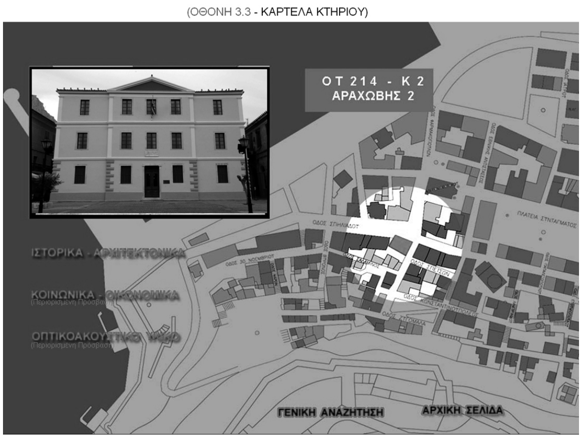

figure 6: Building card, A sample presentation of the data base function, version_01

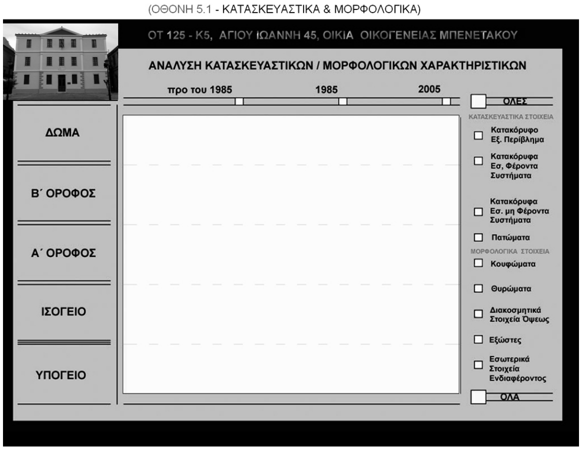

figure 7: Special construction and morphology characteristics per floor, A sample presentation of the data base function, version_01

3. Conclusions.

The development of a digital platform which will allow the integrated recording and documentation of the cultural heritage of historic cities is a project of great significance. It contributes to the wide-spreading and learning of the special characteristics of the cultural heritage of a city, which is an important tool for all the entities involved in the preservation, protection and management of historic cities.

The above system will also prove especially helpful, in combination with the possibilities allowed by new technologies, in conservation programmes for the historic city, in the development of cultural tourism through guided visits in the city, as well as in educating the younger generations on issues concerning their local history.

The most significant problem of the above effort is to achieve the scientific and at the same time comprehensible presentation of the information, without resorting to simplifications and interpretations that may alter historic evidence and mainly to be able to present accurately the information that constitutes the general image, the aesthetic qualities and the meaning of the historic city.

4. Contributions

Professors M. Adami and E. Maistrou were responsible for the historical and architectural documentation of the historic buildings.

A special reference must be made for the contribution of survey engineer and advisor of the City of Nafplion, Mr. X. Antoniadis, the President of DEPAN, Mr. K. Heliotis and the person in charge for the completion of the technical file cards of the project, Ms. A. Tzomaka.

The first recording of the city's historic buildings and public areas was realized within the framework of the project «City Plan Restructuring Project» 1985- 87. prof E. Maistrou was in charge of the project, prof. M. Adami was the chief advisor and S. Malikoutis and K Kiriakides architects, were special collaborators.

A specialized team comprising architects and post graduate students at NTUA worked on the second recording, with Professor E. Maistrou being in charge. The digital photographic documentation was performed by the architect and doctorat candidate at NTUA, M. Balodimou.

The architect Mr. D. Psychogyios, post graduate student at NTUA, collaborated in the design of the database

The archaeologist E. Komata has undertaken the digitation of printed material and the entering of data into file cards

The computer engineer, Mr. A. Anagnostakis has undertaken the development of the software for the integrated recording and documentation system

The architect H. Antoniadis, post graduate student at NTUA, collaborated in the design of the presentation of data.

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Documentation, Interpretation, Presentation and Publication of Cultural Heritage: *Proceedings of the ARCCHIP Ariadne Worksops, Volume 2.*

The 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage
VAST (2006)
M. Ioannides, D. Arnold, F. Niccolucci, K. Mania (Editors)

Short Papers

Persian Heritage Archive

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Abstract

Persian Heritage Archive is one the approved task groups of RecordDIM international initiative. In this task group, a unified approach is to be provided for proper documentation of Persian territories. As part of the guidelines suggested by the International Committee for Heritage Documentation (CIPA), we have established a national non-governmental documentation cell named Borde-Kootah to follow and implement the ideas proposed in the aforementioned task group. As the first step, we classified Persian Heritage remains into several major categories. Then, a case study is carried out for each category of Persian architectural types to investigate these various ancient monuments and to depict the pros and cons of the employed documentation strategies. Based on these experiments, a decision will be made on the final standards and the most appropriate methodology for a unified Persian Heritage Archive. In this paper, as a brief report, some documentation projects that have been recently conducted by authors are introduced.

Categories and Subject Descriptors: Heritage Documentation, RecorDIM, CIPA, Close-Range Photogrammetry, Persian Heritage Archive.

1. Introduction

The most important step at the beginning of the preservation work is to prepare a detailed documentation and recording of the cultural and natural heritage because without precise documentation of the historic structure and its surrounding environment, it would be very difficult to carry out a suitable restoration project.

Documentation of the cultural heritage serves as a tool to make information accessible to those who cannot investigate the site itself. Different reasons can be found for the necessity of this information transfer:

- The object is not accessible to interested people
- The object is too large or too complicated to be overlooked and it would be too time consuming to execute an own investigation
- The object is visible only for a short period of time at its location
- The object is too far for people to afford visiting it
- The object is in danger of deterioration or destruction

In general, most heritage documentation applications specify a number of requirements such as:

- High geometric accuracy
- Capturing all details
- Photo-realism
- Automation
- Low cost
- Flexibility in applications
- Efficiency in model size

2. Persian Heritage Archive

Persian Heritage Archive is one the approved task groups of RecordDIM international initiative. In this task group, a unified approach is to be provided for proper documentation of Persian territories.

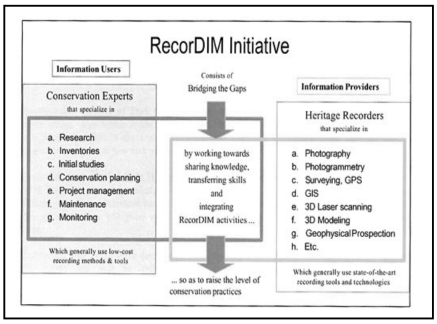

Figure 1: *RecorDIM workflow*

As part of the guidelines suggested by the International Committee for Heritage Documentation (CIPA), we have established a national non-governmental documentation cell named Borde-Kootah to follow and implement the ideas proposed in the aforementioned task group. As the first step, we classified Persian Heritage remains into several major categories. Then, a case study is carried out for each category of Persian architectural types to investigate these various ancient monuments and to depict the pros and cons of the employed documentation strategies. Based on these experiments, a decision will be made on the final standards and the most appropriate methodology for a unified Persian Heritage Archive. In this paper, as a brief report, some documentation projects that have been recently conducted by authors are introduced.

3. Case Studies

Different case studies have been carried out to study both the capabilities of available documentation methods and the documentation requirements related to the enormous number of Persian heritage monuments. Here, three recent documentation projects are introduced.

3.1. Category I: Relief and Sculpture

There exist numerous ancient inscriptions and relieves in Iran that require precise documentation for their study and maintenance. The largest inscription of world, that is the one related to Dariush, the great in Bisotun has been already performed by the first authors. As for a case study concerning Persian Heritage Archive, precise documentation of Elamite inscriptions and sculptures (6th century BC) was carried out.

Figure 2: *Satellite image of Izeh area*

Ayapir (Izeh) is an ancient Elamite town in Iran, this ancient town has the biggest gathered collection of archaeological sites and monuments, which show special religious scenes. The oldest Iranian rock relieves and cuneiform inscriptions have been carved on the slope of Izeh mountains which are related to Early-Elamite period (20th century BC). It appears from the documents that at Neo-Elamite period, a local monarch whose name was Hani, at the same time of Shutruk-Nahunteh II reign, was the ruler of Izeh.

Figure 3: *Kul-Farah III documentation*

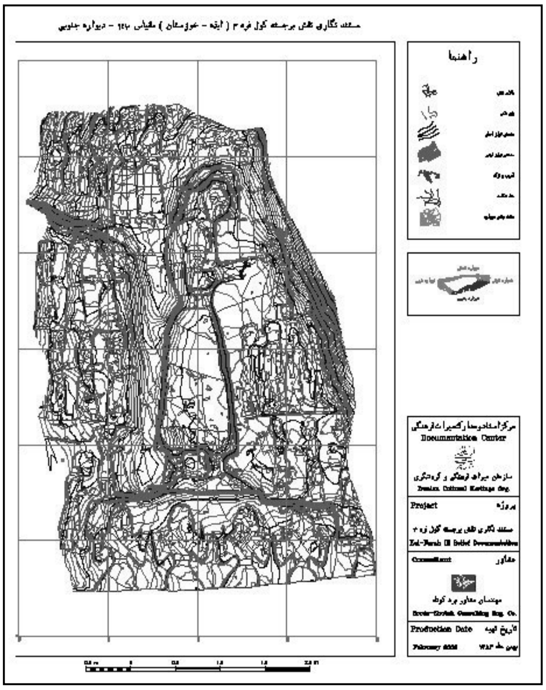

Figure 4: *Photogrammetric map of Kull-Farah relief*

3.2. Category II: Minaret and Tower

Minaret is one of the characteristic architectural types in Iran. To study the documentation of this category of Persian Heritage, the Minarets of Nezamieh in Abarkooh was selected as an appropriate case study.

Figure 5: *Aerial photo of Nezamieh site*

These huge minarets were built in 13th century AC and need urgent restoration operation in order prevent the monument from more inclination or collapse. The complexities were compounded by the problematic working space, high precision order and absolute orientation.

Figure 6: *Documenting inaccessible parts using a lift*

A solution based on digital close-range photogrammetry was employed for the documentation task.

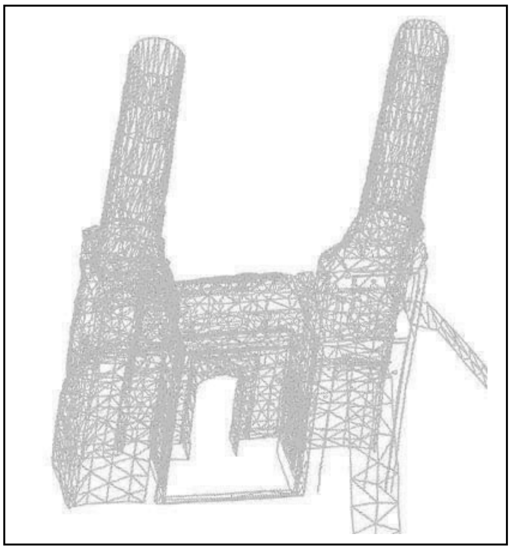

Figure 7: *Triangular Irregular Network Nezamieh*

This monument is in imminent risk of destruction and is currently in the focus of national efforts for safeguarding. The major critical issue is to study the inclination and current condition of conservation of the minarets.

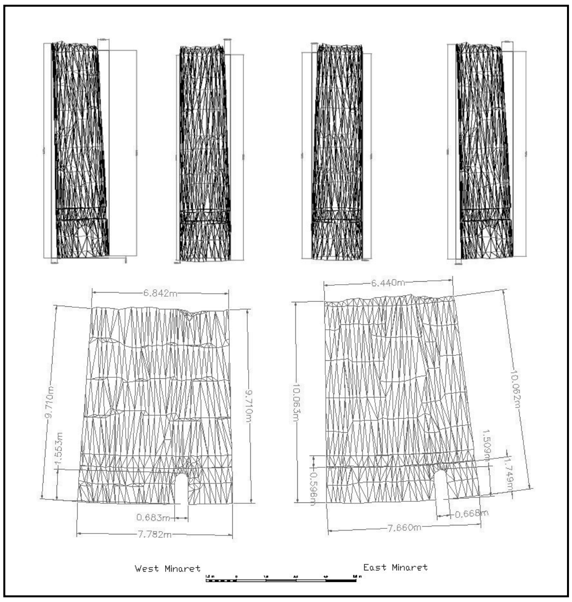

Figure 8: *Analysis of Nezamieh minarets*

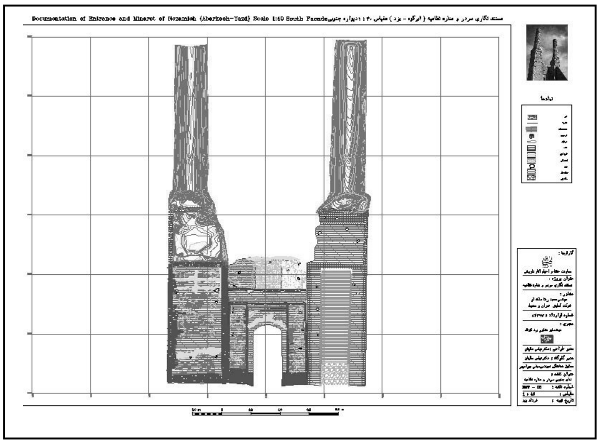

Figure 9: *3D reconstruction of Nezamieh monument*

3.3. Category III: Mosque and Altar

The architecture of mosques may be regarded as the most important category in Persian Heritage. Documentation of Imam- Hassan mosque in Ardestan (10th century AC) was selected as a case study for this category.

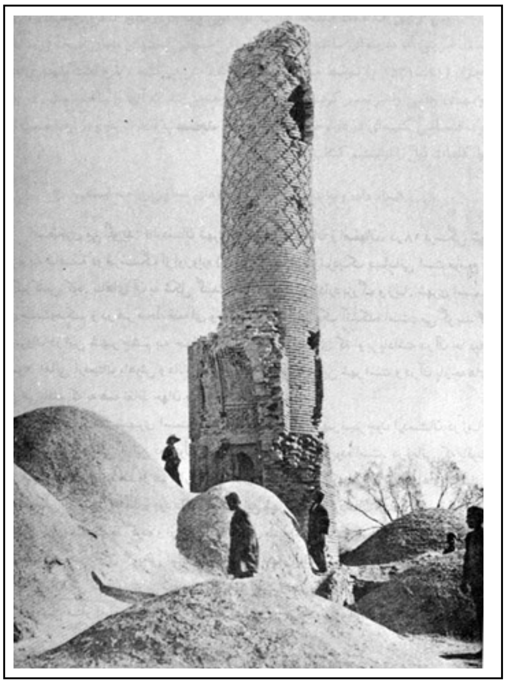

Figure 10: *Old photo of Imam-Hassan mosqu (1911)*

The dataset provided is of importance to prepare an assessment of the structural condition of the elements of the building and as reliable source of information for coming missions that will excavate further study of the monument.

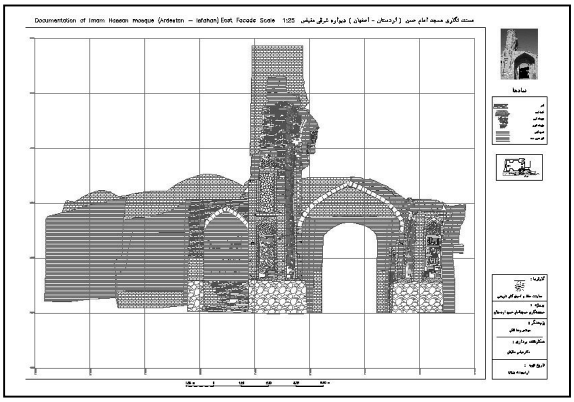

Figure 11: *Documentation Imam-Hassan mosque*

4. Conclusion

The results of different documentation projects and comparative studies on Persian cultural heritage conducted by authors by means of various surveying methods demonstrate:

- The current condition and structural stability of the monuments.
- Methodologies for evaluating the surveys carried out by previous missions, i.e. change detection.
- A solution to prepare a permanent document showing different problems and operations needed to measure the monuments.
- How to propose a model for capacity building of local experts including the development of local structure that is capable of documenting and caring the Persian Heritage. This cell should have strong links to academic and professional institutions, providing further training to experts in Persian territories.
- That, multidisciplinary teams of specialist dealing with conservation of historic buildings should take an active role in the development of *"Persian Heritage Archive"*.

Note

I) Kul-Farah relief documentation was a project of Documentation Center of the Iranian Cultural Heritage Organization (ICHO) executed by Borde-Kootah Consulting Eng. Co.,
II) Nezamieh monument documentation was a project of Mr. Mohammad Reza Malekloo carried out by Borde-Kootah Consulting Eng. Co.,
III) Imam-Hassan mosque documentation was a project of Mr. Reza Saghafi conducted by Abbass Malian.

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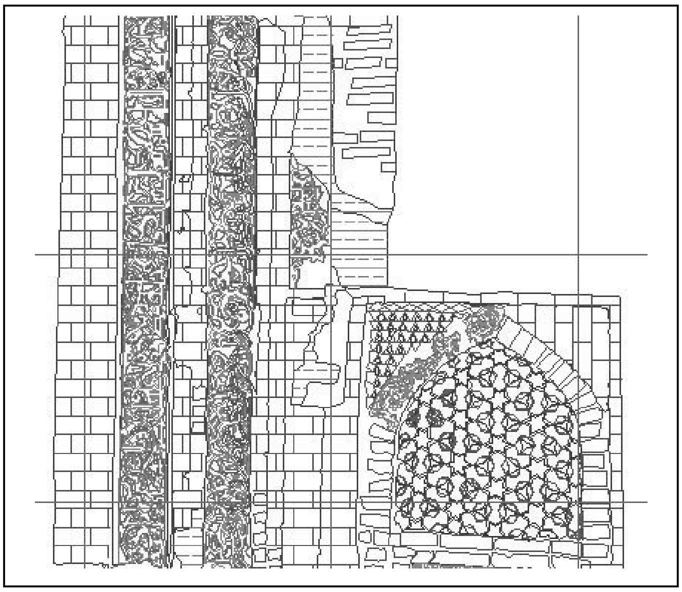

Figure 12: *Details of documentation map of the Imam-Hassan mosque altar*

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Short Papers

MUST System - Location Based Services and Multilingual Simultaneous Transmission for Tourist Fruition

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Abstract

The following is a presentation of the "MUST" - Multilingual Simultaneous Transmission - system that provides radio transmitted (PMR-PLL) audio tracks up to a distance of 100-200 meters in open areas in eight different languages simultaneously. This innovative system, developed with a unique integration of technologies, provides comments, descriptions, and/or background music to groups of users in various types of situations that have been activated using LBS (Location Based System) technologies. The contents can be activated in LBS mode using GPS technologies in open areas while in indoor environments RFID technologies are necessary. The main advantages of this solution are: the low cost of the client devices (audio receivers), joined by the economic advantages of digital audio track self-production; high transportability; the possibility of extending the system's functionalities; the high number of supported system clients: more than 100 receivers can be used simultaneously and the number of simultaneous audio languages can be extended further. The next development of the sinchronized video streaming functionality gives MUST more advantages and implementation possibilities.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Multimedia Information Systems]: Hypertext navigation and maps J.0 [Computer Applications]: General, field sciences J.5 [Arts and Humanities]: Archaeology H.3.4 [Systems and Software]: Distributed systems H.5.1 [Multimedia Information Systems]: Audio Input/Output

1. Introduction

The following is a presentation of the "MUST" - Multilingual Simultaneous Transmission - system that provides radio transmitted (PMR-PLL) or cable transmitted audio tracks in eight different languages simultaneously. Cable transmission system is the best solution for in-door or on-board applications where there are several seats with head-phones output, while the radio solution can be used in open areas where users can move up to a distance of 100-200 meters from the transmitters rack. This innovative system, developed with a unique integration of technologies, provides comments, descriptions, and/or background music to groups of users in various types of situations that have been activated using LBS (Location Band System) technologies and can be set to manual, semi-automatic or completely automated mode. The contents operated in LBS mode can be implemented using GPS technologies in open areas or RFID technologies in closed environments. The system is equipped with its own highly flexible software that can be individually compiled to suit specific commentaries regarding the archaeological area, or theme park, being visited. It is therefore possible to use a single system to provide an audio-guided service in 8 different languages by selecting the route-monument-work of art option of the specific commentary required. The MUST system and its management software have been developed to meet the various and diversified needs of the tourist sector. MUST offers two system options: a fixed centralized option that restricts transmission of all the equipment to within the 100-meter range of the radio signal and a mobile, portable option that can be carried in a backpack or trolley. The system was developed to meet the specific needs of simultaneous transmission of audio content to groups of people of various nationalities and languages. The systems currently present on the market are for the most part conceived to provide pre-recorded or live commentaries but do not offer simultaneous commentaries in different languages. Figure 1 shows the flight-case containing the equipment, receivers, and audio transmitters.

2. Description of MUST

Figure 1: MUST *system.*

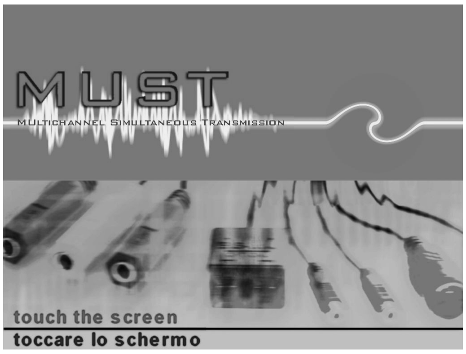

Figure 2: MUST *logo.*

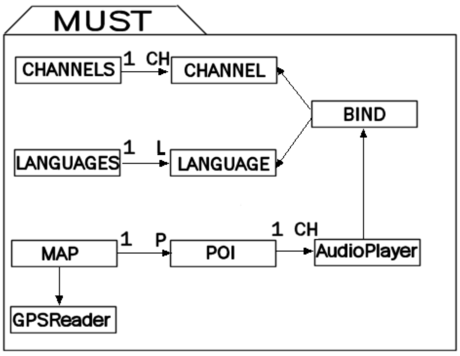

Figure 3: MUST *Class Diagram.*

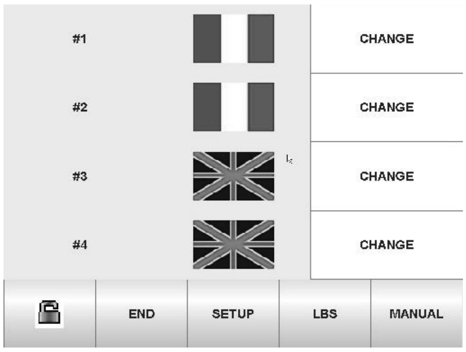

Figure 4: MUST *Binds Configuration.*

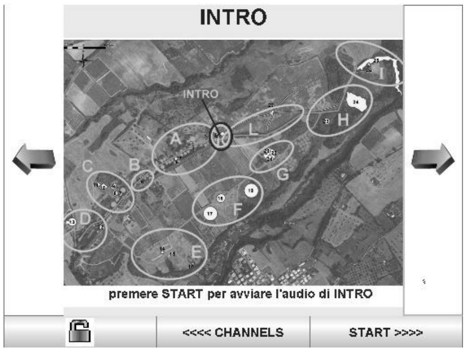

Figure 5: *The Manual selection of POI.*

The MUST system was created as a device to enrich the valorisation and tourist fruition project of the UNESCO site at the Etruscan "Banditaccia" necropolis of Cerveteri (Rome). The particular characteristics of the area, a tuffaceous plateau of about 10 ha with some 400 monuments including tumulus and hypogeum tombs immersed in a unique landscape, made it necessary to develop an innovative audio guide system that could furnish simultaneous transmissions in up to 8 languages. The tour of the monuments runs along 3.7 km route onboard a light-electric train where the users/tourists are equipped with audio guides that describes the site in their own language. MUST offers two distinctive system options: the first system (management and control system) is made up of: a Mini PC with specific software for

Figure 6: *POI's contents controls.*

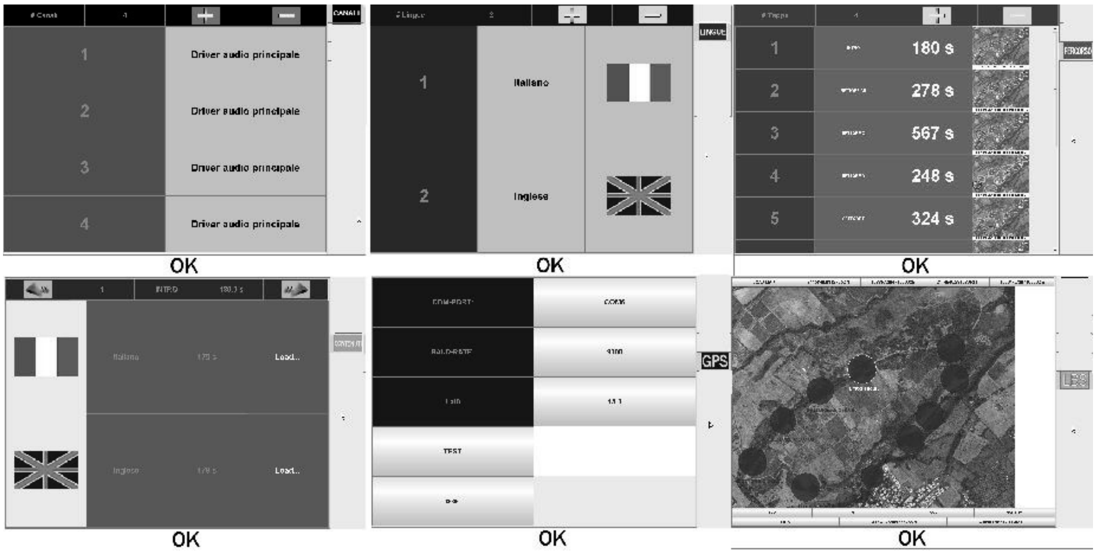

Figure 8: *MUST's Configuration GUI*

Figure 7: *The LBS execution modality.*

the management of multilingual audio sequencing of the relative area being described; a Touchscreen to facilitate use by the operator. An audio card able to distribute up to eight audio tracks simultaneously to the transmission system is connected to the Mini PC. This first system is contained in a sturdy flight case that can be transported manually for software maintenance or upgrading. Three power supply system options were applied: 220V to the network, 12V (6A), and a self-contained system with rechargeable batteries. The second system (Radio transmission and reception system) has up to a maximum number of eight transmitters (PMR or PLL) connected to the first system and the relative receivers - unlimited number - equipped with ergonomic earphones that are distributed to the users. Users can choose the transmission in their own language by selecting from the options found on each receiver. The second system is contained in a case that can hold up to 36 components (ex. 6 transmitters and 30 receivers) and has a battery recharging function that can be connected to the electrical system. If the tour guides need to intervene 'live' with non pre-recorded commentaries, they can connect a microphone to the audio card or disconnect from the central control system and connect directly to the relative transmitter at any moment. For applications in large open areas with different multilingual description sequences, the system can also use a GPS system connected to the Mini PC that activates the audio commentary of the relative object/location that the users are viewing thereby reducing the need of intervention by the tour guide. This configuration, designed especially for Spatial Information Management (SIM), has made it possible to develop a completely automatic process for the integration of heterogeneous data to the system. For applications in indoor environments, MUST can be integrated with synchronized multimedia content management functions for the audio for videos or for wireless transmission towards palm receivers or smartphones.

3. LBS-GPS Application

Location Based Services (LBS) are added value services that use the knowledge of the geographical position of a mobile user to dynamically provide the necessary requirements to the user depending on their location and the characteristics of the surrounding context. In general, the Location Based Services combine information regarding the geographical location with other types of information regarding the surrounding context and environment. These services are usually based on the use of a communication network and one or more localization technologies combined with Geographic Information Systems (GIS) that manage data collection and how it is presented to the final user. Furthermore, in some cases added value application solutions integrated with the technological infrastructure and GIS systems are also used. Their complexity depends on the type of service provided. In this specific case, the MUST system includes very simple GIS functionalities, being a tool dedicated non expert users to manage LBS cvonfiguration and monitoring and to link audio contents to the active areas and positions. Once it was coded in audio format, the information was transferred to the MUST system that, using the position given by the GPS, selects the available information in audio format from the WebGIS application called SITAC (Sistema Informativo Territoriale e Archeologico Ceretano [CMR06]) and transmits this information to the user who asked for it through his position. The system used is based on open source software. The data bank developed foresees the use of a common geographic database (Postgress and PostGIS) that can be accessed through a WAN or the Web. Finally, given the necessity to develop a satisfactory and above all low cost system, an economical and compact entry level GPS was used. The geographic position of the user can be obtained by a reference system integrated within the environment (ex. RFID), or by a total reference system (GPS). The services provided are usually personalized to meet functional and content supply requirements as well as fruition modality requirements in response to the user's profile and position at that moment.

4. MUST Architecture

The MUST system has been developed using JAVA. The MUST class diagram (see Figure 3) defines five main components: Channels, Languages, Map, GPSReader and MUSTAudioPlayer. A Channels instance holds a set of references of size CH to instances of the class Channel. Each Channel object defines a target_audio_device_ID (e.g.. an identifier for a hardware audio output channel) and a channelSEQN from 1 to CH. The Languages class holds a set of size L of instances of Language. Each instance defines the triple (languageSeqN, languageID, languageIcon), where a languageSeqN is a sequential number from 1 to L, a languageID is a string (e.g. "Italian") and a languageIcon is a javax.swing.ImageIcon instance (e.g. an image of the Italian flag). The role of the class Bind is to determine the selected language for a Channel. A Map class defines: a set of size P of points of interest (POI),a georeferenced bound and a bitmap representing the interested area. Each POI instance holds: a POI_ID: a unique integer number from 1 to P, identifying the POI, a pair ((Lon,Lat), Radius) where the pair (Lon,Lat) defines the geographical position of the POI, and Radius (the distance in meters from (Lon,Lat)) is the parameter used by the LBS in determining the active boundary of the POI, a set of CH MUSTAudioPlayer instances and a POI_DURATION defining an upper bound for the time duration of the audio files related to the POI. The MUSTAudioPlayer class defines the methods to play(), stop() or pause() an audio content on a Channel in a particular language defined by an instance of the class Bind. The audio files are stored in a folder named "contents". Each audio file name is formatted as "cilj.wav"; where i and j define respectively the corresponding POI_ID and languageSeqN. Finally, the GPSReader class defines a thread for the MUST's LBS execution modality. This thread continuously reads data from a GPS receiver, converts the coordinates in the corresponding reference system, and triggers the activation of a POIp if the distance between the GPS location point and the POIp.(Lat,Lon) is less than the POIp.Radius. When a POI is active, a sequence of calls to play() is made - one for each of the CH Channel instances - and the corresponding audio contents are streamed to the MUST transmission subsystem via the audio players.

The MUST interface allows a user access to the setup screen, and to the manual or LBS execution modalities. Figure 4 show the first main window where a user can: modify the binds between channel and language; choose between LBS and Manual execution; run the setup phase; exit from the application and lock the touchscreen. Figure 5 shows a POI's choice panel and transmission control for a manual session. Figure 6 shows the "Map" with ten preconfigured POIs. In the same Figure, a particular POI is interested by the presence of the MUST GPS device inside the area of activation. The tourists will listen to the commentary in their preferred language until the audio content will be fully played and/or a new, unvisited POI is reached. If the user selects the SETUP button (shown in Figure 4) a new Window with a tabbed pane of 6 panels appears on the screen. Figure 8 shows an explosion of the configuration GUI, divided in: Channels configuration panel, Languages configuration panel, Tour configuration panel, Contents configuration panel, GPS receiver configuration panel and LBS configuration panel. In the Channels configuration panel, the user can set the number of channels (CH) and their target audio device ID. In the Languages configuration panel, the user can set the number of languages (L), their languageIDs and their languageIcons. The Tour configuration panel allows to define the set of POIs, while the Contents configuration panel allows the user to select the audio files for each POI. Finally, the GPS configuration panel and the LBS configuration panel help the user in configuring the GPS device and in correctly placing the set of POIs on a specific georeferenced map.

MUST uses the JavaSound API [SUN] to handle the different audio streams needed for multichannel broadcasting. JavaSound is a standard Java library (J2SE version 1.3.x and higher) which abstracts the underlying audio hardware and streams, thereby allowing low-level device control and reproduction/recording of different audio file formats, maintaining at the same time the multi-platform capabilities of the Java language. In MUST, each audio stream related to one of the available languages is handled by a custom MUSTAudioPlayer class. Each instance of the class uses the Observer/Observable pattern to report its activity to the rest of the MUST system. Other components of the system, such as the user interface, can register themselves as observers so that they are notified when specific events occur in the audio stream - as an example, when the end of an audio file is reached. Internally, each MUSTAudioPlayer instance employs a local JavaSound audio stream to play the assigned file, plus a local thread to control the audio stream activity at regular intervals, fetching new data from the audio file in the drive and writing that data to the audio hardware. There is thus no need to load the whole audio file in memory, since only a small buffer is used by each player. Audio file length is therefore only constrained by the available disk space. When created, each MUSTAudioPlayer class instance accepts a local audio file name, an audio hardware device name, and a reference to an observer object as the parameters of its constructor, and encapsulates the use of the JavaSound API, so that it is possible to port MUST to a different audio platform by specializing the MUSTAudioPlayer class. Multichannel audio hardware, such as the M-Audio sound card, usually maps its physical outputs to a set of separate audio devices available to the OS. Since each MUSTAudioPlayer class instance handles its own audio stream independently, multichannel audio reproduction is realized by instantiating several MUSTAudioPlayer classes, each assigned to a different audio device representing one of the soundcard's physical outputs. Therefore, MUST is easily scalable to employ as many audio channels as its CPU and audio hardware can handle. Moreover, it is possible to use different formats to encode the audio, as long as JavaSound provides native, platform-specific codecs for them - MP3 format is a typical example. Compressed formats, though, need far more CPU resources to be decoded, therefore uncompressed WAV format is currently employed in MUST to represent audio guides, so that more audio channels can be achieved. This is acceptable, given that there is more than enough space to accommodate uncompressed files in the system's hard drive and that employing a more powerful CPU would pose serious problems to the system's autonomy, heat dissipation and price.

5. Related works

In [GDVG] existing audio guide systems are categorized according to their properties. They are mainly divided in two categories: manual activation and automatic activation systems. Manually-activated audio guides are widely used but they require some learning time. Among groups tour systems, solutions offered by Antenna Audio [Ant] are widespread but require the presence of an operator for each language, while the Actia-Datavox system is GPS-equipped but delivers audio tracks through cables inside a tourist vehicle. Automatically-activated audio guides are easier to use, and in many tourist offices (such as in Venice [APT]) it is already possible to rent a GPS audio guide. To the best of our knowledge, the multilingual radio transmission of audio contents is an emerging technology [Orp]. The combination of GPS and radio transmission technology is yet to be fully explored.

6. Conclusions

Simultaneous radio transmission of commentaries in different languages represents an innovative solution in the field of Multilingual applications, tools and systems for CH. Location Based System (GPS or RFID) integrated in the MUST system allows commentaries to be automatically activated along tourist fruition paths. Another factor characterizing the MUST system is the implementation of low-cost solutions using Location Based and Wireless services to improve the multilingual fruition of cultural resources. The system proposed can be adapted in archaeological sites, museums, theme parks, town and city tours, with or without operator. After the project and applicative stages of this first release, the work group is now elaborating the next phase. The second step foresees transmission not only of audio content but also of multimedia (video, images, 3D reconstruction) content for terminals using the latest developments in technology such as palm pilots and Tablet PCs.

7. ACKNOWLEDGEMENTS

The panel that presented the project here mentioned is composed by the City of Cerveteri, the Soprintendenza Archeologica per l'Etruria Meridionale (SAEM), the Fondazione Archeologica per l'Etruria Meridionale (FAEM), the Galatour company as local tourist agency, the ECOmedia company as technological partner and the Dipartimento di Informatica - Università "La Sapienza" (Rome) as scientific partner. The MUST system has been acquired by Galatour and today is in service on the aforementioned light-electric train.

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Short Papers

Intra-site Level Cultural Heritage Documentation: Combination of Survey, Modeling and Imagery Data in a Web Information System

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Abstract

Cultural heritage documentation induces the use of computerized techniques to manage and preserve the information produced. Geographical information systems have proved their potentialities in this scope, but they are not always adapted for the management of features at the scale of a particular archaeological site. Moreover, computer applications in archaeology are often technology driven and software constrained. Thus, we propose a tool that tries to avoid these difficulties. We are developing an information system that works over the Internet and that is joined with a web site. Aims are to assist the work of archaeological sites managers and to be a documentation tool about these sites, dedicated to everyone. We devote therefore our system both to the professionals who are in charge of the site, and to the general public who visits it or who wants to have information on it. The system permits to do exploratory analyses of the data, especially at spatial and temporal levels. We propose to record metadata about the archaeological features in XML and to access these features through interactive 2D and 3D representations, and through queries systems (keywords and images). The 2D images, photos, or vectors are generated in SVG, while 3D models are generated in X3D. Archaeological features are also automatically integrated in a MySQL database. The web site is an exchange platform with the information system and is written in PHP. Our first application case is the medieval castle of Vianden, Luxembourg.

H.2.8 [Database Management]: Database Applications ; H.5.1 [Information Interfaces et Presentation]: Multimedia Information Systems ; J.2 [Physical Sciences and Engineering]: Archaeology

1. Introduction

Cultural heritage documentation induces the use of computerized techniques to manage and preserve the information produced. In the archaeological domain particularly, data computerization gives solutions to specific problems in allowing inventory actions to save, present or interpret the features. Archaeology is an erudition discipline where the knowledge grows up in necessarily referencing the precious documents already gathered. Computer science has fast appeared as a very convenient way to manage this information, which the development of the field is enriching at great speed in an inflation quite difficult to master. It is required to develop systems allowing to create relationships between the different types of information generated by the working of an archeological site. We have chosen to work at the scale of a site, because there are more completed projects at regional or national levels. In addition, these projects are mostly Geographic Information Systems, whereas we are creating an Information System permitting to manage very different types of data (not only geographical) what is more uncommon. We dedicate besides our system both to the professionals who are in charge of the site and to the general public who visits it or who wants to have information on it. Hence, we are using web techniques and languages to develop our web information system, in order to be independent of any software and to allow maximum accessibility and adaptability to the needs of the diverse actors using the tool. Our first application case is the medieval castle of Vianden, located in Luxembourg.

The system notably combines survey, modeling and imagery data, and our purpose is to highlight up to what point can such a system offer new possibilities for the management and the documentation of the data of an archaeological site. First of all, we will present the objectives of the project and the methods chosen to reach our aims, according to the state of the art in the domain. Afterwards, the tool that we are developing will be presented. We will describe how the different data types are recorded in the system. Then, we will show the access possibilities to this data: through queries and through 2D and 3D interfaces. Finally, we will explain on the prototype of the Vianden castle site the way to create original 3D models and synthesis plans, and the means to update and revise the data for the experts working on the site.

2. Objectives of the project

To introduce the aims of the project presented in this paper, we will give the principal conclusions of the bibliographical study that has been made in the beginning of our work. So, we will correlate the fixed objectives with the lacks and needs identified during this study.
A good overview on computer applications in archaeology has been given by J. D. Richards [Ric98]. This paper reflects that "although archaeologists have been quick to apply the latest technology, in most cases the technological driving force has been outside the discipline" [Ric98]. What means that the use of computer science in the archaeological domain is often driven by software offers rather than by archaeological questions. This is a problem to which we will try to propose solutions.

Concerning databases, Richards write that the description of a document that is recorded in a database is at least as rich as the report from traditional publications. The recording of metadata (data about data) is something common nowadays, notably with the format XML (Extensible Markup Language, standard language of the W3C) which is dedicated to the formalization of such information and which allows polymorphism. This is the format that we have adopted to record metadata about the archaeological features that our system permits to manage. The idea is that an excavation archive can be viewed as a hyper document with texts and images bounded by internal links and allowing readers to follow different paths to retrieve information through the report [Rya95]. And "if such documents can be made publicly accessible, over the Internet, for example, then they begin to blur the distinction between archive and publication". So we have chosen to develop a free Information System that works over the Internet. An example of integrated computerized field projects linking basic finds, plans and context data recording in the field and operated using GIS mapping tools is related in [Pow91], and examples of Internet databases applications are given in [CFR03] and [Ric04].
A drawback of projects carried out currently, according to Richards and as already said in introduction, is the fact that a large proportion of the literature until now has been concerned with the establishment of databases of archaeological sites and monuments at regional and national levels for cultural resource management purposes. They are few projects concerning data management at a site level, the data recorded being obligatory dissimilar at this scale than at a bigger. Consequently, our project is devoted to the management of data generated by the working of a particular site (and not of a group of sites).

Regarding Geographical Information Systems, they have been developed to create relationships between data and to analyze spatial information recorded in databases. In archaeology, the principal applications of GIS are either heritage management (monitoring of known sites or identification of new ones) or explanatory framework (site catchments or view shed analysis). A great quantity of examples are cited in Richards' paper and his conclusion is the following: "There has been a lack of projects that have made effective use of GIS at the intra-site level; the projects on an Iberian cemetery [QBB95], Roman Iron Age sites in the Assendelvers Polders [Mef95], and the Romano-British settlement at Shepton Mallet [BCE*95] are rare exceptions." [Ric98]. For that reason, the project that we are developing concentrates on this lack. We generalize the notion of Geographical Information System in saying only Information System to describe our work. In fact, the types of data that are managed are not only geographical data (maps, vectors) but also archaeological, historical, topographical, architectural, geological, environmental… An information system must permit to carry out a real multidisciplinary synthesis of all resources of the database. For archaeological data especially, the creation of an information system can lead to achieve:

- to treat graphically several information derived from very different kinds of surveys, because a selective superposition could be a precious help for the interpretation;
- to combine elements selected in diverse graphs for the carrying out of visualizations in a synthesis plan;
- to present images and their connections with the concerned texts from the database, to lead to a complex system in which the examination of texts and images would be possible simultaneously.

Especially for our project, the aim is to create a tool permitting to manage data generated by the working of an archaeological site. The term management comprises the gathering and description (metadata) of all the documents (photographs, plans, drawings, models…) already created or that will be done during the further exploitation of the site, and the construction of relationships and links between them.

To continue, visualization of archaeological information is one of the most exciting ways in which computer technology can be employed in archaeology. This word is taken for any exploration and reproduction of data by graphical means. The use of this technique allows visual interpretation of data through representation, modeling, display of solids, surfaces, properties or animation, what is rarely amenable to traditional paper publication [Ric98]. Until now, the most 3D models are intended for heritage center and museums displays, rarely are some available on-line over the Internet. An impressive and popular publication of visualizations of international important sites has been edited by [FS97]. Also virtual reality with fully immersion has a great potential as a medium for interpretation and communication to the general public [GE04]. An example of web-based visualization in VRML that allow to explore an archaeological landscape (large scale) is given in [GG96], and explanations about the use of the SVG format are to read in [Wri06]. One of the principal inconvenience of the types of 3D models used in archaeology until now is that these models are blank. In fact, they only serve for visualization needs and they don't give any other information. Nowadays, 3D models can serve as research interface to access different kinds of information, notably in coupling them with web procedures (scripts). Our project is carrying out this way: we are producing interactive plans in SVG and models in X3D that work like web interfaces to access the database data.

Finally, when spoken about communication in the domain that interests us here, it is often heard as publication. More precisely, significant developments regarding communication currently have appeared with new forms of electronic publications. Electronic publication allows the distinction between traditional archive and hard copy report to blurred, with supporting data made accessible for the first time [Rya95]. From another source, there are advantages through multimedia and accessibility of new forms of data, particularly drawings, plans, video, and photographs [RS94][Smi92]. [McA95] note that doubts have been expressed about the speed of adoption because of resistance from traditional publishers. We can say now that these doubts were well-founded because there are not yet a great quantity of electronic publications in archaeology, especially available over the Internet. However, one of the best examples of on-line publication (peer-reviewed journal of record) is *Internet Archaeology*, an international electronic journal project set up with funding from the United Kingdom's Higher Education and Further Funding Council (HEFCE) as part of their eLib (Electronic Libraries) program [HRR95]. This publication doesn't contain any other material than textual documents. According to Richards, "undoubtedly the major growth area of the second half of the 1990s has been that of archaeology on the Internet, particularly on the World Wide Web" [Ric98]. This is even more true today, the web provides a tremendous opportunity to link distributed resources and to make unpublished material widely available (remarkably uncommon material like detailed fieldwork data, quantities of photos and archive drawings, vectorial plans or 3D models). The traditional division between publication and archive could thus be removed, even if there is still a big challenge to control the way in which the Internet is used (for the discoveries, quality controls or copyrights). From our side, the way we perceive the term communication is more complete than just the publication. Aim of the web site including the information system, is to assist the digital archiving of the documents, their inquiry and their processing by everyone, both the professionals (archaeologists, surveyor, architects, etc.) and the general public. Different types of access to the data are available depending on the user of the system. Representations adapted to museum displays (public attractive) have been done as well as interfaces permitting to update the data directly from the 3D models (for instance) for the needs of the site managers. This system works over the Internet to allow accessibility and simplicity for all the users, and above all to be free from any software. As a conclusion, Richards said that "in all areas of computer applications in archaeology, the discipline has been technology driven and software constrained. Rarely has the use of computers in archaeology been led by archaeological theory, although in specific fields, such as GIS, it can be demonstrated that computers have advanced archaeological knowledge." [Ric98]. Thus we hope the information system we are developing will also serve archaeological knowledge in proposing an other type of communication and sharing of the information generated by an archaeological site.

3. Implementation of a web information system dedicated to archaeological intra-site features documentation

According to the objectives explained before, we will now present the way the project has been developed to reach these aims in the best possible way.
To begin with, it is relevant to point out the fact that the computational base of the information system carried out comes from projects done to integrate photogrammetric data and archaeological knowledge on the web (ISA-PX "Information System for Archaeology using Photogrammetry and XML"). These projects are parts of research of P. Drap and his team [DG00] [DDS*05].
In fact, a certain number of the computer formats (XML, VRML) used in the ISA-PX system were adapted to our needs. The laboratory of P. Drap being partner with us, it has been possible to base our project on the computer developments already done. We have adapted the existing system afterwards to our particular case, notably to allow the management of different types of data (not only data coming from photogrammetric surveys), and coupled with a web site to permit simple data access by everyone. Our system has been named SIA (Archaeological Information System).

3.1. Database management system

The types of data that the system allows to manage are:

- temporal data (description of historical periods)
- spatial data (description of places of the archaeological site)
- different sorts of plans that have been digitized (axonometries, maps, sections, plans, elevations, excavation profiles and plans)
- digital photos or ancient photos digitized
- scanned drawings
- scanned texts
- vectorial plans (generated in SVG)
- 3D models (generated in X3D)

These data are recorded both as XML files and in tables of a MySQL database. These two record possibilities were already available in the ISA-PX system, to obtain standardized data formulized in XML (for simple information exchanges) and a classic form of data searchable through SQL queries in MySQL. More precisely, it is metadata about the before quoted data that is recorded (for instance the provenance, author, subject, coordinates… of a photo). Figure 1 sums up the process to fill the XML and MySQL databases (both are filled simultaneously).

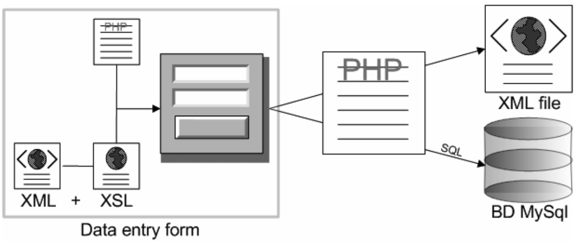

Figure 1: *Filling of the databases (computer behavior).*

After having integrated a first time the corpus of each data type in the form of an XML file generated by the system (data entry form to give the metadata structure), all the metadata is recorded through data entry forms like in Figure 1. The data itself is attached thanks to URL links.
Figure 2 gives an example of the HTML representation of an XML photo file (data and metadata) thanks to an external XSL document. When the user clicks on the miniature of the photo, he have access to the original photo.

Figure 2: *HTML representation of the XML data and metadata of a photo thanks to an external XSL document.*

3.2. Accesses to the data in the system SIA

Figure 3 illustrates the computer behavior of the platform that has been developed. The initial information system ISA-PX has been totally included and adapted to the web interface that has been created to form the SIA system, which permits a user friendly and insightful access to the archaeological data recorded.

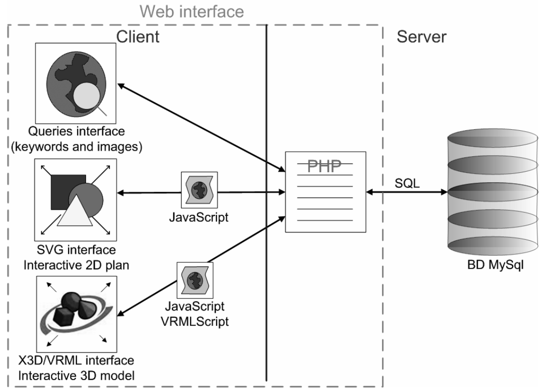

Figure 3: *Types of data accesses in the SIA Information System (computer behavior).*

In parallel to these accesses, two menus are available in the web site to retrieve documents in covering the history of the site and in visiting its places. To sum up, the documents inquiry in the system SIA is schematized in Figure 4.

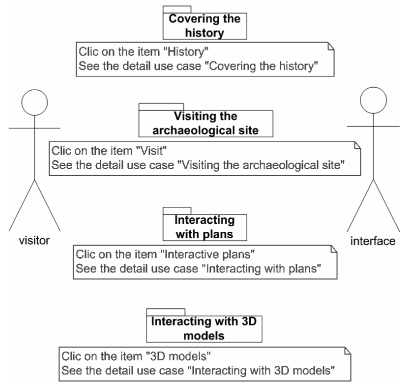

Figure 4: *User's path for the documents inquiry (UML).*

Each use case (presented as a folder here) is also detailed in an other UML schema showing precisely the different operations to do for an efficient exploitation of the SIA information system. For instance, Figure 5 shows the detailed use case "Interacting with plans".

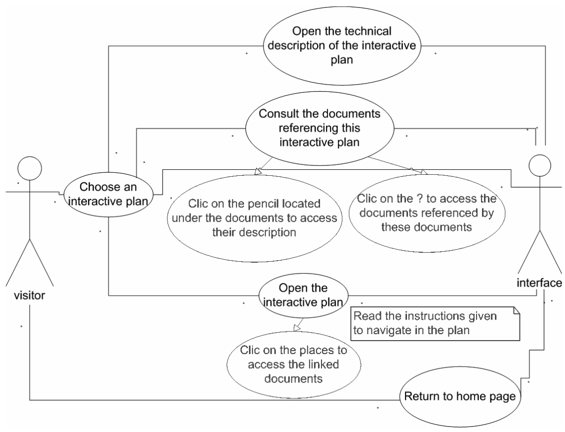

Figure 5: *SIA use case "Interacting with plans" (UML).*

All the UML schemas done to help the users of the system (visitors and expert users) are available in the web site in an item entitled "help and users' paths". Likewise, the queries interfaces (by keywords and images) are explained thanks to UML schemas, to allow the user to find a document as fast as possible if he has particular criteria. The keywords search engine is multi-criteria, what means that the user has choice between different words, he doesn't give the words himself.

3.3. Example of the Vianden castle site

The place of interest on which we have done our first experimentations is the medieval castle of Vianden located in North-East Luxembourg. This archaeological site has a very long and interesting history, during which a lot of documents have been created and hold. Then, this site was very interesting for us to test our system on a real case, notably because we have had access to historical models of the castle made by the MAP-CRAI laboratory of Nancy. So we have collected in the SIA system a lot of data produced by the conservators of the castle (plans, photos, excavations profiles…), along with the MAP-CRAI 3D models (converted from the Maya® format into VRML) and with interactive plans that we have created in SVG thanks to the software Adobe Illustrator®.

All these documents gathered and created have been registered in the database (themselves and the metadata attached) in using the procedure explained in Figure 1.

The principles of accesses to the data are explained in Figure 3. In a more detailed way, Figure 6 shows the example of Vianden site.

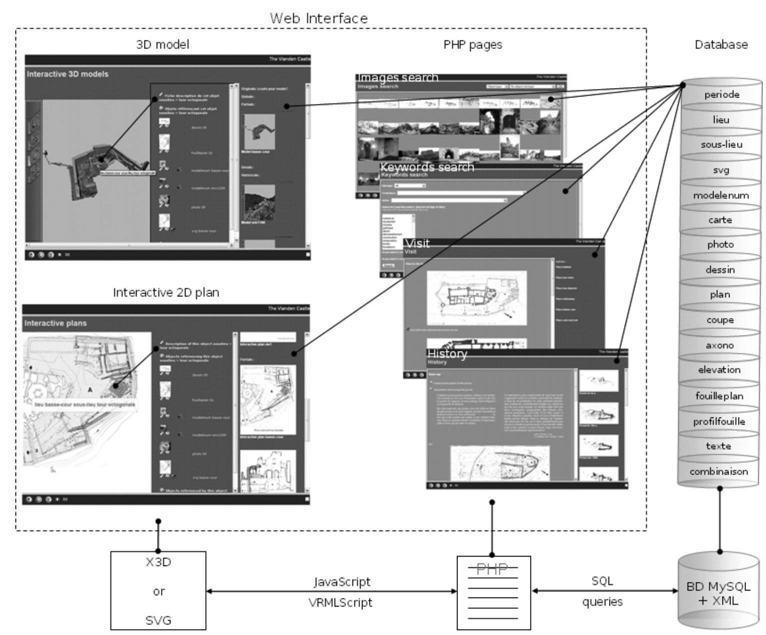

Figure 6: *SIA information system in the case of the Vianden castle.*

Creating models and plans. In addition to the data working possibilities explained before, the user of the SIA system can create his own models and composition plans thanks to multi-criteria data entry forms. In the web pages, he has the choice to select for example one or several places and one or several historical phases for which he wants to create "on the fly" the 3D model to see the evolutions in time of the castle. The procedure is to see in Figure 7. The resulting model presents different parts of the castle (yard, chapel, hall) in two different periods (year 1100 in yellow and 1150 in pink). We can see here the architectural changes that have been done during the 50 years considered. The same process is available to create synthesis plans or photo-montage allowing for instance to superimpose the physionomy of the castle today with its former aspects.

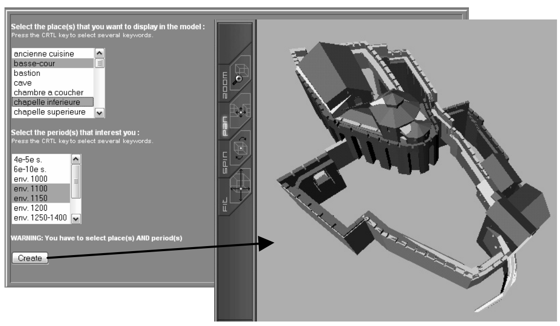

Figure 7: *Process to create on the fly 3D models.*

Updating the data. To look at the data is the first step in the analysis of a dataset. To go further on, the archaeologist (or any expert that is logged on) needs to entry/edit them.

To update the metadata:

- the metadata corpus can be used to correct some basic errors (misspelling, simple inconsistencies, etc.),
- through the graphic interfaces in SVG or VRML, the expert user can directly modify the selected object,
- through different types of research modes (by object type, by location, by epoch, …), the user can straight access to the data and can edit it for modifications.

For the revising, the conceptual model used to describe the objects can change during the time of the study, according for example to new archaeological knowledge. The expert user can modify accordingly the tree structure of the dataset describing the object model.

4. Conclusion and future work

After having set our work objectives in the state of the art of computer applications in archaeology, we have introduced the Information System that we have developed. The web site and the underlying information system allow to record, make use and represent the data of any archaeological site. The SIA system has been made to search solutions to help archaeologists in their tasks at an intra-site level and to avoid that they are software-driven. The full XML choice for textual and graphical representations permits relevant interactions. The use of 2D vectorial graphics and 3D models as user-interfaces to the data link purely documentary data and metadata to geometric representations. We connect very different types of data to emphasize new research possibilities and new information exchanges between many sites to be able to draw conclusions by crosschecking. Moreover, the data are available through the Internet what allows us to work in the direction of communicating them in an innovative and interactive way. Experiments will be carried out soon on a gallo-roman site to highlight the subsisting problems (integration of new data types…) and to test the clarity of the help files created (UML schemas) in order to know if the system is usable by everybody.

Final aim is to create a simple and everywhere accessible tool for all the archaeological sites managers, who wish to be able both to exploit the quantity of data produced and to represent them, in order to make use of this archaeological information system as a virtual storefront for the communication and the e-publication of their findings.

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The Processing of Laser Scan Data for the Analysis of Historic Structures in Ireland

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Abstract

While laser scanners take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information. The testing and application of software platforms, which will manipulate the laser and image data, is necessary in order to identify the most efficient process for analysis of the laser survey data. The main aim of this paper is to present the findings to date of the processing of scan data of 17th and 18th century historic structures in Dublin. The process of reverse engineering is illustrated which generate orthographic plans, elevations and projections of the buildings to facilitate the analysis of the historic geometry, detail of building techniques and materials used.

Categories and Subject Descriptors J.6 COMPUTER-AIDED ENGINEERING Computer-aided design (CAD)

1. Introduction

Current research into automated recording and surveying techniques has been promoted by CIPA which is the International Scientific Committee for Documentation and Architectural Photogrammetry (CIPA) and is a joint committee set up by the International Council on Monuments and Sites (ICOMOS) and the International Society for Photogrammetry and Remote Sensing (ISPRS). The current research within CIPA promotes the development and application of laser scanning and digital photo-modelling for recording architectural heritage, which is emerging as an innovative and novel solution for automating the process of surveying and recording large amounts of architectural data.

2. Processing Survey Data – Further Research Requirements

A laser scan collects a large range of data representing three-dimensional co-ordinates, called “point cloud data”; (see figure 1a) proprietary software is then required to manipulate massive amounts of 3D data. While laser scanners take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information. Dedicated software programmes such as polyworks, Leica cloud-works for AutoCAD and RiScanpro have greatly improved the processing, manipulation and analysis of vector and image data from the point cloud. All of these software platforms have combined algorithms for triangulation and surfacing of the point cloud [REM 2003]. Recent research for improving point cloud data processing has been concerned with reducing the point cloud density without affecting the quality of geometric data and providing data management. High-resolution orto- photographs when combined with the point cloud geometry comprise of more detailed image and geometric information than the conventional data sets of solely the point cloud. The recent developments of plug-ins for existing point cloud-processing software by SANDIG3D and CITY-GRID result in the creation of 3D models from the point cloud and associated image data in addition to the ability to create planes and sections for exporting to other programmes. This data is imported or exported across platforms in the following file formats: ASCII, XML, AutoCAD, 3D Studio or VRML. Recently the research work of English Heritage Metric Survey team and the University of Newcastle upon Tyne have produced a set of guidelines for the use of laser scanning in cultural heritage [BB 2005]. These guidelines establish the best practice for scanning cultural heritage objects for the production of an accurate record. Further research is required in the area of processing of scan and image data across a range of software platforms, to facilitate the identification and analysis of the historic techniques and materials used in the creation of the historic structures.

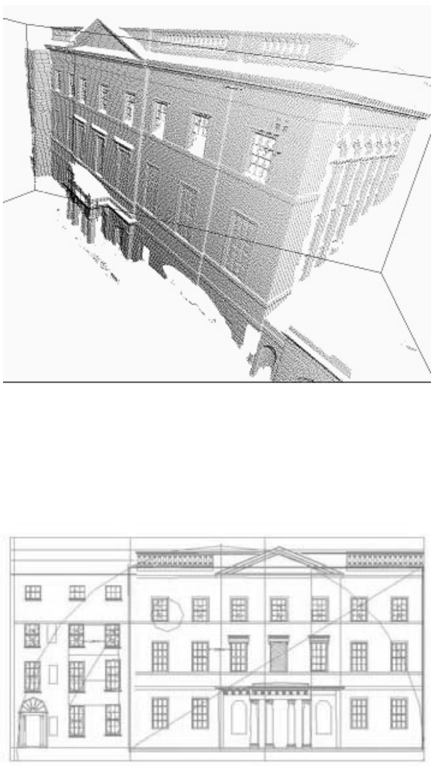


Figure 1:

a. *Top -Example of Laser scan – point cloud of 18th Century Structure – Henrietta Street Dublin*

b. *Bottom - Vector plot from Scan illustrating historic techniques used to establish façade.*

2.1 Data Collection

The following laser scan surveys were carried out in May and October 2006 using a Terrestrial Laser Scanner (*RIEGL* LMS-Z420i,) and were confined to the ***front elevation façade and street fabric*** of Henrietta Street and Capel Street 17^{th} and 18^{th} century Georgian streets in Dublin City. Data was collected using a terrestrial laser scanner combined with digital photo modelling. The terrestrial laser scanner consists of a laser ranger that is directed towards an object of interest by a dual-mirror system. The laser ranger measures distance, using the time-of-flight principle, based on diffuse reflection of a laser pulse from the surface of the object. The laser scanner is combined with a digital camera, which captures corresponding images to the scan, appropriate software is later used to combine the image and scan data. Digital photo modelling is used alongside the laser scanning, but can also be used for independent data collection where laser scanning is not appropriate. Digital photo modelling is the process of obtaining three-dimensional geometry from a single or series of images. The recorded image of an object can be accompanied with measurements, which define a plane on this object [BHM 99]. Camera calibration is introduced to correct for the distortion of lenses, this image can then be correctly scaled to represent the geometry of the recorded object. Information concerning colour and texture of the object can also be provided.

Point Cloud Data

Figure 2: *Point Cloud of Capel Street 18^{th} century Façade*

2.2 Processing

The initial data obtained from the laser scan surveys is described as a point cloud (see figure 2.). Thousands of points are recorded per second, at centimetric grid intervals, across a scanned object to build up a dense 3D-point cloud representation of the object containing, typically, millions of points and requiring specialist software to process. The three dimensional points are in a common co-ordinated system that represents the spatial distribution of an object or site. It can contain also the RGB values for each point. The point cloud density depends on the relative distance between co-ordinates. The point cloud can represent a single or a number of small or large objects or these objects can form a part or whole of a building or site.

The large amount of data, which represents three-dimensional coordinates of an object, must be processed in order to abstract geometry, shape, measurements, and texture. RISCAN PRO the companion software to *RIEGL* 3D Scanners (LMS-Z210i, LMS-Z360i, and LMS-Z420) is used as the platform to process the point cloud survey data. The point cloud can be used as a visualisation tool before processing. The scan can be coloured from the images taken from the same position as the laser scanner. A three-dimensional model used for visualisation is the initial product of the laser scan survey, which allows for full orientation and the creation of walkthroughs of the coloured point cloud.

2.3 Data Cleaning and Sorting

The first stage involves cleaning the data to remove artefacts such as reflections of the scan through objects. As stated previously the point cloud is made up of millions of points and is not suitable for plotting vector orthographical projections or for material analysis. It is not usually possible to export the point cloud into AutoCAD or similar programmes because of the size of the data set. If the density of the point cloud is reduced and the data is cleaned of unnecessary points the data can be imported into Auto CAD for plotting. RiCube is available as an additional software platform for RiScan Pro to process point cloud data, to improve the accuracy and to reduce the amount of data. The point density on the object surface varies significantly due to the varying range to the surface during acquisition. Processing using RiCube is based on sorting all data in an octree structure followed by cleaning and sorting of the data. The processed point cloud can be exported in various formats including 3PF, ASCII, Autodesk DXF, VTK, and WRL as reduced data sets for processing in programmes such as AutoCAD.

Clean scan in CAD

Figure3: *Cleaning Data Artefacts*

2.4 Meshing

The point cloud data does not carry the image data when exported; therefore, edges and texture are missing when the data appears in AutoCAD or similar programmes. The creation of a three dimensional ortho-image allows for all of the image and geometric data to be exported for further processing. This involves processing the point cloud through the following stages triangulation, meshing and texturing with the corresponding position image data and combining the colour textured scan with the corresponding geometric plane of the associated scan image [NDS 2005].

Triangulation is the initial process (see figure 4), which creates a surface on a point cloud; the created surface is made up by triangles connecting the data points. A 2D-Delaunay triangulation algorithm is used to triangulate the data. The Delaunay triangulation is computed from the 2D coordinates of the points mapped onto the computer screen. Triangulated data (also called "mesh") improves definition of the scanned object, (defining objects, edges etc.). The function of smoothing modifies the surface structure of the polydata object by optimising the point data; decimation is a process to reduce the amount of polygons and points in the mesh (see figure 5).

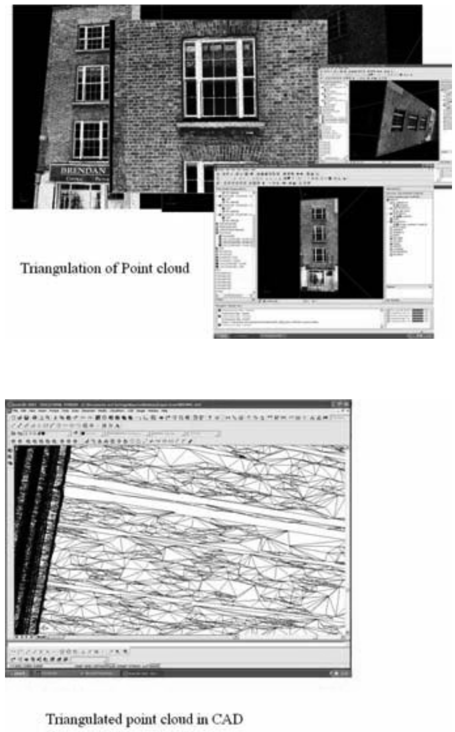
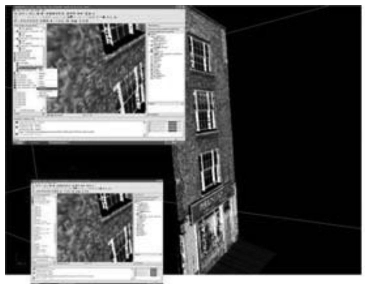


Figure 4: *Triangulation of Point Cloud*



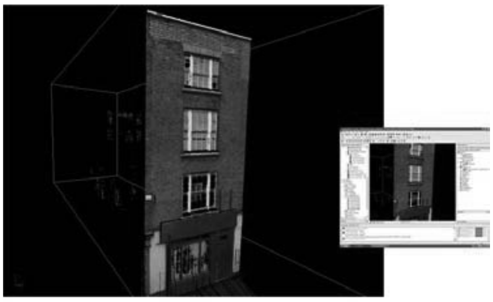
Smoothing and Decimation

Figure 5: *Smoothing and Decimation*

2.5 Texturing

Additionally triangulated data can be textured (see figure 6) with the high-resolution images taken by the digital camera which leads to a nearly photo realistic model.

The texturing procedure takes every triangle and tries to find the optimal image to texture it. The image has to meet several criteria such as smallest distance between camera position and centre of a triangle, visibility of the triangle in the image (no other objects between camera position and triangle) and smallest angle of view. Different parts of the point cloud are triangulated until the desired result is reached.

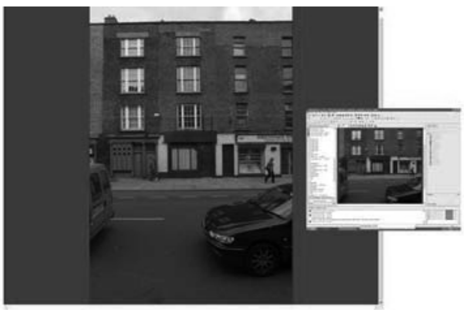


Texturing from image

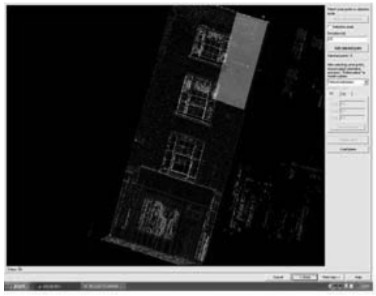
Figure 6: *Texturing of point cloud from image*

2.6 Ortho-Image

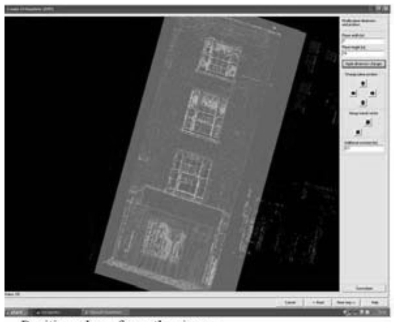
The generation of the ortho-photo is based on the geometry information (scan data) and image data. Images taken by the camera can be distorted by the lens and must be rectified during the processing stage. The ortho-photo represents the data for a particular plane on the x, y, and z-axis; this can therefore represent elevation, plan, or section of an object [RIS 2006]. The planes can be created on the x-y, x-z and y-z axis.



Un-distorting image



Create plane for ortho image

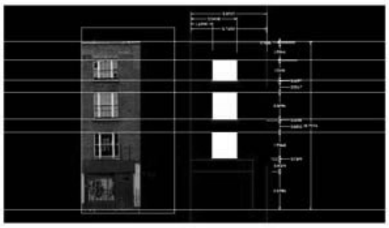


Position plane for ortho image

Figure 7: *Processing of image and textured point cloud data to create orto-image*

Near and far planes are established parallel to the projection plane (distances along the normal vector of the projection plane) between the projection plane and the near plane and the projection plane and the far plane.

Plot from point cloud and ortho image



Plot from point cloud and ortho image

Plot from point cloud and ortho image

Figure 8: *Plotting of vectors from exported point cloud and ortho-image in AutoCAD*

2.7 Reverse Engineering

The final process of reverse engineering is illustrated in figure 8 above, the production of orthographic plans, elevations and projections of the buildings to facilitate the analysis of the historic geometry, detail of building techniques and materials used.

2.8 Conclusion

The following is a summary of the main process stages; initially the point cloud is triangulated and meshed, texturing the triangulated data with colour information from the high-resolution images then follows this. Defining vertical and horizontal planes on the textured scan to match image geometry is then followed by the creation of the orthographic-image; this is a combination of the geometry of the point cloud and the colour and texture from the image. The elevation of the street facades can then be plotted using the point cloud and ortho-image in AutoCAD. The vector plot in figure 9 below was constructed using the above processPDF Generation.

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Short Papers

Low Cost Integrated Spatial Information System For Polish Cultural Heritage Promotion And Preservation

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Abstract

This paper (and associated poster) summarizes the findings of our on-going research project on a planned Polish Cultural Heritage Promotion and Preservation Spatial Information System. The authors proposed to utilize the advantages of a GIS together with the power of a geo-browser and visual information in order to support the promotion and preservation of Polish cultural heritage properties. These properties specifically include unique architectural, engineering and natural heritage elements. As part of the project, legal, organizational, technical, and social issues have already been analysed and although the results are presented in a Polish context, most of the remarks can be applied to other countries or regions. The authors approach foresees the use of the publicly available geo-browsers and community-based participatory data collection in order to enrich the public knowledge and understanding of the basic matters concerning their cultural heritage.

Categories and Subject Descriptors (according to ACM CCS): J.5 [Computer Applications]: Arts And Humanities H.5.1 [Information Interfaces And Presentation]: Multimedia Information Systems H.3.5 [Information Storage And Retrieval]: Online Information Services

1. Rationale

Cultural heritage preservation is one of the strategic aims listed in the Environment and Sustainable Development European Policy Programme. The recording and documentation of cultural heritage provides the world with a historical record of mankind's past achievements. It permits research on the development of mankind and its historical and cultural roots and the possibility to restore, reconstruct or archive the data for future reference.

Obtaining the full professional documentation of a historical building, satisfying official technical specifications, requires groups of qualified people, sophisticated instruments, money and time. The result is a collection of data of different types: geodetic measurements, sketches, cross-sections, drawings, pictures, maps, text, etc. Such complex and precise documentation is definitely useful for many applications including the conservation or restoration of the item (if needed). However, due to the increasing damages to monuments (vandalism, armed and political conflicts, natural disasters or atmospheric pollution) it is essential to record existing items for future generations as quickly as possible. In such circumstances the classical documentation techniques are not the best solution due to time and resource constraints.And yet, even if the number of architectural heritage sites is recorded, the access to the data is complicated because , taking into consideration the Polish context, the documentation mainly exists in the analogue form (i.e. paper) and the search or browse services are not available even offline.

Following the professional and enthusiasts interests in cultural heritage and visual information, and realizing the ability of computer technology to provide effective, cost-efficient data processing and management capabilities, we began the research project on 'The Usage Of Satellite, Aerial And Amateur Images And Geographic Information Systems To Preserve And Promote The Polish Cultural Heritage with an emphasison architectural, engineering and natural heritage sites.

The main challenges of this research are twofold. With regard to images, the study encompasses their photogrammetric elaboration focusing on amateur photographs taken by means of a non-metric camera with unknown sets of parameters (some research have been already shown in [HNN03, NN05, NN01]). In parallel, the study follows the currently expanding techniques to envisage the data,and the methods of creating VR and AR models are examined. Whereas with regard to spatial information systems, our aim is to design such an effective tool that is able to manage and disseminate huge volumes of heterogeneous information (alpha-numerical data, geometrical data, images, VR and AR models), and ideally serves as the Polish Cultural Heritage Information System. The foreseen system is going to be a freely accessed system that the public can refer to in the context of promotion and preservation of architectural, engineering and natural heritage sites. Thus the survey on the requirements of its potential users is foreseen as a part of the research.

2. State-of-the-art

In the scope of protecting cultural heritage, Polish law focuses on the regulation of legal aspects concerning monuments, museums and archives. Acts and regulations provide for a legal framework for their protection, functioning, organization and public access. The basic act of law regulating the issue of protection of cultural heritage in Poland is the Act from the 23 July, 2003 (Polish Journal of Law 03.162.1568) on the protection and care of monuments (hereinafter referred to as the 'Act'). The Act provides compliance of Polish law with the law of the European Union.

Based on this Act, a monument must have the following characteristics: (a) be an immovable estate or a movable thing, their part or collection, (b) be the creation of a person or be connected with human activities, (c) attest to a past era or past events, (d) its preservation must be in the public interest because of its historic, artistic or scientific value. The status of a monument and therefore protection granted by law (by virtue of the law) possess all movables and immovables which fulfil the above mentioned requirements [Gol04, Pru04].

The Act provides the methods for the protection of monuments as follows: entrance into the register of monuments, awarding historic monument status, creation of a cultural park, and conferring protection in the local master plan. Registers of monuments are kept by Voivodeship Conservators of Monuments that are, together with the General Conservator of Monuments, the authorities specifically created for the protection of cultural heritage properties (a voivodeship has been a second-level administrative unit in Poland since the 14th century, in the EU Nomenclature of Territorial Units for Statistics it is referred as NUTS2). Monuments are entered into the register on the basis of a decision of the Voivodeship Conservator of Monuments issued ex officio or on the motion of the owner.

It should be noted, that all monuments regardless whether they were entered into the register of monuments or not, should be entered in the so-called records of monuments but such entrance does not guarantee protection. Records of monuments are only a database of monuments and a basis on which local self-government bodies create programs for the protection of monuments.

The above described registers and records of monuments are open for public access. For natural persons and institutions access is free of charge. In Voivodeship Offices for Monuments Protection each interested person may find out which of the monuments situated on the territory of a voivodeship has been entered into the register of monuments and obtain a certificate of such an entrance. The main problem is the access to such information. The Voivodeships Conservators of Monuments are unlikely to create electronic versions of registers of monuments and publish them through the Internet.

3. Remember to take a picture

How can we increase the access to data? How can we manage complex data effectively? How can we speed up data collection? The authors of this paper were asking themselves such questions in the context of Polish cultural heritage promotion and preservation and specifically those with unique architectural, engineering and natural heritage elements.

Cultural heritage information has important geographic aspects, and therefore the authors chose to use Geographical Information Systems (GIS) to provide effective, cost-efficient heterogeneous data processing and management capabilities. Cultural mapping has also been recognized by UNESCO as a crucial tool and technique in preserving the world's cultural assets.

The question about data capture was still pending when the improvements in technology and the slump in prices of amateur digital photographic cameras provided the best reasons to use this technology. The advantage of imaging techniques is that they are permanent records, which can be the subject to further modelling and/or processing, providing detailed maps (facades included), or cross-sections, and 3D models or animations of the represented objects. The photographs that provide the historical record of mankind's achievements enable individuals to experience the beauty and wonder of the monuments and sites of the past without actually visiting them. As a result of computer visualizations, sightseeing of historical sites is possible even when they are in poor condition and in danger of further damage, or no longer exist.

Realizing that some works of art and historical monuments cannot wait for a professional heritage recorder, authors think that amateur pictures are able to serve as the rough data archive, and propose seizing the advantage of the growing popularity of taking pictures (another good cultural behaviour).

4. Public cultural heritage awareness

Poland is characterized with rich culture and natural and cultural heritage. Interesting occurrences of the culture and the natural and cultural heritage increase the potential of the development of the country, e.g.: heritage tourism, agricultural tourism or eco-tourism, to name only a few. However, it is necessary that the society in general is aware of the cultural heritage. This refers both to the nation, and the local or regional communities. The inquiries effected among students and inhabitants of Warsaw and its suburbs showed that the average inhabitant does not know about the monuments in their area or region (excluding very famous ones), although most of them declare an emotional identification with the region. The care of monuments in Poland today seems to be focused on the protection of large prestigious monuments such as cathedrals, castles, palaces, etc. even though the law does not specify this directly. The majority of people are not aware of the fact that many ordinary buildings like crosses and wayside chapels, houses, bridges, mills, cemeteries, etc are also being preserved. The public awareness with regards to the legal commitments of the owners of buildings with historic and cultural value is also very low. The sad conclusion is that our great cultural potential and the modern policies that are in line with European Union policies with respect to cultural heritage protection, as well as the laws, are partially spoiled.

Public cultural heritage awareness is a fundamental contribution to heritage preservation. The authors approach (namely SIS for Polish CH Promotion and Preservation) is driven by this issue. We are looking for a successful formula for awareness raising. The knowledge of the neighbourhood (on the regional scale) and the country (on the national scale) in the context of monuments helps the citizens better understand the basic matters concerning cultural heritage. Our idea is to bring the public into closer contact with historic buildings and consequently,enrich their understanding of the basic matters concerning cultural heritage.

5. Neogeography

Last year Google opened its mapping service to the public so that hobbyists could use the maps on their own Web pages. The recent appearance of such geo-browsers, i.e. Google Maps and subsequently Google Earth, NASA World Wind, Virtual Earth by ESRI, etc. stimulate a revolution in electronic cartography. The world is so astonished of the second life mash-ups [Paf06] that even they are referred to as 'neogeography' [Jac06]. It is a complementary approach compared to the traditional, geodetic based, Geographic Information Systems, and subsequent Spatial Data Infrastructures (more details can be found in [Gou06]). The indispensable advantages of open source applications,and the unbelievable great success of Google Earth, are currently evoking some changes in our project. Making use of an application based on the Google engine will make our system cheaper (no need to buy reference/geodetic data). Moreover the application based on the Google Map/Local/Earth, encompasses the community-based participatory data collection and thus helps us reach our project goal, that is cultural heritage awareness raising.

6. Conclusions

This paper and the associated poster, present the up-to-date findings of our on-going project on the planned Polish Cultural Heritage Information System specifically focused on the unique architectural, engineering and natural heritage elements. Our preliminary analysis of some legal, organizational, and technical issues, as well as the programmes of the protection of cultural heritage objects and some interviews, showed the great need for greater public cultural heritage awareness. Being driven by this issue, which is said to be a fundamental contribution to heritage preservation, the authors are looking for a successful formula for awareness raising. Thus the foreseen system is to be an effective tool to manage, visualise and disseminate heterogeneous data provided mainly through community-based participatory data collection.The latest idea is to use open source applications i.e. one of the widely known geo-browsers.

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Short Papers

Computer-Assisted Estimation of the Original Shape of a Japanese Ancient Tomb Mound Based on Its Present Contour Map

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Abstract

This paper presents a support system for estimation of the original shape of a Japanese ancient tomb mound, termed Keyhole-shaped tomb mound, based on its present contour map. Using the system, we can make two-dimensional matching of a template and a contour map of the tomb mound. Between 4th and 6th century, Keyhole tomb mounds were built all over the country, of which shapes have been playing a key role in studying the Japanese ancient regime. More than 5000 mounds still remain across the country, most of which are, more or less, deformed for many centuries. The template is keyhole-shaped and superposed on a contour map, which can be controlled by referring to contour lines so as to be a reasonable shape that is likely to be the original shape. This paper also presents some applications of our system and related discussions.

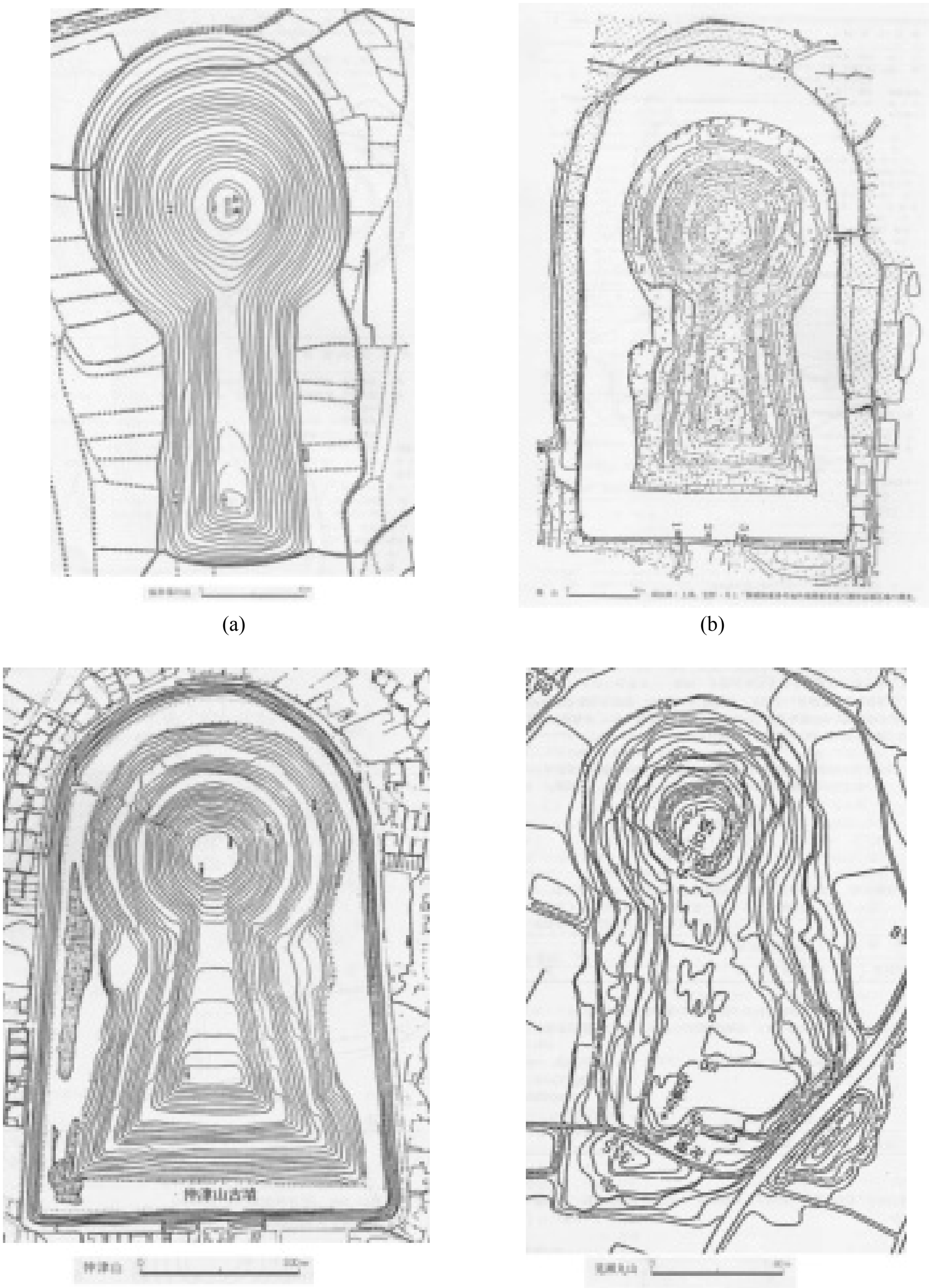
1. Introduction

Most of ancient monuments are deformed from their original shapes for a long time. Generally stone-made monuments are scarcely deformed excepting violent artificial destruction. In contrast, soil-made monuments such as Japanese ancient tomb mounds are often heavily damaged even by natural and slight artificial destruction. The peculiar shapes characterize the Japanese ancient tomb mounds; they have been called *Keyhole shaped tomb mounds* (See Fig.1). Between 4th and 6th century, Keyhole tomb mounds were built all over the country, of which shapes have been classified into several types that play a key role in studying the Japanese ancient regime.

More than 5000 mounds still remain across the country, most of which are more or less deformed for about fifteen centuries. A number of Keyhole tomb mounds have been surveyed and their present shapes have been published as contour maps (See Fig.2). A type of archaeological studies has been focused on estimating the original shape based on a given contour map. It can be regarded as a pattern recognition problem that we estimate the original keyhole shape from a contour map that represents the present deformed shape of a tomb mound. In fact, such an estimating task mostly is going on in the process of trials and errors; such iteration as once drawing a circle and lines on the contour map and next eliminating them is going on until a drawn shape can be recognized as a proper one representing the original shape of the mound.

A support system probably helps improve such inefficient estimating task. The support system presented in this paper provides a keyhole shaped template that can be superposed on a contour map. The shape of the template can be controlled using a mouse and keyboard, while it is always keeping the keyhole shape.

Figure 1: *The biggest Keyhole tomb mound built in the Early 5th century; the Mausoleum of the Emperor Nintoku. The mound in the moat is about 500 meters long.*



(a) (b)

(c) (d)

Figure 2: *Examples of contour maps of Keyhole tomb mounds.* (a) *Early 4c.* (b) *Late 4c.* (c) *Middle 5c.* (d) *Early 6c.*

2. System [O05]

Our aim has been placed on developing a system to support pattern recognition for estimating the original shape of a tomb mound from its contour map. The central idea for developing our system is introduction of the keyhole shaped template (See Fig, 3), which comes from a supposition that every original shape of the tomb mound should geometrically be keyhole shaped; i.e. it is formed with a circle and straight lines.

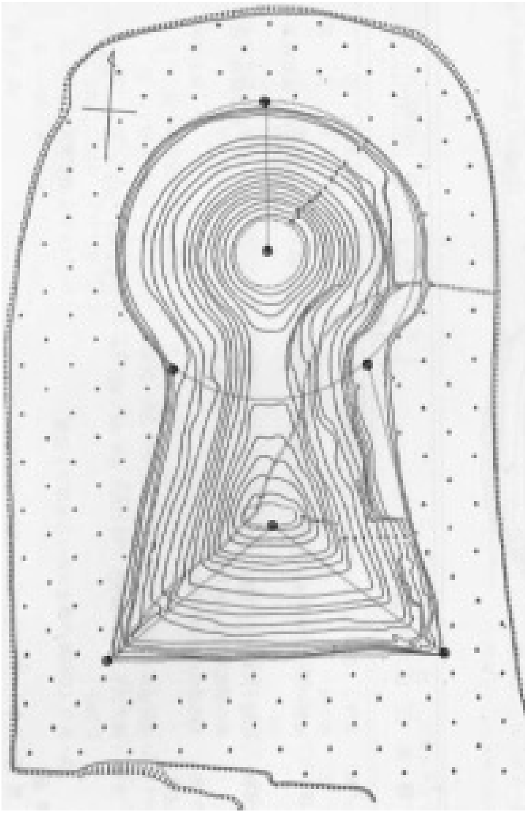


Figure 3: *A green-colored keyhole shaped template superposed on a contour map. Each of red points can be dragged by a mouse for changing the keyhole shape; moving, magnifying or reducing, or rotating the whole shape, or partially changing the shape.*

As far as well-preserved mounds such as Fig.2 (c) are concerned, it is not so difficult to estimate their original shapes. By contrast, we have so many contour maps such as (d), which need much more effort to estimate their original shapes. In such cases, the template has been very helpful for our pattern recognition works. A typical template matching procedure using our system is as follows:

Procedure

(1) Display a contour map taken by a scanner.
(2) Input the scale information written in the map.
(3) Superpose the template.
(4) Control the template using a mouse and keyboard, seeking good fit to the whole of contour lines. Fix the template when it is recognized to be best for description of the original shape of the mound.
(5) Store the estimated values of the *four dimensions* and the displaying image.

Where (2) is needed for conversion of a pixel size on the display into its corresponding real size in the area including the tomb mound: From this, it can be computed how long each dimension of the mound is. The four dimensions referred in (5) mean the length of the mound *a*, diameter of the round part *b*, width of the neck *c*, and width of the square part *d* as shown in Fig.4. Our system provides real values for {*a*, *b*, *c*, *d*} and also the three ratios {*a*/*b*, *c*/*b*, *d*/*b*} based on the finally fixed template.

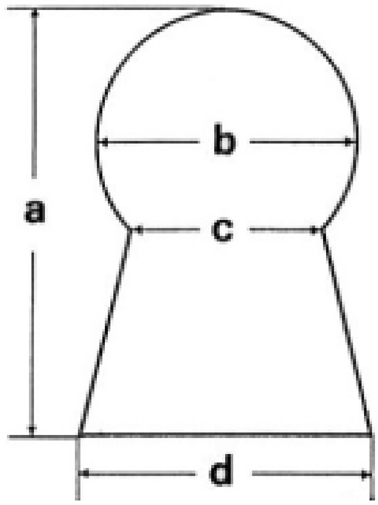


Figure 4: *The four dimensions*

3. Similarity relation [O00]

The Keyhole tomb mounds have so far been classified into several types in different ways[U96]. A well-known approach to classification has been based on similarities between shapes of the mounds. An archaeological supposition is that if plans of two tomb mounds are similar, they might be built in the same age and buried persons might also politically be intimate. Our system would be useful for such shape-oriented classification problem: The three ratios {*a*/*b*, *c*/*b*, *d*/*b*} form a metric space where we can analyze similarity relation between the tomb mounds. In fact, some interesting results have been obtained from our analysis in the metric space:

Fig.5 shows distribution of 28 tomb mounds in the metric space. Where the figure presents projection of their three dimensional distribution in the space into two planes; i.e. (*c*/*b*, *d*/*b*) and (*c*/*b*, *a*/*b*) planes. It should be noted that distribution of the mounds in the first plane clearly shows a temporal sequence of the tomb mounds from the Early to the Late Ancient Tomb Period. Where the Middle and Late tombs situate in the two striped zones, respectively.

4. Computer graphic restoration

A number of the Keyhole tomb mounds were destroyed due to rapid urbanization during the latest hundred years. Among them, there existed some fortunate mounds that were archaeologically surveyed prior to their destruction, of which contour maps and related knowledge were published. In this case, we can estimate the original shape of a mound using our system as well as existing Keyhole tomb mounds.

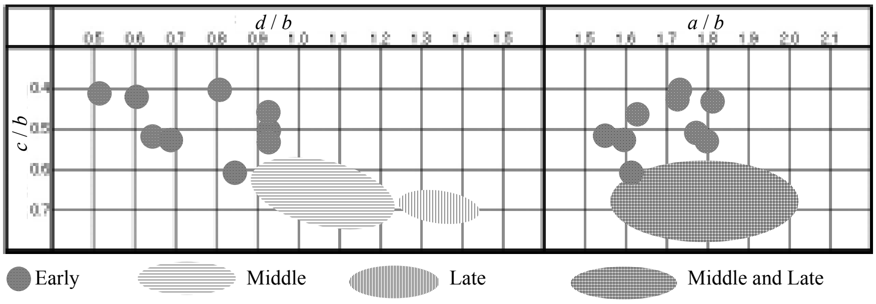


Figure 5: *Distribution of the tomb mounds in the metric space.*

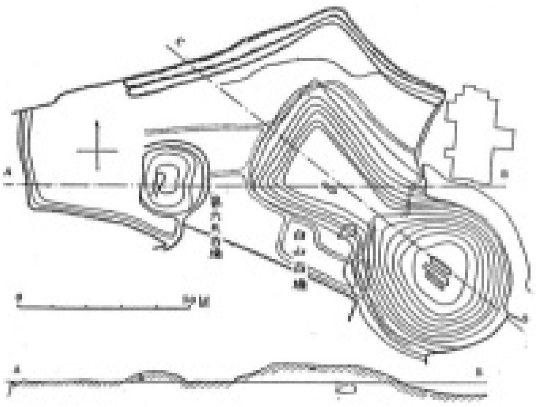


Figure 6: *Contour map of Hakusan tomb*.

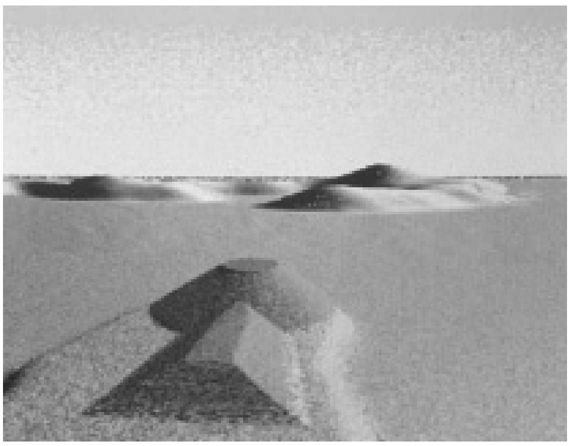


Figure 7: *Computer graphic image of Hakusan tomb*

Fig.6 shows the contour map of a destroyed and vanished big Keyhole tomb mound, named *Hakusan tomb*, located in Kanagawa Prefecture near Tokyo, which has archaeologically been dated to be in the Early Ancient Tomb Period (around early 4th century). It was destroyed in 1940s for construction of a building. Using the system, we obtain the three ratios of Hakusan tomb; i.e. a/b = 1.81, c/b = 0.49 and d/b = 0.81. This shows that the tomb situates within a zone where the nine early tombs distribute in the metric space (See Fig.5).

Fig.7 shows a computer graphic restoration of Hakusan tomb. To generate this image, we employed the estimated original shape as the floor plan of the mound. In addition, we also employed much archaeological knowledge for modeling its three dimensional shape; i.e. description of findings in the survey report, empirical or statistical knowledge about existing Keyhole tomb mounds and terrain data around the tomb.

5. Conclusion

This paper describes a view of our support system for estimating the original shape of a Keyhole tomb mound. As previously described, our system helps *excavate* the original shape of a mound buried in contour lines. This paper also mentions two applications based on the estimated four dimensions of the tomb mound: First, similarity relation between shapes of the mounds is discussed in terms of the metric space formed by the three ratios. Next, an example of computer graphic restoration of a destroyed tomb mound is presented. Since we have treated a small number of the tomb mounds using the system, then our future task will be concerned with analyses on the other many Keyhole tomb mounds all over the country.

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Short Papers

Combining GIS and 3D Graphics to form a tool to empower digital visualizations on Cultural Heritage

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Abstract

The main aim of this paper is to provide a methodology for the integration of Geographical Information Systems (GIS) and 3D Graphic Software (3DGS) in order to form a useful tool for the construction of 3D Landscape models. More specifically the combination of spatial information that can be recovered in great detail for landscape from GIS and its adaptation to 3DGS has the objective of the construction of 3D Landscape models. These models can reproduce in a very precise and detailed manner the topography of the landscape. Using digital geographical data via GIS, three Digital Elevation Models (DEMs) have been created which after necessary adaptations have been transferred into 3DGS. We will study the recovery of geographical data and the construction of 3D landscapes of small, medium and large scales. The processes and methodology of integrating the two technologies will be presented and analyzed reaching conclusions for sizes, formats but also the level of detail of the used files which aims at the optimization of the final result. Emphasis is given to their suitability according to the objective of their visualization but also the sources, demands and limitations that apply in each case. Finally, comments are made on the abilities that researchers obtain from the use of this integrated methodology for the documentation and description of sites of archaeological interest.

Categories and Subject Descriptors (according to ACM CCS): I.6.5 [Model Development]: Modeling methodologies

1. Introduction

The term digital representations of landscapes as used in this paper, is reported in the best and most precise representation of earth surface via DEMs. These models are "mathematically determined, 3D visual representation structures of ground surface, elements and phenomena of nature and society" [Ban01].

Subject in this work is the use of data that emanate from Geographical Information Systems (GIS) and its adaptation in 3D Graphic Software (3DGS), aiming at the most reliable study and digital representation of landscapes and areas with archaeological importance.

This paper treats the creation of DEM of landscapes with archaeological importance. More precisely computers and suitable software are used for the research and the organisation of geographic and spatial information, aiming to attribute to a 3D model and to be presented as picture or a concatenation of pictures developing into an animation. Below all the aspects of manufactured DEM will be given using the more modern cartographic procedures and will stressing their appropriateness depending on the aim that will serve their visualisation but also the resources that are required and the restrictions that are placed in every case.

2. Study Areas

It becomes explicit through the definitions of UNESCO that the surface of earth it constitutes a very important piece of cultural heritage when it does have on it or under it archaeological interest [BSS*001]. We observe therefore the direct relation of cultural heritage with the archaeological landscapes as well as the cross-correlation of each archaeological research with the space that these occupy. Thus the study areas have each their own individual importance as this derives from the role in the history that each one of them presents.

The choice of the most appropriate study areas was based on two criteria:

1. To constitute important cultural "monument" according to the definition of UNESCO (Roe00) and simultaneously

2. The availability of digital cartographic data.

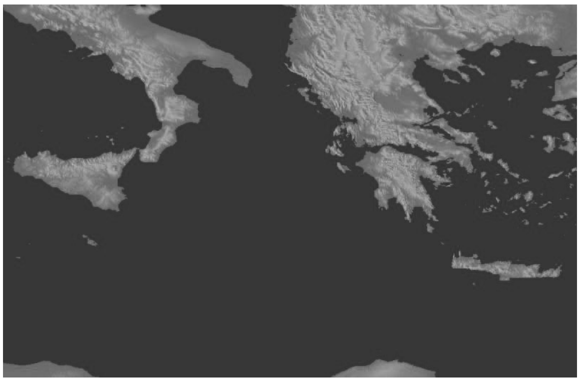

Figure 1: *Study Areas.*

Based on the above criteria the following three geographical areas were selected (see Figure 1):

1. The regions which crossed the Athenians at the Sicily expedition witch covers

a. South East Mediterranean sea and

b. The island of Sicily.

2. As well as the region of Petrified Forest of Sigri located in Lesvos island.

3. Data and Methodology

The challenge that is faced by the present work is the finding of the most optimal way for the unification of two technologies for GIS and 3DGS in order to serve the culture with 3D landscape representations.

An effort was made in order to find a common axis in which the two categories of programs would collaborate with the most efficient manner. Thus our methodological approach was separated in two stages. The first one has as aim the unification of commercial parcels of GIS with the 3DGS while the second one has as aim the exploitation of the capabilities offered by open source software for the management of geographic information.

3.1. Available data

The three areas selected for the implementation of the methodology and were separated into three scales small, medium and large.

After the search and selection of the cartographic datasets that would attribute with the required precision for each of the three study areas the following are available and selected:

For the area of Southern Greece and southern Italy and also for the island of Sicily:

- Contour lines (primary contour interval was 1,000 feet (305 meters), and supplemental contours at an interval of 250 feet (76 meters) are shown in areas below 1,000 feet in elevation) from ESRIs DCW (Digital Chart of the World) and

- Gtopo30 DEM (USGS Global 30 Arc Second Elevation Data Set)

- Raster with pixel analysis 100 x 100 m from the Cartography laboratory, Department of Geography of the University Aegean.

For the area of the Petrified Forest in Sigri of Mytilini:

- Contour lines (4 meters) witch created from digitation of map with scale 1:5000.

3.2. Methodology

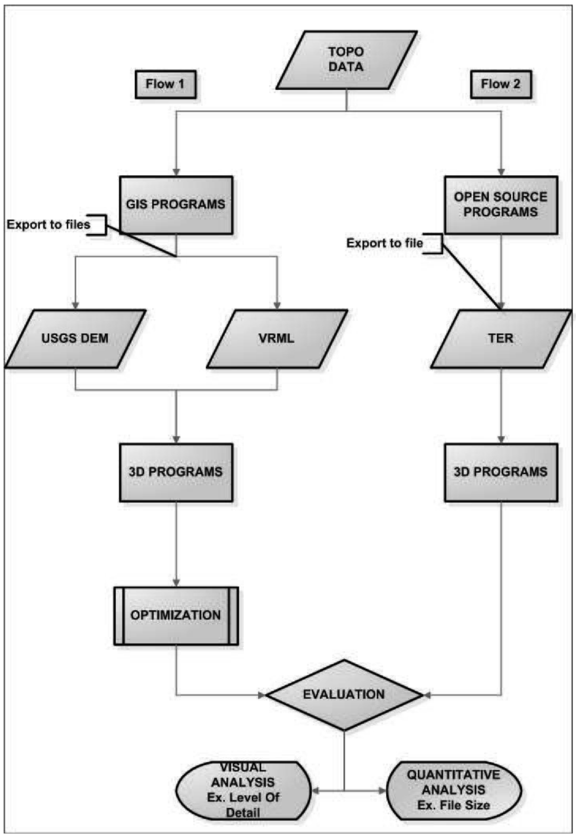

Figure 2: *Methodology Flow.*

The creation of DEM existed having as basic condition that these would have to have suitable format aiming at their import in the 3DGS, knowing that we would use the following software:

- 3d Studio MAX (Discreet)

- Cinema 4D (MAXON)

Much effort was given to find the common axis in which the two categories of 3DGS and GIS would collaborate more easily. Thus the main restriction witch was the compatibility of files between the software's became the initial object of study for the convergence of the two technologies.

Thus our methodological approach was separated in two key routes.

Stage-1: It had as aim the unification of commercial parcels of GIS with the 3DGPS see in Figure-2 Flow-1).

Stage-2: The unification open source software for the management of geographic-spatial information with the 3DGS (see Figure-2, Flow-2)

3.3. Methodology (Stage-1)

In the first case the methodology had as aim the use of GIS and more specifically the commercial parcel of ESRI ArcGis 8.1 that has to create the possibility with the help of extensions using data of spatial information for 3D-representations of landscapes.

After study of file formats with which ArcGis 8.1 attributed the geographic-spatial data in form of files that were recognized by the 3DGS we led to conclusion "That only the files with extensions wrl and dem (USGS) are what can constitute common base and for the two computations". Therefore our efforts had as aim the final file where the result from ArcGis 8.1 should have extensions dem or wrl.

The DEM files as these are produced by GIS in both ways (wrl and USGS dem) contain the spatial information which describes the landscape, but the number of polygons that constitute them was extremely necessary and essential to give the desirable scale form of surface for the study areas. The results of representation in the areas of southern Greece and southern Italy and also for the island of Sicily were not the appropriate (Figure 3)

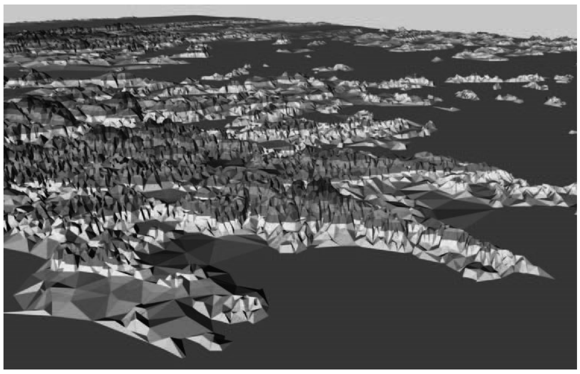

Figure 3: *DEM file produced from GIS.*

Thus we tried to optimize the 3D models in order to take the desirable level of detail in the 3D representations.

In the theory of 3D graphics there are a number of procedures for changing the topology of a model in order to create smother surfaces. These are Optimization, Subdivision, Triangulation and Untriangulation. But there is a question of "Which one is the most appropriate?"

For each study the desirable result differs so there is a need of making different combinations in each case. In our study at first combination of "Subdivision" and "Triangulation" was made to take the desirable level of detail in the 3D models. Final the procedure of "Optimization" was made in order to create the better possible representation and to avoid the creation of non smooth surfaces.

3.4. Methodology (Stage-2)

In the second case the followed methodology had as an aim the use of open source software for the management of geographic-spatial on creation of DEM and their import in the 3DGS.

Therefore by study of available programs and placing as a restriction the solution and confrontation of common spatial data, but also his direct collaboration with the 3DGS. From all these open source programs "Terragen" was selected. This program has the possibility of combining spatial data in order to create high precision DEMs which have the appropriate format to import them directly in 3DGS.

The choice and the use of "Terragen" were also combined and with the use of three plugins as well as for the Cinema4D and 3D-Max. It should be reported that all this are open source programs and are free of charge on the internet.

It should be explicit that with the combined use of these programs we achieve with a big precision the creation of 3D landscape representations of the surface of the earth.

3.5. Evaluation

After the end of each methodology and having manufactures DEM under each study of regions took place evaluation of the results. Their import in the 3DGS had restrictions that they had as main axes:

- The optimisation of DEM (Levels of detail of representation)

- The "economy" in the manufacture of models (Number of polygons in connection with size of files)

- The use and the forms of representation.

The evaluation took place taking into consideration quantitative and by qualitative characteristics produced DEM.

Thus they would have to fill the specifications that had been placed by

- Having the right geographic scale.

- Find itself in the desirable suitable level of detail.

- Have the right relation of detail and size for files.

4. Results and discussion

In the previous sections were given the methodology of creation of DEM from the GIS and the storage of their information in forms of data that are direct recognisable from the 3DGS. Knowing the format the files that are common between the two categories of programs and through the prism of two different approaches should the process be evaluated according to the restrictions had been placed.

4.1. Stage-1

The DEM files as these are produced by GIS contain the geographic information, but the number of polygons that constitute is extremely necessary and essential so that they give the most desirable scale form of surface for the study areas. The result can be desirable in order to cover the needs of representation in the GIS, while in the 3DGS usually corresponds in one simply acceptable DEM (Figure 4).

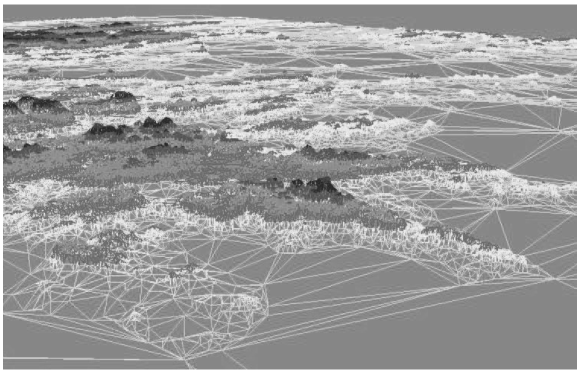

Figure 4: *Part of Greece without optimization.*

As way should be found therefore to increased the number of polygons of DEM in order for the morphology of surfaces that represent to attributed with smoother fluctuations. According to theory of 3D graphics in which the functionality of 3DGS is based on, exist a lot of techniques to optimise the DEM by changing their topology. With their use is possible the increase the number of polygons in a 3D model but also the elaboration of his structure. These have as result the DEM and every 3D model to acquiring the desirable for each case level of detail.

DEM of Mediterranean	Before optimize	After optimize	percent
No of Polygons	517.073	1.035.933	200,3
No of Points	1.646.082	11.224.127	681,87
File size	27.373 kb	293.401 kb	1.071,9
DEM Sicily	Before optimize	After optimize	percent
No of Polygons	220.492	3.012.683	1.366
No of Points	692.050	3.144.617	454
File size	11.559 kb	83.928 kb	726

Table 1: *Comparison of DEM polygons, points and file size, before and afterward the optimization*

Combination of the above processes was followed for all DEMs that were made from the GIS while at their modification and their trials of presentation, the initial results were not expected.

It should be reported that at the optimisation of DEM aiming at the better possible approach the study areas was observed a dramatic increase in storage space but also in the time that they needed for their data processing. This was owed in the information size that they had the DEMs because had been increased dramatically the number of polygons that they are constituted (Figure 5).

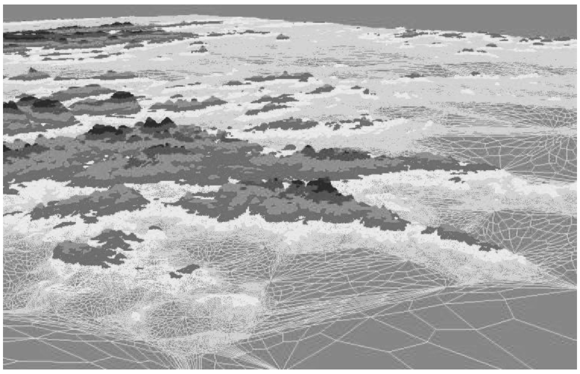

Figure 5: *Part of Greece with optimization.*

Characteristically are the results and the comparison of DEM polygons, points and file size, of South East Mediterranean sea and Sicily before and afterward the process (Table-1).

4.2. Stage-2

With the second approach that had as a base the use of Terragen and his plugins, exceeded all the above obstacles. This became feasible initially from the make that problems of incompatibility did not exist in the produced files. Finally easy and with no problems, import of files in 3D programs had as

File format VRML	file size
South Greece Italy	95.955 kb
Sicily	35.586 kb
Sigri-Petrified forest	6.280 kb
File formatUSGS DEM	file size
South Greece Italy	22.612 kb
Sicily	860 kb
Sigri-Petrified forest	498 kb
File format TER	file size
South Greece Italy	8.201 kb
Sicily	515 kb
Sigri-Petrified forest	130 kb

Table 2: *Comparison of files size*

a result the most efficient visualisation of spatial information according to the restrictions that had been placed.

In this particular methodology the total files size in each scale of representation was very small. Thus has as a result very easy treatment and configuration of DEM files.

Characteristically are the results and the comparison of DEM polygons, points and file size, of South East Mediterranean sea and Sicily before and afterward the process (Table-1).

Evaluation it quantitatively became with base and Qualitative characteristics it showed that the use of second methodology had results filled the initial restrictions.

5. Conclusions

This paper is presenting the process of unification GIS and 3DGS for the most faithful representation of landscapes with cultural content. The aim of this work is to indicate the common way with which these two technologies can blend with the best possible way to constitute a useful representational methodology of archaeological landscapes.

In most cases making 3D representations requires different kinds of visualisation to aim a more realistic effect. As a result this has the need of different levels of detail and the exact determination of them.

The initial step in both of the methodological approaches constituted the finding of suitable spatial data for the regions of study. It should be reported that their choice became with the criterion of requirements and restrictions that emanated from the size of area that they will represent. In this way we accomplish the study of three different cases of areas with different scales (small, medium and big). With this choice it was covered completely the level of detail which is possible to be recovered from the GIS using by all of their precision.

The first methodological approach (Step-1) with the storage of geographic information from the GIS in VRML and USGS.DEM file formats and their direct import in 3D programs, presented important disadvantages in visual representations and more specific in level of details.

Disadvantage of the use of VRML file format was the creation of big file sizes for small levels of detail. This as a result has an optimisation to approach the correct level of detail. The optimisation caused a dramatic increase of elements that describes the topology of DEM. Also we figured an increase in the file size that the topology is stored, without the final result approaches the levels of detail that had been placed for each scale. Respectively the use of USGS.DEM data had important disadvantages contrary to the small size that they had. This data at their import in 3D programs did not keep the geographic information of ground elevation. This as a result is the DEMs that was produced by this file and is presented in a deformed manner. Thus they constituted a non preferable methodology of unification of both technologies.

Through the effort of unification of GIS and 3DGS we discovered problems and difficulties in the first methodological approach. The problems we encountered had a relation with:

1. The file sizes of DEM (were very big).

2. The required limits of detail for realistic visualisations (were poor).

The second methodological approach according to which it became the use of Terragen software and some freeware Terragen plugins attributed the desirable results for each level of detail. We had very precise DEM with important smaller file sizes (Figure 6).

Figure 6: *Photorealistic representation of Sigri's Petrified Forest.*

Comparatively with the first methodology it constituted easier (easy in use programs), cheaper (use of freeware programs) and also "economically" (creation of small file size files). We conclude therefore that it is possible to integrate

GIS and 3DGS technologies in order to create a new category of archaeological landscape visualisations. Visualisations based on precise spatial and geographic data.

6. Future Directions

The study of integrated computational simulations platform for archaeological landscapes, which belongs in the area of Geoinformation applications that is connected with the documentation, management, protection and promotion of archaeological landscapes. This constitutes the next step of integration of these two technologies. 3DGIS will constitute one of the basic tools in this sector of applications which compared to other techniques as the topographic research, offer most advantages for the determination, comprehension, interpretation and presentation of archaeological landscapes. The advantages for the use of 3dGIS are:

- Simultaneous acquisition and production of quantitative and thematic elements

- Exceptionally precise 3D data

- Possibility of producing a precise 3Dmodel of an archaeological landscape.

Developing a thematic cartography that would combine the scientific results of archaeology, with a 3Dgraphic representation adapted in spatial analysis,perhaps confirms that the 3D representations using spatial data becomes an inevitable tool for the archaeologists. A tool to produce new information and conclusions in the research of Cultural Heritage.

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Short Papers

Function-based Shape Modeling for Cultural Heritage Applications

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Abstract

We present a function-based shape modeling paradigm for cultural heritage applications, briefly survey several related modeling problems and their original solutions: bounded blending and controlled metamorphosis, modeling of two-dimensional cells in the form of trimmed implicit surfaces; and describe corresponding cultural heritage case studies.

1. Introduction

Current practice in shape modeling for cultural heritage applications is to use polygonal meshes and other boundary representations for the purposes of interactive visualization. There are other applications for the shape models in the area of cultural heritage: long term archiving of models, recreation of lost or damaged cultural heritage objects, reproduction of existing objects, and interactive inspection of models with arbitrary level of detail. These emerging applications require creating shape models of more high abstraction level than polygonal meshes and other boundary models. Such a model should provide high accuracy of description of not only external appearance but also of internal structure of the real object, including volumetric distribution of its material and other physical properties. Recently several alternative shape models have been applied in the area of cultural heritage: voxels [N97], implicit surfaces (radial-basis functions) [SFS*02], constructive models [VPP*04], and procedural models [HF04].

One of relatively new constructive shape models of higher abstraction level is the function representation (FRep) [PAS*95]. It is a generalization of traditional implicit surfaces, constrictive solid geometry (CSG), voxel, sweeping, and other shape models. This representation supports a wide class of primitive objects and operations on them. The generality of this model comes from the main principle postulating that the modeled object at every step of the modeling process is described in a uniform manner by a single procedurally defined real continuous function of point coordinates.

In this paper, we present our research and development results in the FRep based shape modeling for cultural heritage preservation. We analyze some of open modeling problems related to shape modeling of cultural heritage objects: bounded blending and controlled metamorphosis, and propose original solutions to the formulated problems. From the heterogeneous (mixed dimensional) modeling point of view, we choose implicit complexes [AKK*02] as the basic model and concentrate on modeling of two-dimensional cells in the form of trimmed implicit surfaces. We implement the proposed solutions and illustrate them by several cultural heritage related case studies such as the Virtual Shikki project on modeling and Web presentation of Japanese lacquer ware craft, the Dancing Buddhas project, and 3D modeling of the Escher's drawings.

2. Shape modeling for cultural heritage

The digital preservation of cultural heritage has recently attracted considerable attention in computer graphics, geometric modeling, and virtual reality communities. The *digital preservation* includes the capture and archiving of the form and contents of the existing cultural heritage objects through the use of computer modeling techniques, the reproduction of those objects that have already been lost, and usage of introduced models for active experience in the form of Web sites, multimedia presentations, games, and virtual environments.

One of the important characteristics of the object in digital preservation is its shape, especially for three-dimensional physical artifacts such as pottery, sculpture, and architecture. As it was mentioned in [VPP*04], loss of information is one of the biggest problems of shape modeling in cultural heritage because of using non-standardized (often proprietary) and frequently changing formats for archiving of data and models. Other problems are difficulties of data exchange between different systems and across platforms, lack of understanding of modeling processes and data structures by users, and therefore limited possibilities to verify the application's operations independently.

Current shape modeling systems and cultural heritage preservation systems are traditionally based on polygonal meshes and other boundary representation (BRep) models. These models have such disadvantages as lack of construction history and of the constructive object structure, accumulation of numerical errors resulting in surface cracks, and high complexity of processing algorithms, allow only for simple time dependences and limited parameterization with fixed topology. Traditionally for digital preservation, models of external surfaces and textures of objects are obtained using different 3D scanning and mesh reconstruction techniques [BR02]. Constructive geometric modeling procedures and the fundamental mathematical base for 3D shape modeling, volume rendering, and multidimensional modeling are not well known in the digital preservation community.

From our point of view, internal structures (revealing the logic of construction and material distribution) of objects, as well as their time, and other parametric dependencies also can be added to the consideration. On this basis, we choose the function representation as the most powerful constructive geometric model (see the next section), discuss and illustrate the development of a new paradigm for cultural heritage preservation that includes constructive modeling reflecting the logical structure of objects and cellular modeling of dimensionally heterogeneous objects.

3. Function representation and its extensions

The function representation was introduced in [PAS*95] as a generalization of traditional implicit surfaces, CSG, sweeping, and other shape models. In FRep, a 3D object is represented by a continuous function of point coordinates as $F(x,y,z) \geq 0$. A point belongs to the object if the function is non-negative at the point. The function is zero on the entire surface (called usually an *implicit surface*) of the object and is negative at any point outside the object. The function can be easily parameterized to support modeling of a parametric family of objects. In a FRep system, an object is represented by a tree data structure reflecting the logical structure of the object construction, where leaves are arbitrary "black box" primitives and nodes are arbitrary operations. Function evaluation procedures traverse the tree and evaluate the function value at any given point.

The following types of geometric objects can be used as primitives (leaves of the construction tree): algebraic surfaces and skeleton-based implicit surfaces, convolution surfaces, objects reconstructed from surface points and contours, polygonal shapes converted to real functions, procedural objects (such as solid noise), volumetric (voxel) and other objects. Many modeling operations have been formulated, which are closed on the representation, i.e., generate another continuous function defining the transformed object as a result. These modeling operations include: set-theoretic operations based on R-functions, blending set-theoretic operations, offsetting, sweeping by a contour and by a moving solid, projection to a lower dimensional space, non-linear deformations and metamorphosis, and others [PPS*95, PA04].

A new operation can be included in the modeling system without changing its integrity by providing a corresponding function evaluation or space mapping procedure. In FRep, there is no principal difference in processing skeleton-based objects, CSG solids, or volumetric objects (with an appropriate samples interpolation). FRep also naturally supports 4D (space-time) and multidimensional modeling using functions of several variables. The main idea of visualization is to provide a mapping of such objects to a multimedia space with such coordinates as 2D/3D world space coordinates, time, color, textures and other photometric coordinates, and sounds.

The HyperFun language [ACF*99] is a minimalist programming language supporting all notions of FRep. HyperFun was also designed to serve as a lightweight protocol for exchanging FRep models among people, software systems, and networked computers.

In many application areas, it is quite useful to construct a heterogeneous object model. Heterogeneous objects have internal structures with non-uniform distribution of material and other attributes of an arbitrary nature (photometric, physical, statistical, etc.) along with elements of different dimensions (k-dimensional point sets in n-dimensional space with $k \leq n$). Such objects can be represented as *constructive hypervolumes* [PAS*01] and *implicit complexes* [AKK*02].

4. Shape modeling problems and case studies

The applications of the function representation and its extensions in digital preservation of cultural heritage formulate the following new requirements:

- intuitive and interactive user’s control over the modeled shape;
- precise predictability of the result of modeling operations;
- generality of modeling methods independent of specific restrictions and preprocessing steps;
- support of dimensionally heterogeneous and multi-material models;
- models formulation allowing for further conversion into other auxiliary models suitable for different applications.

The following subsections present several related modeling problems and proposed original solutions, and illustrate them by corresponding case studies.

4.1. Bounded blending and Virtual Shikki

The localization of blending is an example of the operation satisfying the above requirements of intuitive and precise control over the modeled shape. Blending operations generate smooth transitions between two or several surfaces. These operations are usually smooth versions of set-theoretic operations on solids (intersection, union, and difference), which approximate exact results of these operations by rounding sharp edges and vertices. The major requirements to blending operations are tangency of the blend surface with the initial surfaces, automatic clipping of unwanted parts of the blending surface, C^1 continuity of the blending function everywhere in the domain, support of added and subtracted material blends, support of blend on blend, and blending of a single selected edge. Special attention is paid to the intuitive control of the blend shape and position.

To satisfy most of the above requirements for FRep solids, we introduced original bounded blending operations defined using R-functions and displacement functions with the localized area of influence: bounding by control points and bounding by an additional solid [PPK05]. The shape and location of the blend is defined by an additional bounding solid thus making the ternary blending operation (having three solids as arguments). It is provided that the blending surface

exists only inside the bounding solid, and only initial surfaces exist outside the bounding solid. The proposed bounded blending operations can replace pure set-theoretic operations in the construction of a FRep solid with replacing binary nodes by ternary ones and with additional sub-trees for bounding solids. The bounded blending operations were actively used for modeling traditional Japanese lacquer ware items in the Virtual Shikki project (see Fig. 2). We provide in Fig. 1 an example of the sake pot construction from the Virtual Shikki project. More examples can be seen at our Virtual Shikki project Web site:
http://cis.k.hosei.ac.jp/~F-rep/App/shi/Shikki.html

Initially, the model is constructed using set-theoretic operations with two unwanted sharp edges in the area of the spout and at the top of the pot body. For the spout, a cylindrical bounding solid is used for the blending union operation. At the top of the body, a cylinder with a hole is used for bounding the blending intersection operation.

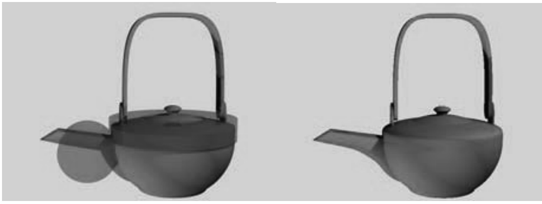


Figure 1: *Two bounded blending operations are applied in the construction of a Japanese sake pot: union of the spout elements and intersection for the top part of the pot body.*

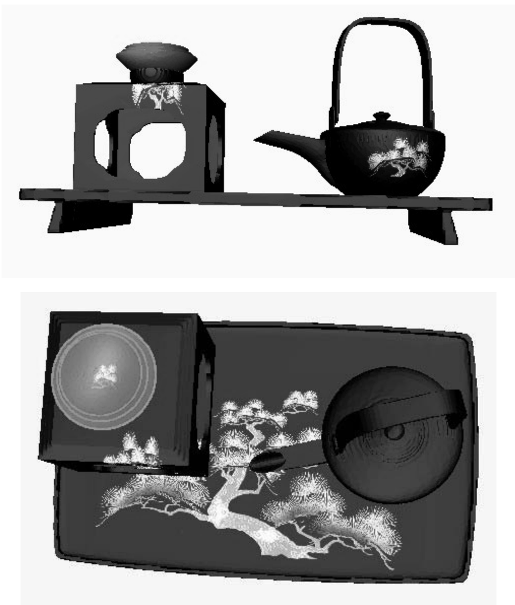


Figure 2: *Front and top views of a Virtual Shikki object VRML model.*

4.2. Space-time blending and Dancing Buddhas

The bounding blending operation is also applied to formulate an original approach to shape metamorphosis through the dimension increase and objects blending in space-time, which allows us to eliminate most of existing constrains in shape transformations. The time-dependent shape transformation between given objects (metamorphosis) is one of typical space-time modeling operations. In general, the initial and final shapes for metamorphosis can be topologically different. The existing approaches to metamorphosis are based on one or several of the following assumptions: equivalent topology (mainly topological disks or balls are considered), polygonal shape representation, shape alignment (shapes have common coordinate origin and significantly overlap), possibility of shape matching (establishing of shape vertex-vertex, control points or other features correspondence), the resulting transformation should be close to the motion of an articulated figure.

Linear interpolation between functionally defined shapes has proven to solve some of the above problems for computer animation and artistic applications. The problem which remains open is a transformation between non-overlapping shapes, which combines metamorphosis and non-linear motion. We have developed a new approach to shape metamorphosis using blending operations in space-time. The key steps of the metamorphosis algorithm are: dimension increase by converting two input k-D shapes into half-cylinders in (k+1)-D space-time, applying bounded blending union to the half-cylinders, and making cross-sections for getting intermediate shapes [PPK04].

The bounded space-time blending procedure for 2D shapes consists of the following steps:

- two initial 2D shapes are given on a 2D plane;
- each shape is considered as a 2D cross-section of a half-cylinder (a semi-infinite cylinder bounded by a plane from one side along the time axis) defined in 3D space-time;
- two half-cylinders are placed at some distance along time axis to provide a time interval for making the blend;
- the bounded blending union operation with added material is applied to the 3D half-cylinders with two planar half-spaces orthogonal to the time axis forming a bounding 3D object (a slab between two planes);
- consecutive cross-sections of the blend along the time axis are combined into a 2D animation.

In the case of 3D objects, each shape is considered as a 3D cross-section of a half-cylinder defined in 4D space-time.

The proposed space-time blending was used in the case study of 2D metamorphosis in the Dancing Buddhas project. The idea of this case study came from a concept that each Chinese character (*kanji*) of the text of the Lotus sutra is in fact a Buddha, which can be illustrated by 2D transformation of a Buddha shape into a Chinese character. Two polygonal shapes were obtained from the images: the Buddha shape (see

the image in Fig. 3) consists of the main concave polygon (49 segments) and two simple polygonal holes, the Chinese character (see the image in Fig. 3) consists of two disjoint components, one of which is a simple concave polygon (left part of the character) and another (right part of the character) is a concave polygonal shape (12 segments) with five holes. We applied the proposed algorithm using bounded blending in 3D space and obtained an animation, where all topological changes are handled automatically. Several frames of the animation are shown in Fig. 4 and the full animation is available at
http://cis.k.hosei.ac.jp/~F-rep/STBB/FSTBB.html

Figure 3: *Initial Buddha shape and a Chinese character.*

4.3. Trimmed implicit surfaces and Escher's rinds

We mentioned in section 3 the problem of modeling objects of mixed dimensions and the approach based on combination of cellular and functional representations. The geometric domain of FRep in 3D space includes 3D solids with so-called "non-manifold" boundaries and lower dimensional entities (surfaces, curves, points) defined by zero value of the function. For example, an implicit surface patch can be defined as an implicit surface trimmed by an intersecting solid. A specific problem of modeling two-dimensional cells as trimmed implicit surfaces was considered in [PP04]. Some applications such as visualization or physical simulation based on finite-element meshes require the conversion of an implicit complex to the pure cellular representation. Such a conversion of a trimmed implicit surface to a polygonal mesh was a subject of our research.

This work was also inspired by art works of M. C. Escher namely "Sphere Spirals" (1958), "Bond of Union" (1956), and "Rind" (1955), showing spiral shaped surface sheets cut of a sphere and human head surfaces. The proposed approach is to represent the trimmed surface by a kind of constructive tree, where the initial surface and the trimming solid are represented separately as two primitives defined by equations or as two FRep sub-trees – arguments of the set-theoretic operation.

The initial surface can be polygonized using one of conventional algorithms and the resulting mesh can be trimmed using vertices classification against the trimming solid. The polygon subdivision (mesh adaptation) has to be applied near the surface-surface intersection curves to remove trimmed parts of the initial implicit surface and to more precisely approximate the trimmed surface boundary.

Fig. 5 presents two experiments with the implemented implicit surface trimming algorithm related to modeling some art works of M.C. Escher. The initial implicit surface for the "Rind" model was constructed using set operations with R-functions on algebraic primitives, soft objects, and convolution solids. Note that Escher's works are 2-dimensional drawings of 3D objects. Modeling and rendering them directly in 3D as we did in the above examples can be considered as a step to live heritage applications such as multimedia, virtual reality, or gaming interfaces to artistic and historical cultural environments.

5. Discussion and conclusion

In this section, we discuss advantages and known problems of the function representation in cultural heritage applications, its conversions and combinations with existing shape models, and different levels of utilization of FRep models in virtual environments.

5.1. Advantages and problems of FRep in cultural heritage

Let us summarize advantages of using FRep in cultural heritage applications. First of all, it provides a precise mathematical definition of modeled objects. The use of other existing models is supported by conversion of them to and from FRep. Thus, several other types of shape models can be included in FRep as modeling primitives. For the efficiency of visualization and interactive manipulation, FRep models can be converted to BRep or voxel models. The combination of FRep and cellular models provides necessary framework for modeling dimensionally heterogeneous objects.

The combination of geometry and attributes in the constructive hypervolume model [PAS*01] allows for modeling not only the shapes, but material and other object properties. Support of multidimensional and particularly time-dependent models in FRep is useful for the modeling aging objects with the help of finite element analysis. The recovered structure and constructive elements of the object can be employed for rebuilding lost objects and for the implementation of "live heritage" applications such as animation or interactive multimedia.

The clearly defined open text format of FRep models in the HyperFun language obviously increases the survival period of the archived models, especially in comparing with not openly specified proprietary formats.

The major problems of FRep are time consuming function evaluation at each given point, which currently retards interactive applications; capturing sharp and thin object features during rendering; interactive manipulation and editing. Parallel and distributed processing and special hardware can help resolve most of these problems in near future. Another difficulty is that constructive modeling usually requires high levels of 3D modeling skill and is labor-intensive. One of the possibilities of automation is fitting of a parameterized FRep model to a cloud of surface points [VPP*04].

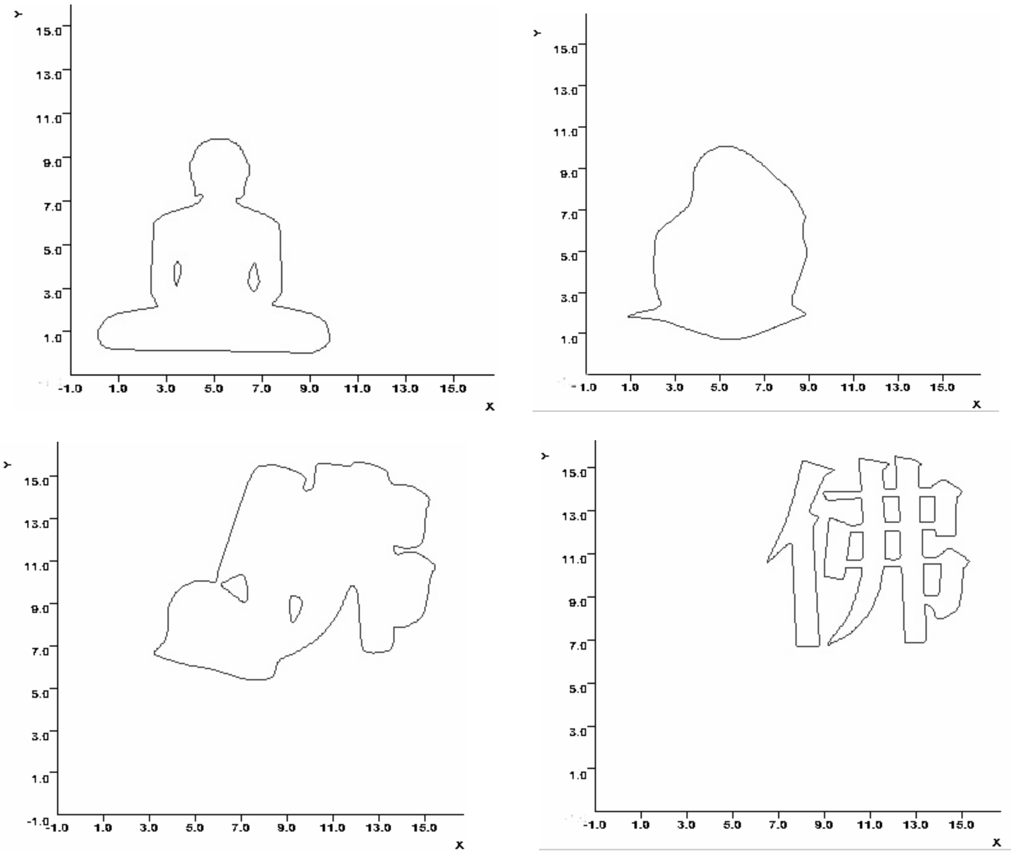
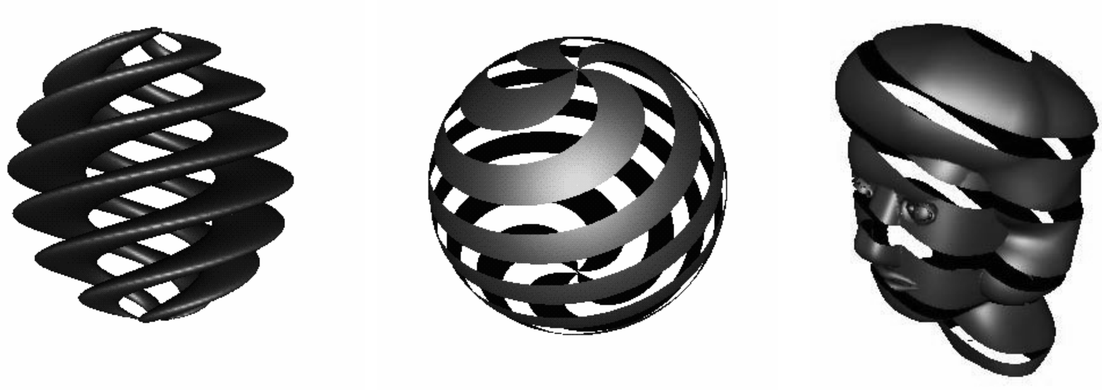


Figure 4: *Frames of the animation: transformation of a Buddha shape into a Chinese character.*



a b c

Figure 5: *Models of "Sphere Spirals" and "Rind" by Escher: (a) trimming solid as a union of three spirals; (b) trimmed sphere surface; (c) trimmed head surface.*

5.2. FRep in virtual cultural environments

There are different levels of utilization of FRep models in virtual environments. The simplest way is to polygonize object surfaces and to export them in one of available Web 3D formats, for example, in the Virtual Reality Modeling Language (VRML). Examples can be seen in our Virtual Shikki project. The next level is embedding of FRep models into existing protocols such as a special VRML node proposed in [MSL02]. In the case of small local object modifications such as carving, embossing, or engraving, a FRep model can be directly updated in the virtual environment and its image can be locally modified by ray-casting or polygonization [S01]. If the overall shape of the object is changing in the interactive process, then a voxel model or another auxiliary model is needed to support the visual feedback. An example of such global shape modification is the group metamorphosis with immersive interactive control in the Augmented Sculpture project [ACK*05].

6. Conclusion

This paper describes an approach to some actual shape modeling issues related to the digital preservation of cultural heritage. On the basis of the survey of existing problems and requirements we have chosen the function representation as the basic mathematical model. From the analysis of the potential application areas we have selected several modeling problems and provided original solutions to localization and control of blending set-theoretic operations, general constraint free shape metamorphosis, modeling and rendering trimmed implicit surfaces.

The proposed methods and algorithms have been applied in several case studies related to cultural heritage. The bounded blending operation was used in modeling traditional Japanese lacquer ware in the Virtual Shikki project, which has resulted in a Web site with 3D models in HyperFun and VRML formats. The proposed space-time blending was used in the presented case studies of 2D metamorphosis in the Dancing Buddhas project, where an animation of Buddha shape transformation to a Chinese character was generated. The application of trimmed implicit surfaces for modeling spiral objects by M. C. Escher was presented. We also discussed different levels of utilization of FRep models in virtual environments.

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Short Papers

Efficient Field Capture of Epigraphy via Photometric Stereo

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Abstract

We describe a highly portable field technique for estimating surface normals, geometry and albedo from walls and other areas of archaeological sites using limited sets of digital photographs. Surface geometry and albedo are extracted from photometric calculations, yielding a complete model with estimated per-vertex colour. This technique is demonstrated to be practical in pre-production for the digital planetarium film Maya Skies.

Categories and Subject Descriptors (according to ACM CCS) I.3.3 [Computer Graphics]: Modeling – Object Scanning /Acquisition, Modeling – Appearance Modeling

1. Introduction

Photometric stereo has been shown to be an effective method for capturing high-resolution geometry and reflectance properties of ancient inscriptions [EHD04]. Classical photometric stereo [WOO80] requires a static camera pose for each photograph acquired in a given image set, while lighting varies. Our technique relaxes the fixed camera constraint required by previous systems in order to decrease the time required to document epigraphic inscriptions in situ. In practice, our technique obviates the need for a camera tripod and multiple light sources during capture, which can simplify field work. We demonstrate that efficient field capture for ~700cm^2 regions can be completed in ~15 seconds, and that subsequent processing can be completed quickly and with minimal user interaction.

2. System overview

Our technique offers a portable and convenient approach to photometric capture. Figure 1 shows the key components of the system. A standard digital still camera and flash unit are rigidly attached using a simple aluminium boom (Figure 1, shown right). This assures that the geometrical relationship between the camera and light source is fixed. The second component is a light gathering frame which contains a fiducial dot pattern and four cones (Figure 1, shown left). During acquisition, the frame is positioned such that the surface under inspection is visible through a central hole in the frame.

The position and orientation of the camera-flash system is varied during capture, yielding several photometric digital images. Camera localization is derived from the observed positions of the five fiducial dot markers in each image, and incident lighting direction is inferred from the shadows cast by the cones on the planar region of the frame. Knowledge of the geometrical relationships between camera, flash and frame allows photometric surface reconstruction under a changing camera viewpoint. The frame also provides image-based light attenuation correction [PCF05]. Typically the surfaces under inspection are well modelled by a Lambertian reflectivity assumption, although other Bidirectional Reflectance Distribution Function (BRDF) models could be applied [NRHGL77, PCF05].

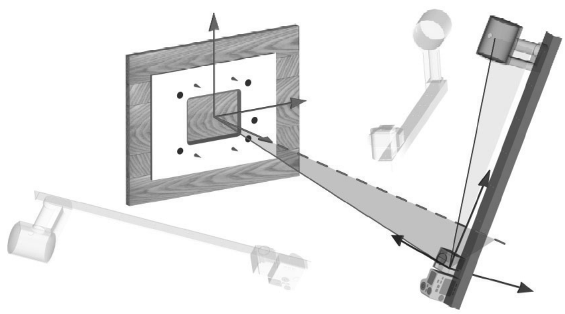


Figure 1: *System equipment. Light gathering frame (left) Camera and flash attached via boom (right).*

3. Geometry and texture estimation

3.1 Image acquisition

Our subject in Figure 2 is a small region of the Venus Platform, a structure in situ at the Maya site Chichén Itzá, located in Yucatan, México. At Chichén Itzá, we acquired image sets for twelve test regions during field work in October 2005. These sample areas were selected to represent texture variations observed throughout Chichén Itzá. The stone surfaces under study all feature a dominant Lambertian component in their BDRF, and therefore prove highly suitable for high quality reconstruction using photometric stereo techniques.

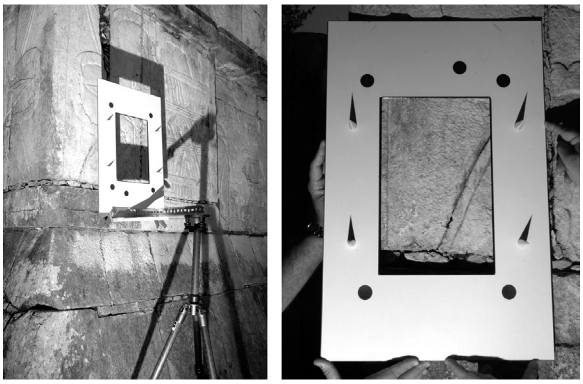


Figure 2: *Fiducial frame in-situ at Chichén Itzá (left). Image data, showing fiducial markers (right).*

3.2 Camera calibration and lens distortion correction

Camera calibration is a prerequisite to accurate optical localization, deriving specified parameters, e.g. focal length and a model of lens distortion. This is a well-explored topic in the literature, with several approaches in regular use. We have tested geometric reconstructions using images processed using 1) the Intel OpenCV library / Bouget camera calibration toolbox and 2) the Rational Function radial distortion model of [CLF05].

In the first case we rely on existing code and compute camera intrinsics using a sequence of checkerboard images (Figure 3). Here, lens distortion is modelled with a low-order radial polynomial along with tangential distortion. The software provides methods for resampling an input image to remove lens distortion.

The second approach instead models lens distortion effects using a rational function approach. Calibration can be achieved using a single image of a scene containing straight lines. Let x,y signify canonical image coordinates, and U the distorted version as a homogeneous vector, then:

$$U = A\left[x^2 xy \;\; y^2 x \;\; y \;\; 1\right]^T \quad \textbf{(Eqn 1)}$$

where A is a 3x6 parameter matrix.

Both techniques yielded acceptable results. Correction for lens distortion proved critical in achieving quality reconstructions due to adverse effects of distortion on camera localization.

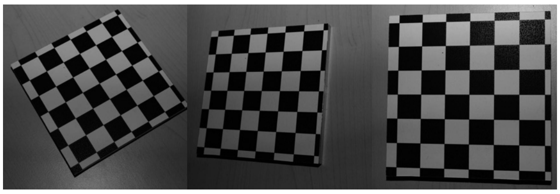
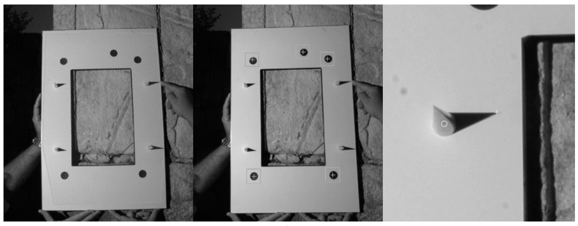


Figure 3: *Images used to compute camera intrinsics.*

3.3 Image processing

Our end-user application "SurfaceImager" encapsulates the complete reconstruction pipeline, incorporating means for user input where necessary. Having loaded the photometric images and calibration parameters, the user performs segmentation, defining the target area (Figure 4a). The fiducial markers on the frame are automatically identified and the camera pose estimated (Figure 4b). Finally, the effective position of the flash bulb is determined by searching for the shadows cast by the cones (Figure 4c), a task achieved in a manner akin to tracing the shadow of the gnomon on a traditional sundial. As the flash is fixed relative to the camera, information can be combined across multiple images in a global optimization.



(a) (b) (c)

Figure 4: **(a)** *Interactive image segmentation.* **(b)** *Automatic fiducial detection.* **(c)** *Shadow tip localization.*

4. Results - Geometry and texture estimation

Photometric stereo estimates geometry as a set of surface normals, along with parameters specifying a model of surface reflectivity. This is done by inverting the model given a number of samples of surface intensity with known incident lighting direction. With a Lambertian surface model the camera observed surface intensity I is defined as:

$$I = \rho \vec{N} \cdot \vec{L} \quad \textbf{(Eqn 2)}$$

Where ρ indicates surface reflectance, $\vec{L}$ surface-relative lighting direction and $\vec{N}$ the surface normal. Standard photometric stereo maintains a static camera viewpoint. Photometric samples are acquired by varying light direction and observing intensity change at a single pixel. Denoting lighting direction and intensity at a given pixel across the N photometric images with subscript, then:

$$\left[I_1 I_2 \cdots I_N\right]^T = \left[\vec{L}_1 \vec{L}_2 \cdots \vec{L}_N\right]^T \vec{N} \quad \textbf{(Eqn 3)}$$

Clearly this can be solved by premultiplication with the pseduoinverse of the L matrix (this can be achieved in an efficient manner, for example via singular value decomposition), providing an estimated normal for each camera pixel.

To apply photometric techniques, our system first rectifies the input images to a common viewpoint. This can be done approximately using a planar perspective un-warping. Figure 5 shows a set of input images along with their corresponding rectified views. A 3D range map is then derived by integrating the recovered surface normals.

Total image acquisition time for the images shown in Figure 5 was ~15 seconds. Rectification and photometric stereo processing steps for a mesh with dimensions 1024x592 were completed in ~6 seconds, using an AMD x4600 processor running a 64-bit operating system. The final output was a 1024x592 albedo map (essentially an RGB texture map), and a 1024x592 height map providing ~600k independent height samples. This provides geometrical information equivalent to laser scanning the ~700cm^2 sample area at a resolution of ~300μ.

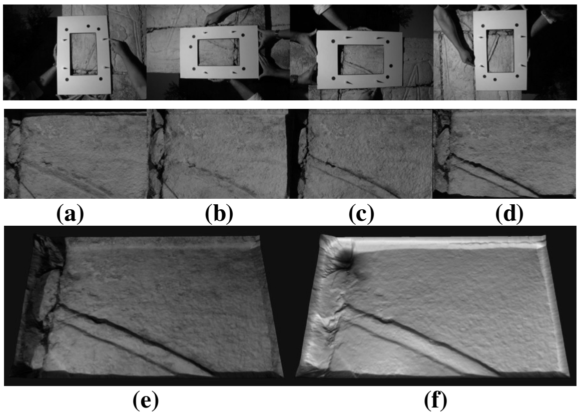


Figure 5: (a) – (d) *Input photometric images, captured with varying camera and lighting direction (top row). Rectified versions; note static viewpoint, moving illumination direction (bottom row).* **(e)** *Reconstructed 3D surface with lighted colour albedo.* **(f)** *Jet colouring scheme highlights detailed geometry.*

A discernable bevel is seen at the boundary of the reconstruction illustrated in Figure 5. This artefact is seen when, for a given pixel, the light-gathering frame casts a shadow onto the subject in one of the four input images. An approach in which shadowed pixels are excluded from photometric stereo calculations in a reliable manner is proposed in [CJ05]. In Figure 6, shadowed regions are culled in the reconstructions shown.

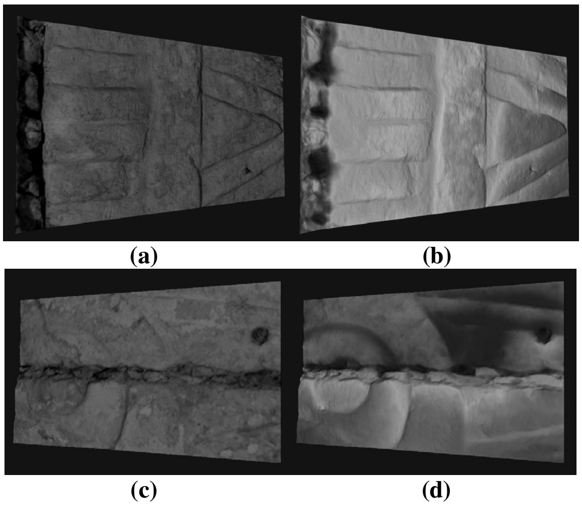


Figure 6. (a) *A second reconstructed 3D surface with lighted colour albedo.* **(b)** *Jet colouring scheme highlights detailed geometry.* **(c) – (d)** *Colour albedo and jet colouring for a third example.*

4. Downstream use in film production

Complete digital versions for specific structures at Chichén Itzá are required for the educational planetarium film *Maya Skies*. As the final rendered material will be presented on hemispherical screens measuring up to 70' in diameter, subtle epigraphic details will be clearly visible to planetaria viewers when geometry is placed near the scene camera. Even distant regions of the scene may require high levels of detail, since each rendered frame will be 4,096x4,096 pixels. Given the demands imposed by the full-dome output format, high resolution geometry and texture detail are highly desirable. However, since the required models must include highly detailed features of the type seen in Figure 7, mesh simplification is clearly required prior to rendering.

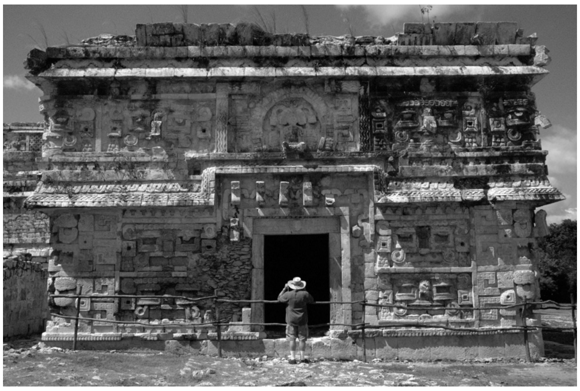
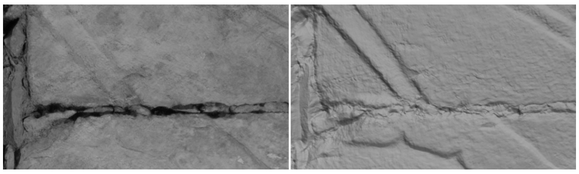


Figure 7. *Complex epigraphic detail seen at Chichén Itzá demands geometric simplification for efficient rendering while preserving the features seen above.*

Several techniques have been proposed to achieve a high level of detail at a relatively low geometric cost using normal mapping, notably [CMSR98]. Using SurfaceImager, we export geometry with texture coordinate information in .OBJ format, accompanied by an image texture map in .BMP format. The output geometry is then decimated into a low resolution triangle model for use as a normal mapping basis. We compute the normal map using both the original output geometry and the decimated geometry; results are seen in Figure 8.



(a) **(b)**

Figure 8: (a) *Color albedo image from photometric stereo calculations.* **(b)** *Normal map for the same region, computed from SurfaceImager geometry.*

Next, we load the decimated geometry into Alias Maya, the application selected for lighting and rendering in *Maya Skies*. Here, we apply the original color albedo map exported by SurfaceImager and the computed normal map to the low resolution geometry. Results rendered from Maya with a single light source are seen in Figure 9.

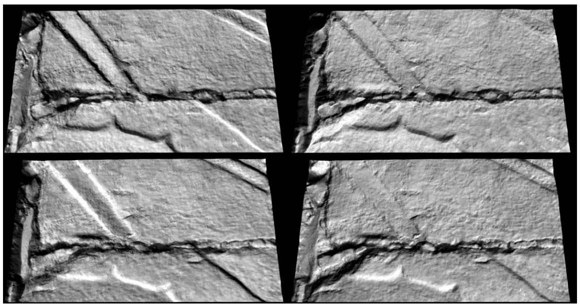


Figure 9. *Recovered geometry and color albedo, lighted and rendered in Alias Maya. A single light source (simulating sunlight) varies in position with each frame.*

Despite the high level of geometric simplification in the decimated base model, the normal map effectively preserves the details seen in the original photometric reconstruction. We found that automated rapid synthesis of normal maps from our photometric stereo approach was practical, requiring ~12 seconds to compute maps at 1024x1024.

5. Future work

We have found that geometry recovered using our system is free from low frequency noise often seen in close range laser scan data. Therefore, we believe this technique could be explored for sampling smaller subject regions than those shown in this paper, but with comparatively higher detail. In Figure 10, our current method is used to compute 1,024 x 1,024 samples over a 42 x 42mm surface region, giving a ~41 micron sampling in both x and y dimensions.

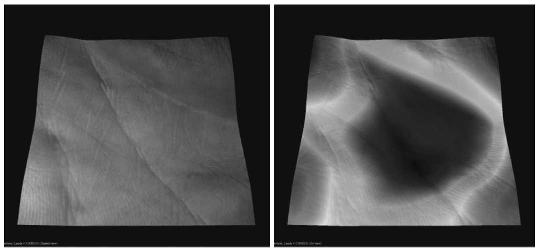


Figure 10. *~41 micron sampling of a human palm.*

6. Conclusions

We have demonstrated the application of a novel approach to surface geometry and albedo capture. The system requires only simple low-cost hardware and standard digital photography. Processing is rapidly performed on a standard PC using our "SurfaceImager" application with only minimal user interaction. The system has been shown to be capable of very high detail recovery for epigraphy, rivalling that of traditional laser scanning hardware. Having acquired this data, we have discussed how it may be processed to produce models suitable for use in modern rendering software, in particular for the production of photorealistic images in the educational film *Maya Skies*.

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Complex Documentation of Charles Bridge in Prague by Using Laser Scanning, Photogrammetry and GIS Technology

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Abstract

The Charles Bridge in Prague is a worldwide known historical monument. It is on the World Heritage List (UNESCO) with the historical center of Prague and it belongs among the national symbols of the Czech nation. During catastrophic flooding in 2002, which the Charles Bridge resisted, some of its parts were damaged. A decision about a gradual reconstruction was taken then. The first logical step was a complex documentation of the bridge. From the last reconstruction in the seventies of 20th century, the documentation is not complete, some parts have not been found and its quality is not sufficient for today. The major measurements were made in 2005. The laser-scanning technology was used for determination of the bridge form lines and edges. The "wire 3D model" was created from the laser-scanning data set. Using the digital photogrammetry, the detailed 3D model with all stones was created after that. About 2000 images, more than 1000 geodetically measured control points; a boat and special climbing equipment were used. All of about 70 000 stones were processed in the 3D model in AutoCAD. As the second step, a special database for information about stones (quality, material, exposition, damage ...) was created. Mouse clicking on a stone in the model depicts the related data.

I.3.3 [Computer Graphics]: 3D Visualization

1. Introduction

The Czech and Roman Emperor Charles IV founded the Charles Bridge in Prague in 1357. After the catastrophic flood in 2002, which the Charles Bridge resisted, some parts were damaged. For the partial reconstruction the new documentation was needed. The major geodetic and photogrammetric measurements were made in 2005.

Figure 1: *Charles Bridge in Prague*

2. The laser-scanning technology

The laser scanning has been a very popular technology recently; it is a non-contact mass measurement of 3D points. This new progressive technology has been in practice since 2000. The laser-scanning technology was used for determination of bridge form lines and edges. The 3D edge model was created from the laser-scanning data set. The Firm GEFOS a.s created the basic vector model of the Charles Bridge with accuracy of about to 5 cm (Leica/Cyra). Some parts of the bridge were measured by using Callidus 1.1 system (Czech Technical University).

Figure 2: *Leica laser scanner (Gefos a.s.)*

Using the digital photogrammetry, the detailed 3D model with all stones was created after that. About 2000 images, more than 1000 geodetically measured control points, a boat and special climbing equipment were used. All of about 70 000 stones were processed in the 3D model in AutoCAD. For control point's determination, a new self-reflecting total station (distance measurement without reflecting prism) was used; this device is very good for inaccessible points (Trimble 5000, distance measurement to 300m).

Figure 3: *Callidus laser scanner (CTU Prague)*

3. Project

Works started with image acquisition. During this phase first problems arose: due to inaccessibility it was not possible to scan some parts of the bridge and therefore it was necessary to locate them independently by using classic surveying methods. Photographic conditions represented another problem. The transformation itself does not require taking photographs under the same light conditions but when creating a model and visualizations it is necessary to have photographs of the same quality. Control points for transformation were acquired from the wire model or by direct measurement. Particular parts of the bridge are not flat and that's why an adjustment plane was used for each part and points of the model were projected to this plane. It was necessary to pay attention to deviations of individual points from this plane and in case that the deviation exceeded the value of 5 cm; the plane had to be divided into smaller parts. This way enabled to substitute 3D surfaces by 2D planes without decreasing the required accuracy of final schema of construction (planed absolute accuracy up to 10 cm max.). Particular arch rings represented a special case where it was necessary to divide the arch surface to more flat surfaces, which substituted the arch. A representative 3D model of the bridge giving an overview of particular schema of construction-joint location was created from schema of construction-joint and the wire model (AutoCAD). It was necessary to transform the 2D areas to 3D again. This work required a good orientation in space, a right selection of a coordinate system, in which the plane was put in to the model, and to consider the surface rotation or its splitting to smaller parts which fit to the 3D model as much as possible. Even though the surface manipulation was accurate, this way led to divergences in junctions of the edges in the wire model and the inserted surfaces or two adjoining surfaces. It was necessary to eliminate these problems using manual editing. The created schema of construction-joint and the 3D model are also a part of the information database of the bridge. On the basis of this database, a geological prospecting of a part of the Charles Bridge is performed and therefore the next work concerning this historical monument will be eventually updating the reconstruction according to the research results. Furthermore, it is planned to add schema of construction-joint of bridge towers and subsequent visualization of the bridge. As the second step, a special database for information about stones (quality, material, exposition, damage …) was created. Mouse clicking on a stone in the model depicts the related data.

Figure 4: *Trimble 5000*

4. Information system

The development of our special application for data storage and processing started during the year 2004. At the time of searching for the optimal software solution no was found that would both meet all our requirements (connecting spatial and non-spatial data, 3d graphics etc…) and be financially acceptable (this work was low-cost with helping of PhD students). However, the software developed by us enables communication with other systems such as AutoCad or Microstation through vector format dxf. As a development technology, the programming tool Borland Delphi 2005, a graphic library OpenGL and more support components (database connection, XML technology support, and libraries for extended 2D projection) were used. The main program application of the information system is created for Windows 32 platform. In order to run it correctly it is necessary to have a standard PC with Windows operation system, a graphic card with OpenGL support and also network or Internet connection for connection to distant data source.

4.1. Structure of saved data

The saved data can be divided into spatial and non-spatial:
Spatial data – the system saves information to its own binary format named .scl. Using this way the data can be

saved right to a file on local disk or as meta-data to one record of the connected database table. Non-spatial data – can be divided into text data, pictures, sounds, videos and other unspecified data. The last version of the system is able to work with all these data types on local disk, only the text data can be also saved to a database table where one object of the 3D model is represented by one record in the database table. For simultaneous work with one model across several computers photographs were stored on the network disc – then it was possible to use the data on more computers at the same time. In this moment we are already developing technology that can save pictorial data into the database. In case that the text data are saved on the local disk, they are saved in XML format. Mutual connection of spatial and non-spatial data is ensured via a unique identifier related to each object of the 3D model. This identifier is created automatically during a model creation but can be easily modified by the user. IDs are assigned automatically to make-work easier. Then, a user can change them without limit. If an existing ID is entered, the system will automatically warn the user that there is a conflict – the same ID already exists.

4.2 3D model creations

An existing model created in some of external 3D CAD applications (AutoCAD, Microstation, 3D Studio etc.) can be used as the 3D model. In this case a universal vector format .dxf is used for import. Integrated editor (vectorization) can be used to refine the 3D model, this procedure can be used for instance for digitalization of smaller flat parts of the 3D model. A special editor have been written which biggest advantage is its connection with 3d model – vectorized data are transformed into 3d model in the real time so you can see the result of the vectorisation process immediately. It is also possible to add non-spatial data in the editor directly. In case of the Charles Bridge model creation this procedure was used for schema of construction-joint creation of flat surfaces of the model. The 3D model can be also created by direct entry of coordinates or by import of spatial coordinates from a text file.

4.3 Vectorization

A special tool for transformation/vectorization of 2D background data (photographs most often) was made in the application for details creation of the basic 3D model. It is a transformation of a photograph into 3D model created with laserscanner – improvement of the rough model. As identical points we used the anaclastic points and the relevant points from the photo. The biggest problem of transformation as such is of course the right selection of anaclastic points; the selection of the relevant point is done manually. This tool was primarily made for the creation of particular bridge surfaces. To place a 2D object from 2D background data to a 3D model, several types of transformation can be used. These transformations can be combined at large, even within one 2D background data. Identical points (2D background data to 3D model) are used for transformation of key calculation. When vectorizing mainly the flat surfaces, a simple affine or projective transformation can be used. In reality there are mainly general surfaces. Such a bridge, as the Charles Bridge has almost no flat surface. It was necessary to create a special type of transformation for these surfaces. Particular steps of this transformation (2D to 3D) can be described in the following way: Transformation of identical points to plane (a plane is always formed by the three most distant identical points); a projective transformation is used for creation of triangular network of identical points finding the nearest triangle of the transformed point 2D to 3D transformation, vertexes of the appropriate triangle are used as identical points. To perform the transformation it is necessary to know at least 3 identical points but due to sequence of particular surfaces of the whole object it is necessary to enter a maximum number of known identical points.

4.4 2D presentations

Concerning the necessity to present the 3D model also in printed form, the system has an integrated tool for simple presentation creation. Within one document it is possible to create a number of presentations; each presentation can consist of a number of sheets. Texts, geometric formations and 2D presentations of spatial objects (automatically calculated from the 3D model) can be placed on every sheet.

4.5 Object selection according to criteria

One of the main project goals was to create a simple tool for filtration of particular objects within the whole 3D model according to various criteria. The final application enables to apply filtration on geometric characteristic (e.g. an object larger than 1m) as well as data characteristics of objects (characteristics saved in external XML file or database). The selection can be simply saved and eventually a setting of a color and solid style in which the object will be displayed can be made. Selections saved this way can be called out anytime. Several selections can be displayed in one 3D model at the same time. In case that some object is a part of more selections, it will be displayed in the color and style of the selection found as the first. Each object can be a part of any number of selections but in the same moment a selected object may be highlighted by 2 selections only (full colour + crosshatch). When the selection is deleted, objects, of course, remain intact but if the object itself is deleted information about selection/s of the deleted object is lost too.

4.6 Outputs

An important part of the whole system is also represented by tools intended for data export to external formats, eventually for preparation of print sets. The main output tools are:

- 3D drawing – any part of the 3D model can be exported, for instance it is possible to export a part of the model defined by selection, .dxf format is used as the export format
- text data – it is possible to export characteristics of selected objects, the exported data can be saved in

.XML format and in .CVS text file (particular records separated by semicolon)

- print outputs – using a connected printer it is possible to print a prepared presentation and also a simple list of selected objects.

5. Conclusion

This report is focused on documentation of Charles Bridge in Prague (UNESCO, Czech Republic) by using laser scanning, photogrammetry and GIS. This project is sponsored by grant Czech Grant Agency Nr.205/04/1398.

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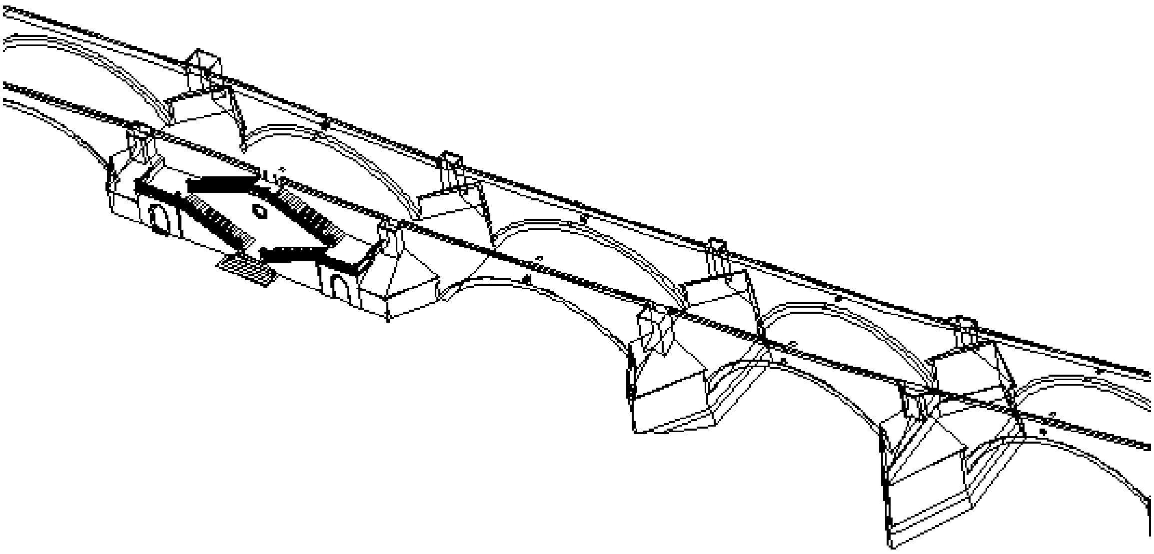

Figure 5: *Edge vector model (Firm Gefos a.s.)*

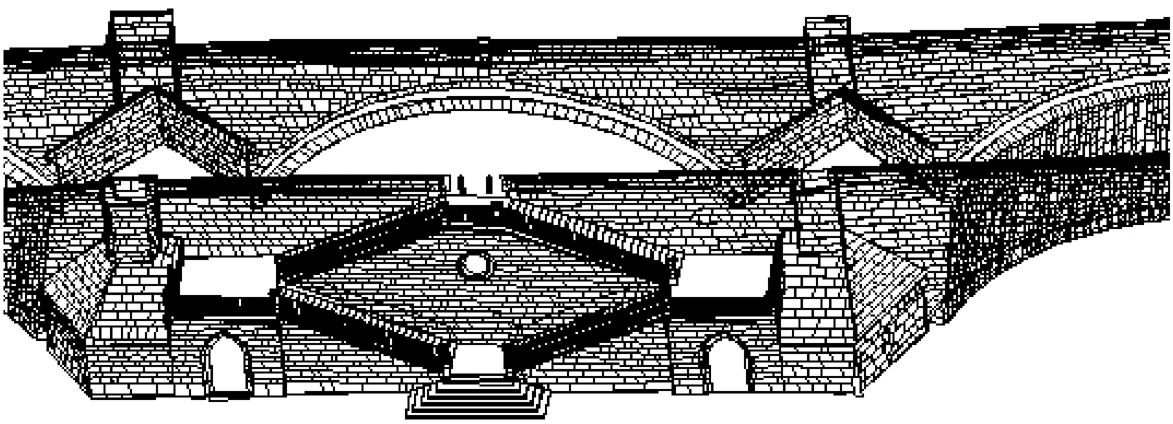

Figure 6: *3D model*

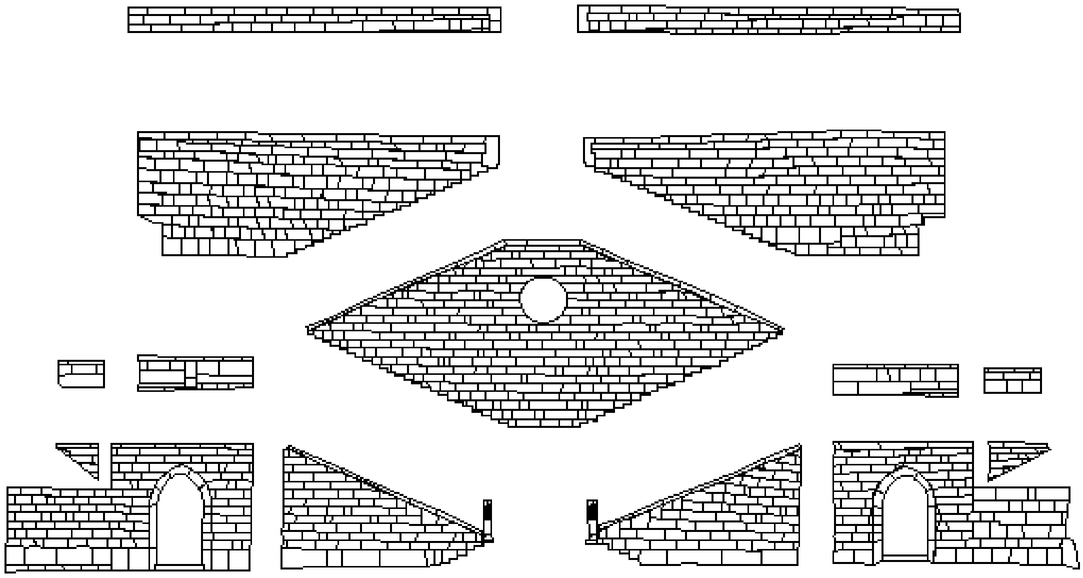

Figure 7: *2D planes*

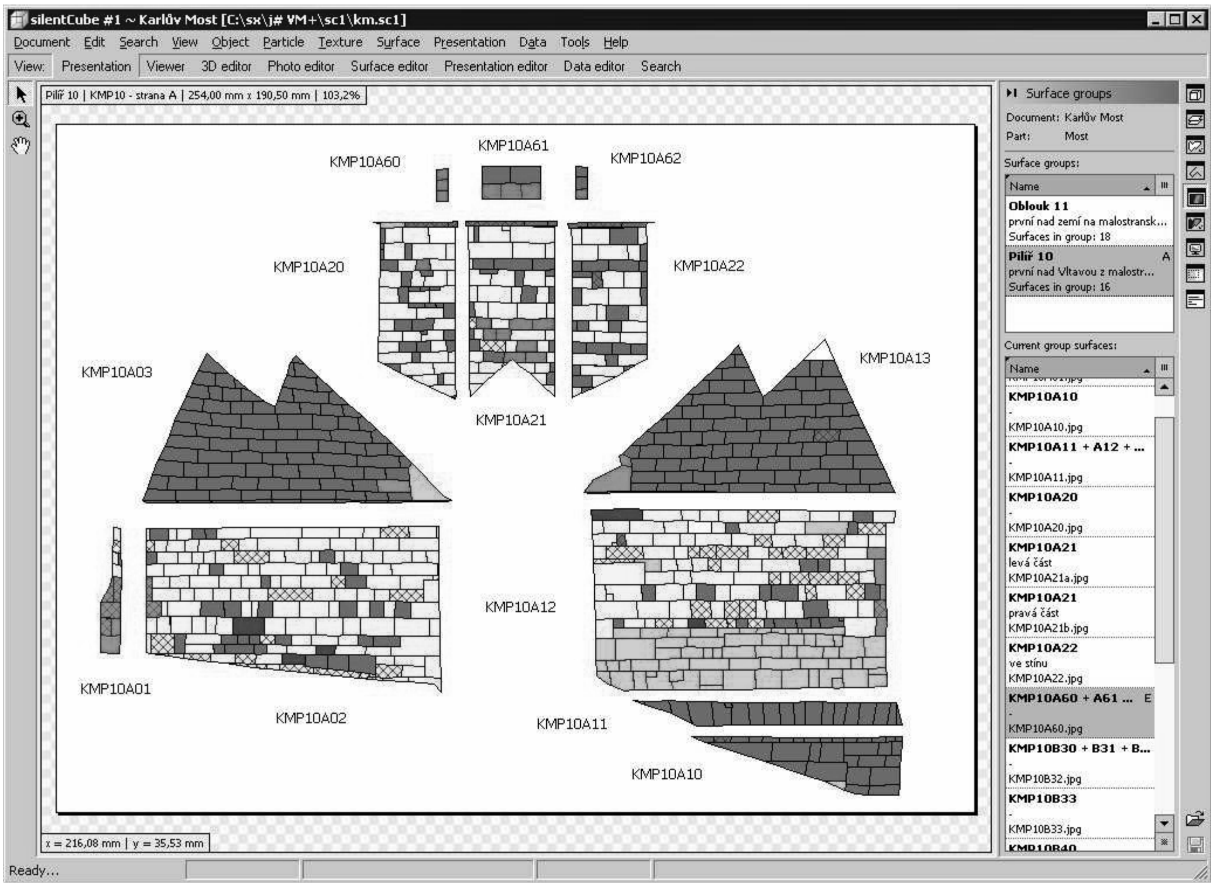

Figure 8: *2D outputs*

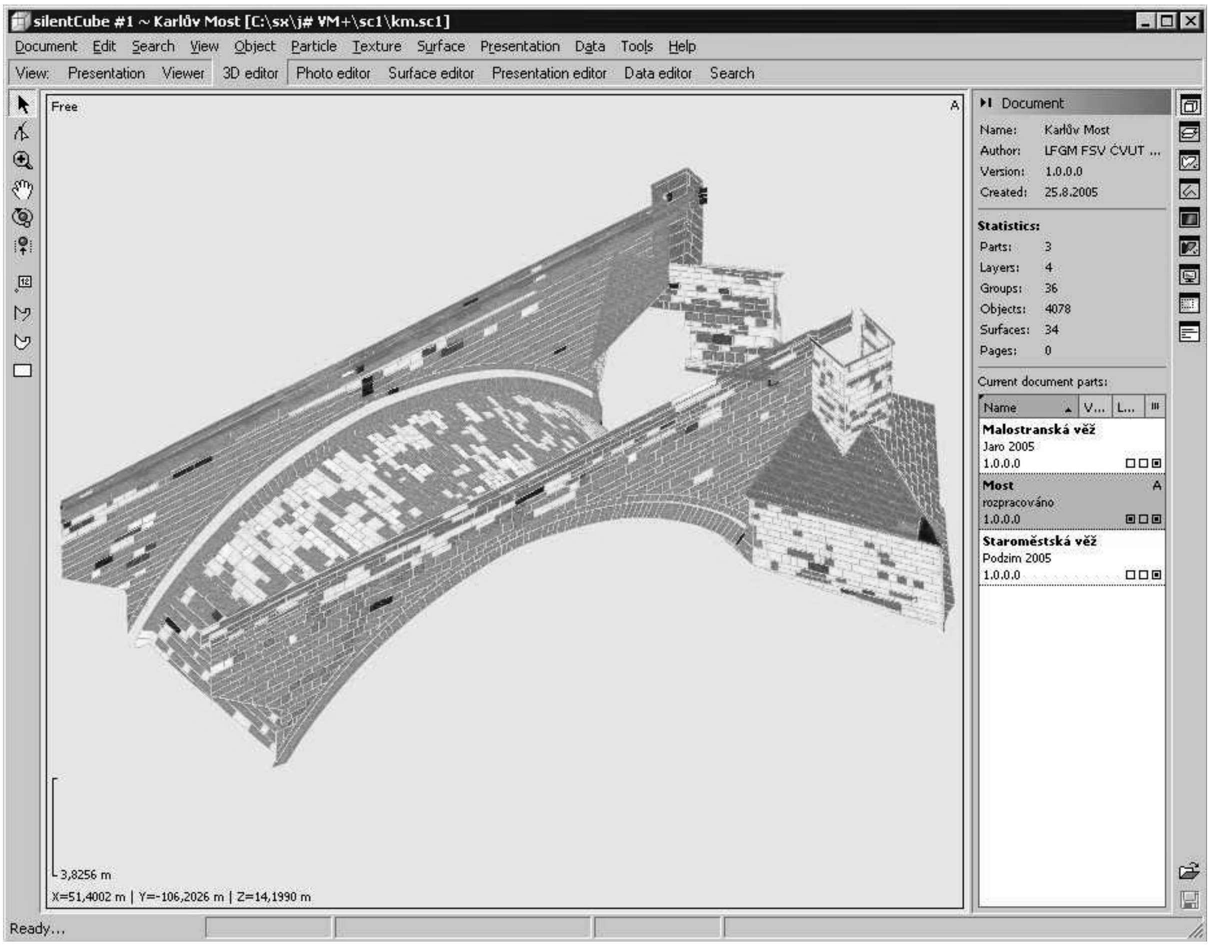

Figure 9: *3D* d*atabase of Charles Bridge*

Figure 10: *Documentation of Charles Bridge*

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Short Papers

Graphical Annotation of Semantic Units in a 3D GIS for Cultural Heritage Research and Presentation

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Abstract

This paper is to show that an interoperable 3D GIS with support for semantic information can be used for very finely granulated objects as well as for objects covering vast expenses, thus allowing to link models of an archaeological find, its surroundings and the larger landscape in a single system. For this, a common model that allows the management of semantic data which is loosely coupled to features, or parts of these features, of the real world, has been designed. It permits to give objects multiple meanings, depending on the concepts of the individual users, as well as to give semantic data specific areas and levels of validity. This approach is then explained by showing two use cases – one in a numismatic context, the other one exploring the development of wall paintings over time. In both cases, even minor elements in the images used can be defined as semantic areas and be annotated with information, both for expert and amateur users. By providing a Java-based Internet tool, these users can collaboratively work on these interpretations and annotations. Finally, the time component is shown to be important for both cases, and ways of presenting changes over time are given.

Categories and Subject Descriptors (according to ACM CCS): H.3.5 [Information Storage and Retrieval]: Online Information Services, H.3.7 [Information Storage and Retrieval]: Digital Libraries

1. Introduction & Objectives

A multitude of technologies is currently being investigated for their applicability in the context of cultural heritage applications [OBP04]. These technologies include geographical information systems (GIS), used for the visualization, management and especially for the mapping of finds. Like cultural heritage itself, GIS research is a wide field in which a multitude of engineering and scientific fields are touched. For the context of this work, the applicability of an interoperable, net-based 3D GIS with temporal support (also known as a 4D GIS) is researched for several use cases in cultural heritage. One of these is the collaborative annotation and scientific use by archaeologists, another is the presentation of information to a greater public, and the final one the use of such a system for education. More specifically, the stakeholders that can benefit from this work are:

- *Experts* in the cultural heritage field like archaeologists wishing to interpret and analyze finds collaboratively. This can be done by selecting finds, annotating them, reading other's annotations and also commenting on these annotations. The collaborative work is ensured by providing access to the annotations and 3D data via an interoperable GIS, consisting of a server and a specialized client for the advanced annotation interactions described in this paper. These experts also have a need of publishing their data in a searchable and retrievable way in the Internet.
- So called *intermediate users* [Coo03], i.e. users with a high interest in the subject and preexisting knowledge on the topic. Examples for this group are teachers and hobbyists (numismatics wanting to know where their items were found and the like)
- *Casual* users, i.e. tourists or other groups without specific knowledge on the topic. The system could be made accessible on-site or at a museum for this audience.

Generally, 3D content creation systems are being used to visualize reconstructions, to give both experts and amateurs alike an additional way receiving insights into old settlements or other structures. A 3D GIS aims to allow both, that is, to manage the actual, complete data including 3D shapes and attached attributive data, and to create rich visualizations. However, the uses mentioned above also have specific requirements, especially when it comes to scientific work, like analyzing finds and trying to interpret them. For this, our system makes use of social software concepts, like the Wiki. A Wiki is a system in which everyone can change or add information, to create a set of linked hypertexts. Wikis have the advantage of reflecting a lot of knowledge that is otherwise implicit in a society since they animate every user to contribute his specific knowledge ([Wag04], [Hef04]). Another concept used is tagging, a process in which a user can assign simple words that represent a concept to an item, thus categorizing the item. Tagging is used throughout social software, be it for annotating images (`Flickr.com`), links (`del.icio.us`) or scientific publications (`connotea.org`), mainly to convey semantic information. As knowledge management systems, these approaches have received some criticism [Car05], but at the same time, they enjoy continued support and have grown to a considerable size.

Together with the data management and visual capabilities of our GIS, which include non-photorealistic rendering as well as simple environment simulations, these concepts form a system that can be used by the described user groups in a variety of ways, such as the following:

- Visualization of the changes of elements of time, specifically of wall paintings. One example where this can be applied would be to see modern reconstructions or various phases of paintings in churches or other buildings.
- Selection and annotation of areas within the 3D scene by using a specialized picking tool and a dialog-oriented 2D interface.
- Commenting and adding on annotations that have already been given, thus enabling a discussion between experts in the actual context of the finds.
- Reading of information that is assigned to specific areas of a 3D scene, e.g. characteristic units of a wall painting or of areas that have a common meaning, such as a finding. This visualization can be customized towards a user group by specifying an intended audience for each annotation.

Our hypothesis is that these use cases can be covered by a 4D GIS with support for semantic and thematic data by using the geographical context as the connecting element, and that such a 4D GIS can bring with it a series of specific advantages to cultural heritage users:

- Data with a geographical reference can be linked into a 3D environment from all kinds of sources, freeing experts from the requirement of modeling the environment themselves.
- Attributive data from the field of cultural heritage, like the distribution of finds, is presented in a rich, interactive way and in its context.
- Both spatial and thematic data are accessible, can be filtered by various properties and be researched by various user groups.

What needs to be done to link a system with these capabilities to the user groups is the development of domain-specific tools, in this case for cultural heritage research and and to view this information in a user-customizable and filterable way. These are described in the following chapters.

In comparison to standard GIS, this system is special in that it can be classified both as “feature-driven” and as “domain-data-driven”. In a “feature-driven” system, which is the most common modeling structure in GIS, information is connected to physical features of the real world, while in a “domain-data-driven” system spatial regions, features or other classes of localizations are attached to data from all kinds of domains. This approach gives us the flexibility required to employ a single system for the described applications and wide group of users.

2. Related work

The usage of a 3D GIS or even GIS with temporal support alone is not a new idea. Especially for presentation purposes, 3D GIS, in some cases with an Internet client, have been used, such as in [GWMS03]. Also, the presentation of dynamic objects or objects with temporal uncertainty has been a subject of research. However, in practical work, the use of a 3D GIS with Internet support is still not very common. For presentation purposes especially, purely presentation-oriented systems like *Shockwave* are used, with relatively limited degrees of interaction, especially with other users.

When looking for systems that allow to annotate geographic areas, one will find that this concept is quite commonly used currently, with the most prominent applications being based on Google Earth. In this software and applications based on it, locations can be tagged or enriched with information by using the KML interface to Google Earth. However, these annotations are limited to simple 2d-Points. Also, there is a lot of social software employing comparable approaches, like the aforementioned *Flickr.com* or *Blogwise*, which allow to add a geographical location to an image or text.

Using a 3D or 4D GIS for data management in cultural heritage seems to be rather uncommon, Most of the time, the formats specific to the technology employed for capturing data are using, like specific 3d scanner formats. For thematic data, simple databases that are customized towards the specific type of finds or other requirements are used. Often, theses are desktop databases connected to a database application, which make it hard to share the contents.

For managing the semantic aspects of cultural heritage data, there has also been research in applying semantic web technology on the specific data and issues that cultural heritage brings with it. An interesting approach was presented in [SLM06], where a system using ontologies and mappings between these used data from four content providers was demonstrated. This is very much akin to the handling of ontologies in our system, where so-called core ontologies are used to map between various domain-specific ontologies.

Regarding the user interface, so called 2.5D WIMP GUIs are still widely regarded the most usable class of interfaces, even though in research many other concepts have been tried. These GUIs have been improved over the last 25 years and are capable of offering many views on the same monitor, multiple windows stacked on each other and employ embedded 3d scenes or effects. An example for such a GUI is the current MacOS interface. There have been some attempts to use complete 3D GUIs, among them the Looking Glass Desktop from SUN and also interfaces for immersive environments, like a CAVE. However, these interfaces usually shine only in a small area of applications, and give no advantage to reading or writing text, for instance.

Since much of the information that will be linked in into our system is text-based, we have decided to not integrate the annotations as a whole directly into the 3d windows of our system, but instead to use multiple windows that are opened when a user selects the appropriate tools and annotations from the 3d scene. This allows a gradual shift between the 2D and the 3D UI paradigms and plays on the strengths of each concept in a complementary way. There has been some criticism regarding these dimensionality breaks, but this criticism was mainly directed at immersive stereoscopic systems, where the eyes actually have to adapt to varying object distances.

While both individual elements employed in the concept, 3D-GIS and the digital presentation of semantic information, are regularly used separately by the stakeholders, the combination of both in a single module is this form is new. Museums and archaeological websites often present animated 3D-reconstructions of sites and objects, and in particular the former employ electronic media with different content levels to reach both the expert and the lay visitor. However, the quality and quantity of semantic information, in particular for the expert, are generally limited. Sources of electronic content for the expert are generally restricted to classic databases or else 2D graphic presentations (e.g. `www.findsdatabase.org.uk`).

The concept presented here not only seeks to combine the best of previous approaches, it goes further than the individual elements, improving the quality of both visual and semantic content. In particular, the provision of a facility for the expert stakeholder to annotate fields in this form opens up new possibilities for academic discussion.

3. Using a 4D GIS to integrate and create information

For this work, the core aspect was to provide a set of usable tools to heterogeneous groups to add annotations to 3D scenes and to link their thematic data into a 3D GIS. This is done by the provision of a set of interactive tools, from which the back-end concept is then developed.

Figure 1: *Selection tool for annotating a texture image in a richly textured 3d scene of a latin caldarium.*

3.1. User View

The first and most basic tool is for the selection of an area in the 3d scene, as displayed in Figure 1. This marquee can be either an area (e.g. a rectangle) or a volume, like a box. The selection and marking of annotations is implemented by using variants of the virtual pointer ray-casting and aperture UI metaphors [BKLP04]. This means that a ray is calculated from the virtual camera position to the mouse cursor when the user clicks, which is projected into the 3d scene. For the creation of scopes, this metaphor is extended to an aperture metaphor, where clicking for several times will create a selected area with a direct visual feedback.

Figure 2: *Annotated Regions of a 3d scene.*

For example, the tool for creating a rectangle required two clicks, while three are required for a box. The area picker can be used on any geometry, like a cave wall or a church portal, as long as a continuous surface exists and the starting and end points are visible to the user. This means that in the case of a column, the tool is limited to selecting a portion slightly less than half of the column. More complex forms can also be covered, like a closed polygon. This requires a relatively complicated user interaction and will be reserved to advanced users, and also not implemented in the first version.

Figure 3: *Creation of a WikiAnnotation by using a dialog and the typical MediaWiki syntax.*

When such a marquee has been created, it can be modified, so that it fits the intended region in a better way, and its border type can be defined. When a user thinks his selection is correct, he can click on one of the icons displayed below the selection. Each of these icons represents one of the annotation types that are available. Following this selection, a dialog is created that contains the input elements specific to that type of annotation (Figure 3). However, creating information is just one step. The second step is using and visualizing that information. For this, a filter panel is used that allows a user to preselect the information he is interested in by thematic, spatial and time criteria, as well as by user-specifiable criteria like a full-text search. The annotations that match these filter criteria are then displayed as marquees in the 3D window, with the annotation types already attached to a scope in inverted tones. Clicking on one of these icons allows the user to view the "deposited" information in a window created on top of the 3d scene.

An additional type of selection tool available in the spatial annotation view also allows to display time-variance in the state of the objects inside the selection, if this data was acquired. This tool can be used for example to compare different wall paintings that have been painted on top of each other, or to compare a wall painting before and after a restoration. This can help both amateurs and professionals to directly understand these developments and reconstructions.

3.2. Scopes

As mentioned, another important aspect in the design phase of the system was to allow the system to be driven from various information directions. To achieve this, each information object, including the annotations as well as metadata, gets assigned to a scope. A scope can be of different types, for example of these:

- *Global:* The selected area is expressed relative to the global coordinate reference system.
- *Local Object:* The selected area is expressed relative to the transformed coordinate reference system of a geometric object, like a building.
- *Local Surface:* The selected area is expressed relative to the transformed coordinate reference system of a surface of a geometric object, like a single wall.

When a user now wants to use his thematic information by linking it to the system, he can do so by importing the data. For the creation of the scopes for the imported data, several strategies can be used. The easiest way is the availability of coordinates attached to the thematic data (Global Scope). However, attribute-matching to Features can also be used (Local Object Scope). Attaching the information automatically to local surfaces in a common way is rather difficult, so we have provided an interface in the style of the *Strategy* pattern, that is, the user has to provide an implementation that "knows" how to attach the thematic information to surfaces. In this approach, the data remains with the creator and does not need to be copied to another resource. It can be made available to others by publishing it as a data model, but that is not a necessary precondition. In this way, the data can be easily used in various applications and can also be kept in a structure reflection the individual requirements, as opposed to a central data store with a fixed scheme.

3.3. Information management and Back-End

Leaving the level of user interaction and the visible objects, another core aspect of this work is, as described, to also provide the back-end framework to collaboratively annotate geometric representations of cultural heritage sites and to filter and read this information. For this goal, several preconditions need to be fulfilled. One of these is a data model capable of handling the complex relationships between the data, as shown in Figure 4.

We are using a data model that describes both geometric data of all kinds (the so-called common functional model [Rei05]) as well as quality information, thematic data and semantic information. This latter data is linked to geometric data via a concept of areas of validity. Generally, such an area of validity is rather abstract. It can be defined in 2D or 3D space and include a time component, be described by simple geometric form like a rectangle or a complex form like a NURBS surface. Furthermore, the concept allows to select between absolute borders, uncertainty areas and smooth borders by supplying the *Section* with a characteristic curve (Figure 5).

Annotations are modeled as Attributes in the common

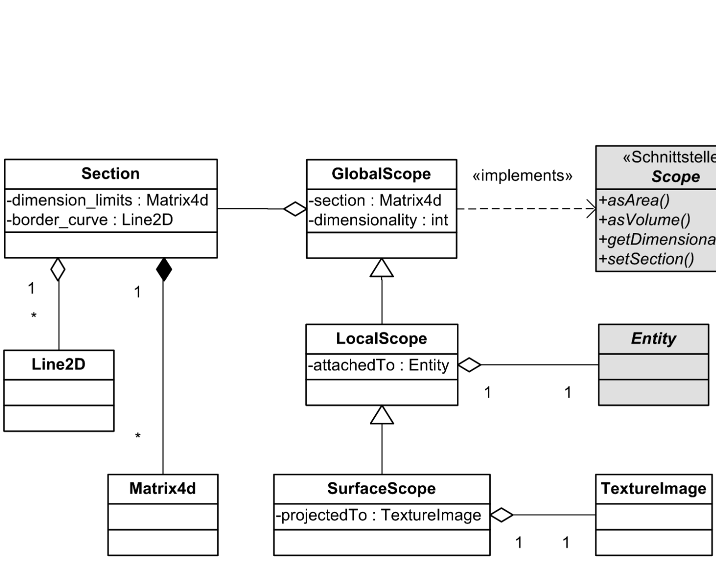

Figure 4: *A simplified UML class diagram showing the relations between information elements (Attributes and Annotations) and spatial elements (Entities and TextureImages).*

functional model, which are a general container class for all kinds of thematic data, ranging from semantics to binary multimedia data. Annotation types supported in our implementation are:

- *SimpleAnnotation:* A simple text annotation, without additional media linked in, or advanced formatting. This can efficiently be used for discussions, via the children attribute inherited from the abstract superclass Annotation. We are using this type to provide a Usenet-style threaded discussion capability.
- *ConceptAnnotation:* This type represents the attachment of a concept in the sense of an element of an ontology. In social software, this ontology is usually built dynamically by the users by tagging, as described in the introductory chapter. Both basic structures can be very useful; using a given ontology will be the rule if a specific schema exists for a certain area of scientific work, while the dynamic variant will be useful in cases where such a common nomenclature does not already exist. In our case, we are evaluating whether so-called micro-formats [Kin05], structures that have resemblances both to a formalized ontology and a dynamic ontology, can be created in such an environment. When entering a ConceptAnnotation, the system suggests concepts to use by querying what other Annotations are incident with the new scope.
- *WikiAnnotation:* In this implementation, this is simply modeled as a link-in to a Wiki page, that is, a document that can contain markup, text, links and images, is saved in a specific format and usually rendered in HTML by a browser. An Annotation-Tree can only have one WikiAnnotation (children of the same type are not allowed).
- *ImageAnnotation:* This annotation has been included as an example of adding other media than (hyper)texts. The ImageAnnotation can either access a local resource or an Image available via http.
- *RatingAnnotation:* RatingAnnotation: This Annotation type can be used to express the quality of another annotation, that is, it can only be used as a child to another Annotation.

One can always add multiple annotations to a scope; a typical range would be a *WikiAnnotation*, a *SimpleAnnotation* (with subsequent discussion elements) and a *ConceptAnnotation*. Optionally, an Annotation can also have a target domain, that is, a reference to a certain user group. This allows the author of an annotation to declare at what kind of people his work is targeting.

Figure 5: *Various border definitions, the first without a fall-off line, the second with a fall-off resembling a Gaussian normal distribution, and the first one defined by an additional polygon defining the starting of the decay.*

On the level of persisting the annotations, we have decided to keep only a minimum of information in a central core database, with the actual annotations being saved in the system that matches them best. For example, the WikiAnnotations are saved in a MediaWiki, with only the scope, some metadata like the date and the author and finally the URL being saved in a linking database. In the same way, multimedia content is linked, since there is no benefit to be gained from centralizing these often very big objects.

4. Evaluation

The evaluation of this concept is done by implementing it and then providing the system to two user groups, one being researchers who specialize in the analysis of ancient coin finds. The sample area for this case is the Martberg, where both celtic and roman settlements were located and where more than 10.000 finds were already made [WW98]. The data that these archaeologists have collected consists of several databases, each with information on where a find was made and will be interpreted by a team of scientists. For the evaluation, a set of questionnaires will be used to determine whether the capabilities of the system and the user interface cope with the requirements for their work, especially with the aim of providing a scientifically usable and accurate tool.

A second evaluation scenario is based on the wall paintings of the same settlements. These have been reconstructed carefully from fragments [Gog06] that were found and are now being annotated with the various elements. The aim of this scenario is to have both a data entry phase, but also to have a presentation platform for the intermediate and casual users. Again, evaluation will mainly follow the established usability research methodologies.

5. Conclusions & Outlook

With the implementation of the concept currently being finalized, we can not yet draw final conclusions, but the need for the described tools has shown itself in interviews with field experts. Regarding the presented concept, it has already shown itself to be very versatile and is also being used in other projects, e.g. to represent points of interest. With respect to the developed tools, our aim was to keep them simple in a first step by limiting the forms that can be created; however, additional capabilities will be necessary later on.

Besides these implementation details, one of the main aims we are following for future development is to enable everybody to publish his thematic data into the geospatial domain. For this, one of the most important aspects is to make the linking of this data to other thematic information and the GIS data as easy but at the same time as flexible as possible. This requires the additional investigation into concepts on how semantic information can be easily mapped from one thematic domain to another, an area where we think that many of the concepts coined under the term of social software can be used. These strategies will then have to be adapted to specific user groups, and be tested.

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Short Papers

New Trends in High Resolution Survey for the Cultural Heritage Metric Survey Applications for Restoration

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Abstract

High resolution 3D survey systems have long existed especially for mechanical applications. Prototyping high resolution instruments have also been developed and used in the Cultural Heritage field in order to create accurate 3D models able to form a strong basis for reproduction, restoration and conservation purposes. Different solutions have been proposed that are: laser distance measurements on controlled mechanical tables, self-controlled harms, stand-alone instruments, etc. Different measuring principles have been successfully adopted: laser distance measurements, structured light, laser triangulation, etc.

All these systems have some limitations from an economic and technical point of view. The technical problems are due to the stability of the acquisition reference systems during the survey or to the need to have direct access to the object. The economic problems are due to the high costs of the instruments.

A new generation of high resolution and high precision scanners have recently been introduced: these try to solve both the previously mentioned problems. At a cost of less than the usual amount for a terrestrial scanner of low accuracy and with a direct survey in a 3D reference system materialised on the object, or nearby, these new instruments (the so-called third generation scanners) allow a complete surface of convex and concave objects to be scanned avoiding the necessity of moving the object from its natural location and without heavy instrumentation.

The paper describes this new generation of instruments, recently acquired by the Research Group, and a first comparison with old instrument generations is made in order to point out the new opportunities offered by them; the new applications in Cultural Heritage documentation and further developments of reverse engineering and prototyping in this domain are underlined.

Categories and Subject Descriptors (according to ACM CCS): J.6 [Computer-aided Engineering]: Computer aided Manufactory

1. Introduction

3D surveying is becoming more and more important in many applications fields.

In land, architecture and archaeological surveying applications the old approach concerning the 2 ½ D modelling has been replaced by modern technologies such as LIDAR, GPS, digital photogrammetry (generally called direct geo-referencing technologies) which allow an easy and attractive solution to a complete 3D survey approach.

While the previously described goal was achieved in the last decade, the complete 3D approach, with a high degree of accuracy (less than 1 mm), was approached in the past by many other industrial and scientific applications (e.g. Animation, Archaeology, Architecture, Dentistry, Education, Fashion and Textiles, Foot Wear, Forensics, Games, Industrial Design, Manufacturing, Medicine, Movies, Multimedia, Museums, As-built Plants Rapid Prototyping, Reverse Engineering, Sculpture, Toys, Mold Making, Web Design, etc.).

Many surveying principles have been adopted (e.g. triangulation, LIDAR technology, structured light, photogrammetry, holography, etc.) and the 3D survey has been realised using different solutions in order to guarantee the stability of the reference system.

The accuracies range from 20 µm up to 0.2 mm and a wide range of software solutions offer the technicians a complete and affordable approach to the 3D survey.

2. The stability of the 3D acquisition reference system: possible solutions

The accuracy of the 3D survey systems depends on two main factors: the accuracy of the single point acquisition and the stability of the reference system used during the acquisition of the whole surfaces.

As far as the accuracy of the single point acquisition is concerned, the adopted techniques are able to reach the required accuracy: LIDAR, triangulation, holography, digital photogrammetry, structured light, if well used, are able to obtain all degrees of accuracy.

The stability of the reference system during the acquisition process was solved in the past by considering the object as being movable inside an equipped laboratory or situated in a site where it is possible to install the instruments.

Laboratory instruments are based on two different solutions:

- a more classical approach, where the stability of the reference system is guaranteed only by using mechanical solutions (see Figures 1 and 2);
- advanced solutions, where the stability of the reference system is controlled by a mechanical and stable system and by a remotely controlled solution (see Figures 2 and 3)

Figure 1: ***Left*** **-** *CAM^{3D} an optical 3D sensor for fast and high-precision object shape scanning* ***/ Right*** *- The FARO Laser ScanArm the first ever seven-axis contact/non-contact measurement device with a fully integrated FARO Laser Line Probe*

Some portable Laser Scanner can be considered in the same class of high resolution instruments as a possible solution for reducing the volume of the instruments to be moved when the object cannot be displaced from its original location. In this case, the reference system is fixed by using a tripod and can be moved quite easily around and inside the object to be surveyed (see Figure 4).

Figure 2: ***Left*** *- Laser scanner used in the Digital MichelangeloProject* ***/ Right*** *- FastScan Cobra a single camera laser line scanner. It uses a built-in magnetic tracker to obtain the position and orientation of the scanner.*

Figure 3: *Leica T-Scan laser remotely controlled by the Laser Tracker*

Figure 4: *The Minolta VIVID Laser Scanner*

An analogous solution is the one adopted in hand-held scanners which use a built-in magnetic tracker to obtain the position and orientation of the scanner during the survey (the limitation is that only non metal objects can be surveyed because of interferences with the magnetic tracker. See Figure 2).

All the previously shown solutions consider the stability of the reference system during the acquisition to be guaranteed by the mechanical stability of the used structures and, obviously of the floor where these structures are located on.

If these conditions can be satisfied inside an ad-hoc laboratory and if the object has to be surveyed in other sites, the scanning is only possible if all kinds of vibrations are avoided during the acquisition phase. High resolution scanners usually have to be placed very close to the object and if a scaffold is needed, the reference system cannot be considered as stable as in the level of accuracy that is typical of this kind of instruments.

In order to avoid this kind of problem the solutions adopted is not to fix the reference system inside the instruments but on the object itself. These instruments are mainly based on a photogrammetric approach. (see Figure 5)

Figure 5: *TRITOP photogrammetric*

In these cases, an accuracy of less than 1 mm can be achieved by using calibrated digital cameras, strong image blocks and the scans of the recorded object have to be performed using special digital photogrammetry software (e.g. autocorrelation at a sub-pixel level, etc.). The acquisition phase is quick, but a control network has to be build and the post processing of the primary data can be heavy in terms of time.

The stability of the reference system is achieved assuming that the surveyed object is a rigid body during the image acquisition and the camera is stable during the exposition time.

3. Practical considerations

All the solutions that were rapidly and not so completely described in the previous paragraph have been realised to satisfy particular needs, so it is obvious that not all the possible external survey conditions can be managed in a proper way.

In addition, if the shape of the object is very complex (convex and concave surfaces like a pot or a jar or a statue) the mentioned systems can mean many scans have to be performed in different configurations of the system itself: in this last case, the single scan has to be registered at the end of the acquisition phase. Sometimes the object is small and many of the available systems cannot perform the scan due to the dimension of the devices.

A new 3D scanning system is described in the next paragraphs. This new solution (presented at the end of 2005) adopts some new solutions which can be useful to overcome the limits of the old systems, especially in the field of architectural and archaeological high resolution 3D surveying.

4. The HANDYSCAN 3D by CREAFORM

Produced by CREAFORM, a Canadian Technological centre for reverse engineering and 3D digital solutions, HANDYSCAN 3D has been classified as the third generation instrument of high resolution 3D scanners.

It has been presented as the first self-positioned hand held scanner in the world.

The basic idea of this instruments is very simple (it is a digital photogrammetric system) but the adopted solutions represent a true novelty from different points of view in the Cultural Heritage surveying field.

The first interesting aspect is the dimension and the weight of the acquisition unit which can be handled for long periods without stress for the operator and it allows the possibility of obtaining all the details even in the case of very complex objects.

The second attractive aspect is the possibility of acquiring objects of different dimensions: from small objects (e.g. rings, fragments, etc.) to very large objects (e.g. statues, large epigraphs, etc.).

Figure 6: *Handyscan 3D: the acquisition unit (980 g, 160 x 260 x 210 mm, ISO accuracy: 20 µm + 0.2L/1000)*

Finally, the third attraction is the price, which is lower than the current quotations of the less accurate terrestrial laser scanners, even considering the laptop for the storage and the visualisation of the acquired data.

4.1 The acquisition phase

The acquisition unit (see Figure 6) contains two digital cameras mounted onto a rigid body. Four laser spots are placed around each lens and, at the bottom of the handle, there is a special laser tracker which is useful during the acquisition process to mark the surveyed points.

Before starting the survey, the instruments have to be calibrated both as far as geometry an radiometry are concerned.

The geometric calibration is performed by using a special control plate which is provided with the instruments (see Figure 7). The scope of this phase is to refine the relative orientation of the two digital cameras in order to avoid small movements of the mechanical components that accour during the transportation or due to the change in environmental conditions and so on. The geometric calibration fixed the base of the photogrammetric system and so the scale of the survey.

The radiometric calibration aims at setting the photographic parameters for the two camera lenses and the intensity of the laser tracker in order to speed-up the measurement process. The radiometric calibration is performed by acquiring some parts of the object with a common texture. If the object has different colours and/or illumination conditions this procedure has to be repeated before starting the acquisition on the portion of interest. (see Figure 7).

Figure 7: *The geometric and radiometric calibrations of the HANDISCAN*

Before starting the 3D survey, the reference system has to be fixed. Several reflective targets (small 6 mm diameter circles) are fixed to the object using an irregular mesh with sides that can reach up to 10 cm. Using the two stereoscopic cameras and the eight spots around them, the reflective targets are surveyed and placed in a unique reference system which is now fixed on the object. If the object cannot be marked directly, it is possible to build-up a control network using other solutions.

In addition the operator defines the volume in which the object (or a portion of it) is contained. This volume is subdivided into voxels. It is possible to choose among three different resolution levels: low, medium or high. For the low resolution, the surveyed box is divided into 2.1 Mega voxels; the medium into 16.8 Mega voxels and the high into 134 Mega voxels. There is therefore a ratio of 1 to 8 between the medium and low resolution voxel numbers and the same between the high and medium resolution voxel numbers.

Figure 8: *Placing the reflective targets on the object.*

The dimension of the voxels (the resolution of the survey) depends on the dimension of the acquisition volume. If high resolution is required, the object has to be split into different scans which are oriented in the reference system of the acquisition thanks to the previously acquired reflective targets. The accuracy is always the highest accuracy of the instruments (see Figure 6 comments). Finally, the acquisition can be started: the operator has to check the distance between the acquisition unit and the object (red and green leds on the top make this possible in a practical way) and, by looking at the laptop, control the completeness of the acquisition that is displayed in real time as an STL format model.

During the survey, the stereoscopic cameras perform the absolute orientation using the previously acquired reflective targets.

At the end of the acquisition, the recorded data are: the target positions, directly acquired points, STL format 3D model.

4.2. Data processing

The handling of the data can be performed using one of the well known software packages (e.g. RapidForm, 3Dmax., etc.). CREAFORM has a special link with Geomagic Studio which can directly manages the data from the HANDYSCAN3D system.

The accuracy of the acquired data, their flexible resolution and the real time check of the completeness of the acquisition phase are the best requirements for a quick and correct model approach.

5. First experiences

The Geomatic research group of the Politecnico di Torino is the first Italian institution equipped with this system and it is testing possible applications of the HANDYSCAN3D in the field of Cultural Heritage Documentation. The activities are supported by the Italian Ministry for Research in a National project (PRIN2004), coordinated at a national level by Prof. Carlo Monti.

The first experiences were developed on two different objects: the Melograno Fountain (in the Issogne - Valle d'Aosta Region –Italy. Melograno means pomegranate tree) and some damaged parts of the Holy Shroud Guarini Chapel (in Turin – Piedmont Region – Italy. Destroyed by a fire in 1997 and now under restoration).

Figure 9: The Melograno Fountain and the Holy Shroud Guarini Chapel after the fire.

5.1 The Melograno Fountain 3D model

The Melograno Fountain requires a protective covering of the inside part of the stone made base because the water is destroying the old stones.

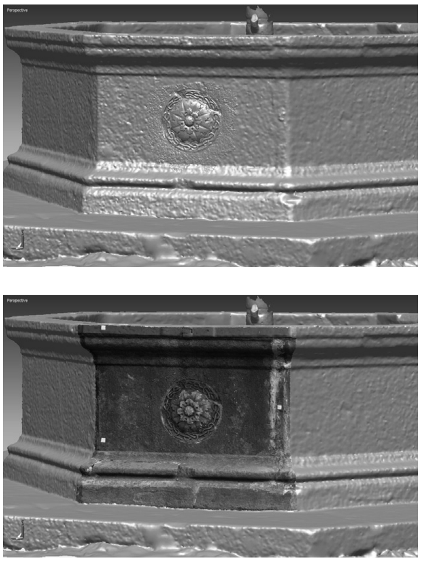

Figure 10: *The multiscale model of the Melograno Fountain (surface and image mapped surface)*

The restorers decided to protect the stone using a special plastic material which had to be modelled exactly following the shape of the interior (see Figure 11). The accuracy required is of about 2 mm. No terrestrial scanners can be used because the lack of accuracy that occures during the modelling process. The surface to be scanned is very large therefore the placing of the reflective targets was a long process and it was subdivided in 8 different scans. The exterior surfaces of the stones was surveyed using a terrestrial laser scanner (RIEGL LMS-Z210) and the decorations again using the HANDISCAN3D. All the three types of scans have been connected using a control network surveyed by traditional topographic instruments. Figure 10 shows the result of the integration in a multiscale 3D model of the stone parts of the Fountain.

5.2 The Holy Shroud Guarini Chapel restoration

The restoration of the Guarini Chapel requires many different professional skill. A multidisciplinary team (coordinated by Arch. Mirella Macera) is working on the different aspects using the most advanced techniques.

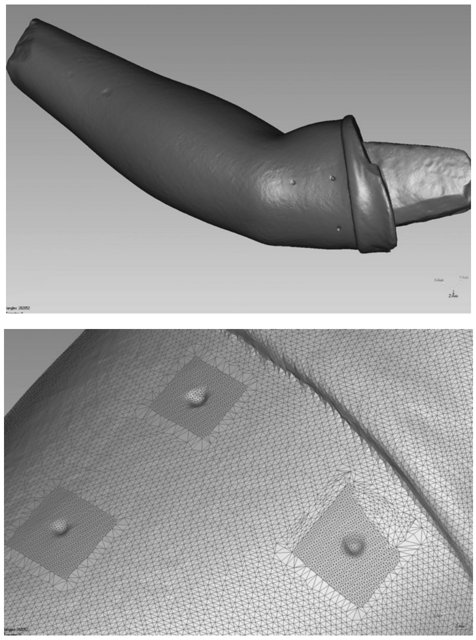

Figure 11: Guarini Chapel: 3D model of a part of a statue's arm (above) and the multiscale model .

As far as the restoration of the decorative stone part of the inside surface of the dome is concerned, the restorers have two main problems: for the restoration of the chapel, they want to replace the destroyed elements with original materials (mechanical carving stones) or other synthetic materials. For the restoration of the statues, the specialists need a 3D model in 1:1 scale in order to design the mechanical solutions for the placing of the original parts detached by the fire.

Figure 12: *Survey of the stone decorative elements of the Guarini Chapel on a scaffold and 3D model*

HANDYSCAN3D was used in both cases, thanks to its adaptability to extreme work conditions. The survey of the stones to be replaced by 1:1 models had to be done from a scaffolding (see Figure 12) and with an accuracy of about 1 mm, no traditional instruments could therefore be used due to the vibrations of the scaffolding. The replica of the detached components of the statues requires final accuracies of less than 1 mm.

5.3 Practical considerations

Considering the two previously described experiences and other tests performed on different shaped objects it is possible to highlight some interesting properties of the HANDYSCAN3D.

The system is easy to transport and can be managed by a single person.

The acquisition software is very easy to use and self documented: the short course (2 days) provided by the CREAFORM team (EUROFORM3D for Europe) is sufficient to be independent in the acquisition phase of the 3D model. The real time check of the STL model during the survey allows the holes of the scanning to be completed on the field and the subsequent data processing for segmentation and modelling are therefore, quicker and simpler to perform.

The acquisition runs very rapidly therefore the required time only depends on the shape and complexity of the object to be surveyed.

The reference system fixed on the object (or around it) allows acquisition in all cases where more traditional instruments with the same accuracy can make a survey impossible or at least very difficult.

The possibility of using different scan resolutions allows a logical and coherent acquisition: high resolution only has to be applied when necessary. This possibility avoids the need of strong decimation of the data during the modelling process.

6. Final considerations and “to do list”

Obviously, it is not possible to give a definitive answer concerning the use of HANDYSCAN3D in Cultural Heritage Surveying, but the first results are surely encouraging.

In the next months our research group will:

- expand the test fields in order to test different materials and shapes;
- study the techniques that are useful to orient digital images in order to map the 3D models;
- analyse the metric accuracy of the instruments in different acquisition procedures.

CREAFORM has set up a “HANDYSCAN User website” where the users can share experiences and contact the development team: this is a good initiative to offer producers interesting subjects to improve the performances of this instrument.

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Short Papers

Photo-Tacheometry

- Recording Geometry and Creating a 3D-Model On Site and in One Step –

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Abstract

Photo-tacheometry very tightly combines elements of classical photogrammetry and tacheometric polar coordinate determination. It is a fast, highly automated method, predestined for mainly flat-surfaced regular shaped buildings and monuments. Geometry and photo realistic 3D models are obtained in one step on site. So completeness and correctness of the recording are controlled step by step when establishing the model. There are different automation levels in photo-tacheometry. A rather high degree can be reached when using a motorized total station, which is the method described here. A first example is given for its practical use. The need for futural developments is discussed and ways for the augmentation of its effectivity are shown. A main matter of concern is to make potential users curious to adopt this new comparatively inexpensive method into their own spectrum of recording methods.

Subject categories: photo-tacheometry; laser scanning; photogrammetry; low cost technology; 3D-model, architectural surveying; video-tacheometer; cultural heritage documentation

1. Introduction to an innovative measuring method

The term photo-tacheometry indicates that this is a very close synthesis of core elements of the well known recording methods photogrammetry and tacheometry. There is no similar approach to be found in literature except some former papers of the same author (SCH5 a, b, c). Although developed in the last three years photo-tacheometry has still to be called an innovative method for architectural recording: its working mode and its effectivity are not yet in the mind among experts. Photo-tacheometry is now in a state where the optimisation of practical aspects gains importance. Although it is a fast cost saving method it is hardly known and not practised by the users. Reason for this is that in general "geodetic" recorders are not familiar with the photogrammetric components while recorders with photogrammetric background are not familiar with the possibilities of notebook controlled motorized total stations.
Photo-tacheometry has many different facets; there are different stages of operation, different degrees of precision attainable, different methodical ways to come to results and to control them. In this short paper it is not possible to demonstrate all different functionalities of photo-tacheometry. However apart from some more general information some components are explained and a practical example is given.

2. Main features of photo-tacheometry

Application of photo-tacheometry only requires a few well known, common instruments: a reflectorless measuring notebook. Preferable is the use of a motorized total station, which is connected with the notebook by Bluetooth. The motorization and the spatial separation between the controlling notebook and the instrument enable some special measuring modes and a high degree of automation. This will be shown later.
The main idea behind photo-tacheometry will be explained using one typical very simple example, which demonstrates, how coordinates and texture can be generated together in one step.
A precondition for every work with images in photo-tacheometry is their exterior orientation. This preparatory procedure is closely integrated into the workflow; since the total station is used on site, identification and referencing are done fast and in one step. After orientation the image is fixed with the (global) coordinate system and available for all ongoing work as well as for possible densification of the network to be done much later.

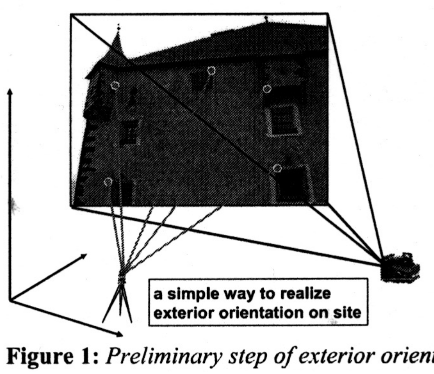

Figure 1: *Preliminary step of exterior orientation*

Afterwards the typical proceeding of photo-tacheometry may start. Coordinates are determined by a mixed tacheometric-photogrammetric procedure:
In the example the user decides that the surface in question is represented by a plane. **First** its geometry in **general**, that means their position (not the dimension of the wall and not the boundary) is determined by tacheometric measurement. In the **next** step a rather simple approach follows: boundary points in the image are clicked at, defining the boundary of the shape derived from the tacheometric measurement. The intersection of the image-rays (starting from the projection centre through the image boundary points) with this shape provides the enclosure of the surface; this is the photogrammetric part in photo-tacheometry. In this second step the coordinates are calculated from the intersections **and** the texture of the surface is cut out from the image at the same time. In practise the second step is realized by a simple click into the image reconstructing the ray from the oriented camera position to the object. This general mode of operation is possible because the preliminary exterior orientation of the image was done. The simple procedure is demonstrated in figure 2.

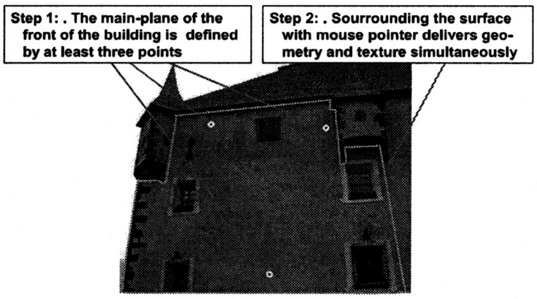

Figure 2: The *general procedure- a fundamental tool*

Again: the general form and the position in space of the (regular, i.e. flat) shape of a building are determined with the total station while the point **coordinates and** the **texture** result from the intersection of the reconstructed image rays with this shape. This way to act is fundamentally different from the well known approaches with multiple images. It is possible in this way because tacheometers nowadays allow reflectorless measurements.
Using a motorized total station enables to measure the shape faster: The image as well as the total station are oriented in the same coordinate system. This allows to steer the instrument **exclusively** by click into the image.

So after the images are oriented the user is free to work close to the building taking advantage from the Bluetooth connection from the notebook to the instrument.
In order to show the fundamental differences to the well known recording methods a brief description of these approaches is given: The aim of all methods is to create a virtual model of the object with as few characteristic points as possible. In laser scanning in order to achieve this, a huge number of single points is recorded of which none has a direct connection to the object. This point cloud is used to generate regular surfaces which then are intersected to get a geometric model. Finally this model will be covered with texture from the image of the object. - In photogrammetric image based modelling object geometry is generated from intersections of directions from the positions of the cameras to the object. A disadvantage is the need for overlapping images, taken from different points in space and the fact that the accuracy depends on the distance to the intersection points. - Using traditional tacheometry the geometric model is defined by point measurement and often the texture is derived from rectified images, which is a rather time spending procedure.
So, what are the advantages of photo-tacheometry?
The procedure explained here at first glance seems to be rather complex and neither economical nor simple. However, the process itself is in fact rather fast, comfortable, robust, exact and efficient, usable without detailed knowledge about the theoretic background and therefore a real alternative to photogrammetry as well as laser scanning or conventional tacheometric recording. This of course also depends on the individual characteristics of the object. In the procedure described above, the surfaces of the building have to have sufficiently regular shapes like plane, conic, cylindrical or spherical. In this case there are large advantages in comparison to the other methods (see figure 3). Results are obtained immediately on site. So correctness and completeness of the 3D-Model can be checked immediately.
In comparison to photogrammetry distance to the camera does affect the accuracy much less: in photogrammetry there are at least two straight lines intersecting at an angle depending of the basis' length; in phototacheometry only one straight line is intersecting a solid (in the example a plane) more or less orthogonal. A study dealing with this theme will be published later. - In comparison to laser scanning the method is more efficient as long as the recorded object is not too complex.
On the other side irregular planes may be captured quickly

	Phototacheometry	**Laser Scanning**	**Photogrammetry (image based modelling)**	**Traditional Tacheometry**
acquisition cost regular expenses	moderate, instruments often already available (1) moderate (1)	high (3) domestic evaluation (2)	moderate (1) domestic evaluation (3)	instruments available (1) high (3) (as method is slow)
overlapping of images	not necessary (1)	not necessary (1)	necessary (3)	not necessary (1)
results on site	yes (1)	no (3)	no (3)	no (3)
accuracy	relative high (1)	relative homogenous (2)	depending on base to distance ratio (2)	high and homogenous (1)
recorded complexity	low - medium (2-3) in the actual state	low-high (1)	low-high (1)	very low (3)

Figure 3: *Comparison of photo-tacheometry with familiar methods when visualizing regular shaped objects (from 1= good to 3=bad)*

as well, using a representative net of triangulation points (see below).
However, only long-term practical use of the method under different conditions in the field will provide more accurate information. In the preceding chapter a typical functionality of photo-tacheometry was explained. However the combination of different tools embedded in a workflow is of special interest for practical work.

3. Examples for the work with different tools

Thanks to the notebook-controlled, motorized reflectorless measuring total station a manifold automated measurement procedure is possible (more comments on extensive automation in chapter 4). It has to be stressed again that the method allows the determination of the geometry and the texture-elements not only in an extremely effective, fast and comfortable way, but also featuring comparatively high geometric precision (see figure 3) with redundant control of the process [Sch05a]. The software relieves the user of many decisions and considerations.
In the example depicted in figure 4 the step of exterior orientation was done (see figure 1). This allows to steer the instrument exclusively by click into the image. So by three simple clicks the main plane of the building is defined. It has to be remarked that **positioning** these points has not to be very exact, because they only define the exact position of the shape in space but they do not serve for the direct determination of the **dimensions**. Like demonstrated already (identical to figure 2) the geometric model is obtained in the next step by cutting out the surface texture polygonally. Simultaneously with the texture by these clicks into the image the 3-D geometry is calculated.
In the next step (step 3 in figure 4) the knowledge about the parallelism of planes is used to minimize the effort. If one can assume that the surface of the oriel is flat and sufficiently parallel to the main plane defined in step 1 it is sufficient to tell the software to define a parallel plane and to make one single click onto this plane. This will cause the total station to turn to this point and to measure the coordinate corresponding to the clicked point in the image.
The software calculates the parameters defining the parallel plane. In next step (4 in figure 4) the texture is cut out polygonally and the corresponding 3-D coordinates of the oriel are calculated automatically in the same step. As there are often parallel or rectangular planes work proceeds rather fast, using adequate software tools.
In figure 4 some more steps are denoted. It is very helpful and time saving for all following steps that those points already measured are marked in the layer of the image. These may be points which are either measured directly with the total station or calculated by means of photo-tacheometry in the former steps. The outcome is a 3D-object model (see figure 5) on site.
In the preceding chapter regular surfaces were defined by tacheometric measurement followed by mathematical modelling of the shape. If the surface however is not sufficiently regular (a possibility to control is mentioned at the end of chapter 4) it may be helpful to create a triangulation net of points simply by mouse-clicking on characteristic image points. As explained before the total station is then steered in an automatic process to the corresponding point of the object. The coordinates of this point are determined automatically and the texture of the triangles is cut out. In both cases the very efficient tacheometer-control and the steering by a simple click on image points with the cursor are responsible for the method being highly economical. All the time the user exclusively uses the notebook which is linked to the total station by the bluetooth connection.
Thus someone is able to select the characteristic object-describing points of an irregular object surface on site and face the object directly: this provides notable advantages in order to achieve high quality recordings. In this measuring mode no direct manual contact is necessary to operate the instrument, no movements around the tripod do occur et cetera. Thus the total station may potentially be situated at an elevated point guaranteeing a better view to the object.
Obviously, this procedure is excellently suited for fast and cost effective recording of an object's surface-topography. An analogy to topographic terrain-surveying is unmistakable:

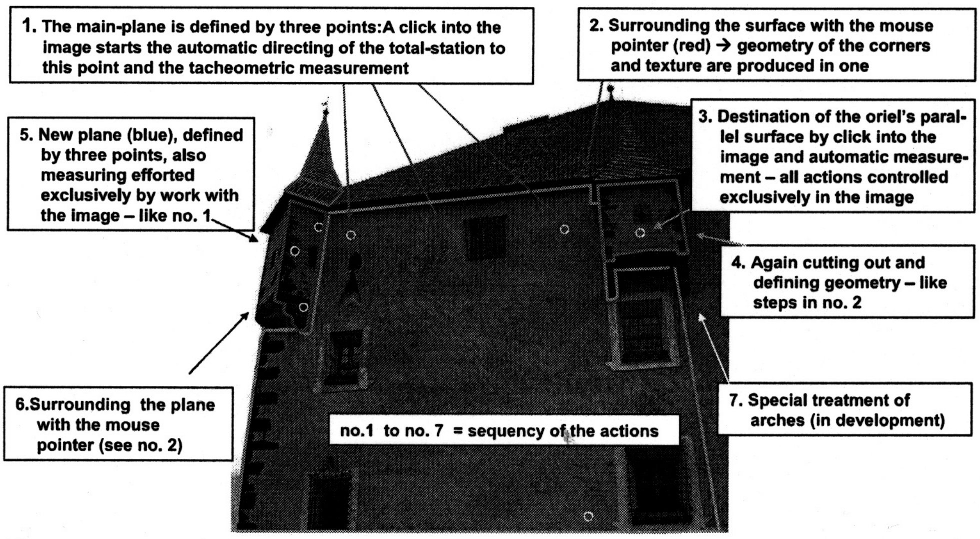

Figure 4: *Example for the work with geometrical primitives: all functions steered by the image*

Relatively few points may be needed to record an area while still obtaining a good model of the surface (see rocks in fig. 5). The recording of the morphology of an irregular surface enables deformation-faithful recording of the object in one step. Besides the manual construction of a triangulation network also a regular grid may be used. In this case a slow, but fully automatic recording of smaller regions is possible. The resulting point cloud may be treated analogous to the proceeding in laser scanning (example in SCH05c)

Time consumption for this way of recording (from the beginning up to the final model) is shown in table figure 6. According to this the work steps marked with three different colours in figure 4 do require approximately 5 minutes.

Figure 5 shows the resulting virtual 3D-model (VRML).

As long as the object's surface is not too complex, not too irregularly bent and/or not too ornamentally designed, photo-tacheometry is superior to the other methods mentioned above. All the other approaches also do not offer the possibility to control accuracy and completeness at any time and on site.

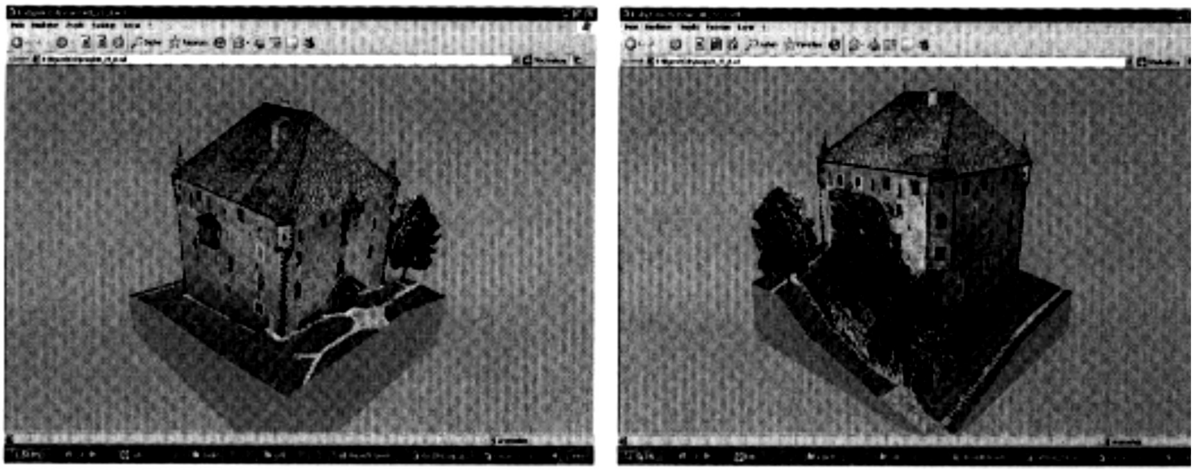

Figure 5: *3D-model of Ciastel Colz in La Villa, Alta Badia, Northern Italy*

preparational work (i.g. similar in photogrammetry and laser scanning)	positioning the total-station	5 min
	orientation in the network	2 min
	take a picture	1 min
	orientation of an image	2 min
work with the image	- select an image	20s
	- define a main-plane by 3 or 4 points	20-25 s
	- „cut“ to define coordinates and texture	4s/pt
	- definition of a parallel plane	10 s
	- definition of a perpendicular plane	20-25s
	- cone / cylinder	1min
	add a segment	30-40s
	define boundaries	4s/pt

Figure 6: *Time involved*

4. Some additional aspects

- It is frequently desired to be able to work on site very close to the architectural object, like for example in the fields of building research and building documentation. In these cases the phototacheometric way of measuring as shown here is predestined. However, if time on site is short, only minimum requirements have to be fulfilled: In the example in figure 4 only the coordinates of those points marked with circles would have to be measured on site, which are the ones determining the geometrical primitives. The rest of the data required to recover the geometry and the texture can then be generated off site in the office.

- While surveying large objects or in case high accuracy is crucial the network of surveying points has to be adjusted. However, there is no conventional polygonal net necessary. The net may rather be constructed in a more organically way by adding the local net of each standpoint, using easily identifiable natural object points. That way it can expand together with the project.

-The grade of detail can be augmented any time later as there are well destined points of high quality everywhere available at the object.

- Figure 7 shows three different levels of development of the method: a simple manual one (no1) , the motorized way as illustrated and recommended in this paper (no 2) and the future photo-tacheometry equipped with video total station as an extension of the motorized total station (no 3). In order to work with photo-tacheometry basically (no 1) it is not obligatory to work with a motorized total station. However it is much faster and giving more possibilities to control the measuring procedure. Video total stations do already exist and have been tested [Jur05] [Top05] [Wal05]. This new type of instruments featuring built in cameras to observe the object directly –and also combined with "externally" made images like described here- will surely have an impact on automation. They will make measuring more efficient in two ways:

a. some steps will run faster and improve performance

b. more sorts of building details may be recorded in a

Expansion stage	Tacheometer	Camera	Notebook	Conclusion
1 simple	reflectorless measuring total-station	good consumer-camera	connected to the total-station by cable	time of recording much longer than in stage 2; offers low comfort
2 recommended and described in this paper	motorized reflector-less measuring total-station	good consumer-camera or photo-grammetric camera	control of total-station without cable (bluetooth here)	high degree of automation, minimum recording time; redundant control
3 fully available in the near future (?)	video-total-station (= image assisted total-station = IATS)	see above	see above	feature extraction, extensive automation

Figure 7: *Stages of expansion depending of different hardware*

simple way by extended capability in regards to small-scale objects.

This will be possible by using feature extraction in image interpretation [Rei04].

-In the former paragraphs was said that correctness may be controlled on site. Off course this may be done more visually by controlling the growing 3-D model, however there is also the possibility to use the fact that the total station is motorized for a sort of automatic control of the coordinates derived from cutting out surface (shape) surroundings: the total station can be told to point to the calculated object coordinate and then make an independent measurement. This method may also be used as a certain control how good the geometric primitive (i.e. plane, cylinder) fits with reality. Questions of precision and accuracy will be discussed later in another paper.

- There are often some special structures to be found at architectural monuments which appear repeatedly. They have for example the form of fascia or there are recurring single elements. We are going to develop specific tools to enable recording of this kind of object geometry quickly and accurately especially with regard to visualization. Generally the efficiency of photo-tacheometry has to be augmented for applications on objects with more complicated surfaces.

- At present the software controlling the instrument and the image processing is being improved continually. The integration with AutoCAD as visualization platform is realized. The implementation of some more special tools will help photo-tacheometry to become a more and more respected method alongside the well known and well established ones.

5. Summary

In this paper initially the fundamental functionality of photo-tacheometry is explained, namely the destination of coordinates derived from only one oriented image on one side and from the shape of the surface of the object (only the geometric primitive which is determined from measurements with a total station. and not the 3D-model !) on the other side. Especially in this context it is of interest that the motorized total station may be steered but by the image. A practical example for the use of different tools and for the workflow is given. Some comparisons with the common methods used for visualization show that it is worthwhile for users and providers of services in the field of recording of buildings and monuments to get familiar with photo-tacheometry as a fast time-saving recording method using no special hardware but hardware which is widespread. Explaining the operating mode of photo-tacheometry has proven to be rather difficult. However it has to be underlined that in practice the method is easy to handle. For its use no deeper knowledge of photogrammetry or intelligent tacheometry is necessary.

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Short Papers

The e-volution of Stereoview Technology in CH data

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Abstract

This paper promotes the replacement of subjective interpreted manual sketches by objective stereoview Technology, which, in the field of Cultural Heritage is more than overdue.
It is liked to emphasize, Stereoviews, possibly better known as 3D-imagery, are extremely well suited, to become a common approach for particular e-documentation of World Cultural Heritage.
This paper provides both, current research as well as practical results in this field of 3D-visualization Techniques as state-of-the-art tools for recording, documentation, interpretation etc., concentrating on Cultural Heritage.
After this introduction chapter it is intended to submit an idea of the outstanding documentary value of 3D-images and of its broad range of applications by presenting masterpieces for historic as well as for recent 3D-photography. In this context it is also liked to refer to the authors`RecorDIM-website 3dsite.icomos.org. Since these samples represent huge collections of Heritage Stereoviews, the following part deals with international 3D-image-archives.
The next chapter is on gaining "3D-niche-photography" based on a telescope-rod-platform Lite. This means ground born (!) extremely high resolution (digital 3D-) aerial photography, showing about 10 m height, which for large scale Cultural Heritage mapping obviously promises a great future. It is anticipated, this digital low budget Technology will spread enormous in the very next future.
In the following are highlighted advantages for the practical use of Heritage stereoviews,e. g„
- ***the still underestimated effect of gaining a complete additional dimension and***
- ***advantages of 3D-visualization for the enhancement of spatial structures, as well as***
- ***pointing to the extremely high detail resolution and to***
- ***the queue "sketch, 2D-photography, 3D-photography, which is strongly understood as an increasing degree of comparison!***

Finally there will be presented a completed list of virtual 3D-visualization-methodology, including "Down-Under"and Felix-Solid-State type 3D-screens to replace the 2D-PC(-screen).

Categories and Subject Descriptor (according to ACM CCS): I.2.10 [Documentation]: 3D/Stereo-scene analysis

1. Introduction

This paper promotes the replacement of subjective interpreted manual sketches by objective stereoview Technology, which, in the field of Cultural Heritage is more than overdue.
It is liked to emphasize, Stereoviews, possibly better known as 3D-imagery, are extremely well suited, to become a common approach for particular e-documentation of World Cultural Heritage.
This paper provides both, current research as well as practical results in this field of 3D-visualization Techniques as state-of-the-art tools for recording, documentation, interpretation etc., concentrating on Cultural Heritage.
As a homage to the Joint Conference on the e-volution of Information Technology in Cultural Heritage in Nicosia, Cyprus, Figure 1 shows a masterpiece of a Heritage stereoview of the ruins of the temple of Apollo in Curion

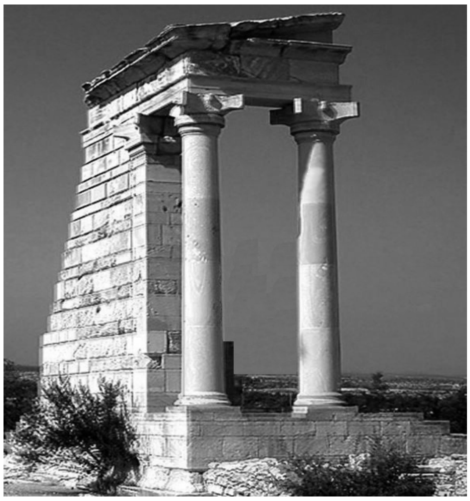

Figure 1: Masterpiece of a Heritage stereoview of the ruins of the temple of Apollo in Curion (Cyprus)

Figure 2: ***Manual sketch of the ruin of the temple of Apollo in Curion (Cyprus) (modified according to Witte), compare Figure 1***

(Cyprus) in the color anaglyph mode. Use red/magenta color anaglyph glasses to catch the full 3D impression.
A comparison of Figure 1 and 2 already proofs the superiority of Heritage Stereoviews over manual sketches.
There is no doubt, the importance of Heritage Stereoviews will increase with the digitization rate with sufficient resolution, expecting an "e-volution" of Stereoview Technology in Cultural Heritage

2. Masterpieces of Heritage Stereoviews

It is intended to submit an idea of the outstanding documentary value of 3D-images and of its broad range of applications by presenting masterpieces for historic as well as for recent 3D-photography. In this context it is also liked to refer to the authors`RecorDIM-website 3dsite.icomos.org. Since these samples represent huge collections of Heritage Stereoviews, the next chapter deals with international 3D-image-archives.
The following samples of outstanding existing historic masterpieces for Heritage Stereoviews today are part of the famous Keystone-Mast collection, see Figure 3 until Figure 5 and Chapter 3.
Figure 6 and Figure 7 show recent masterpieces for Heritage Stereoviews, taken under "expedition-constraints" with a single lens-camera, after the processing of color anaglyphs, finally to convince the user, *the queue "manual sketch,* 2D-photography, 3D-photography", strongly should be understood as an increasing degree of comparison. This means, sketches would never allow to obtain the brilliance of color Stereoviews.

Figure 3: Two Masterpieces of the Keystone-Mast Collection representing approx. 50000 historic heritage Stereoviews, dating approx. 1905:
-Buddha of Kamakura "Dalbutsu"in Japan(top)&
-Interior Throne Room Beijing, China (below)

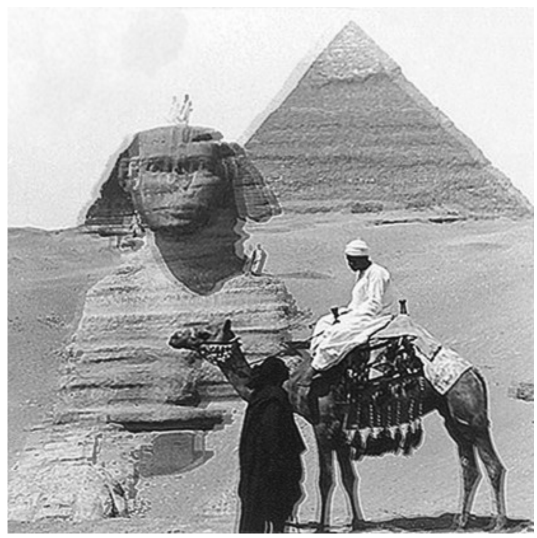

Figure 4: Early Heritage stereoview of Egypt, dating approx. 1905 presented as color anaglyphs (recognize a person climbing the Sphinx)

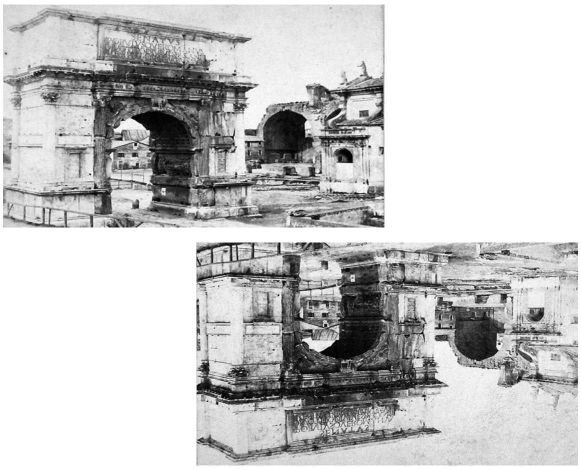

Figure 5: The Titus Arc of the Forum Romanum presented in the "Down Under" mode for stereo- strip- and/orfor stereo-panorama--imagery. Use a mirror to percept the right beside the left image.

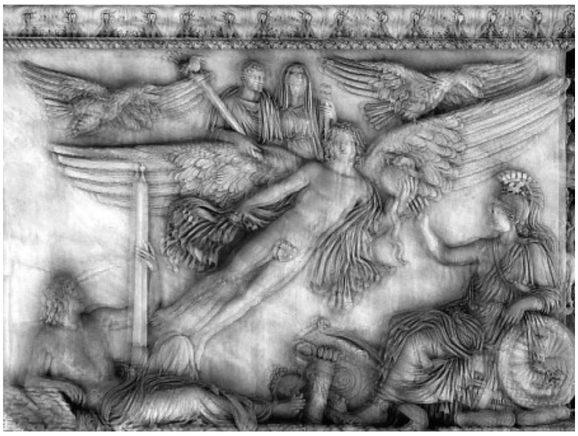

Figure 6: Heritage stereoview Masterpiece: column base:Antoninus Pius(138-161AD) (Martian field, Rome: Vaticano Museum) by W.Schuhr

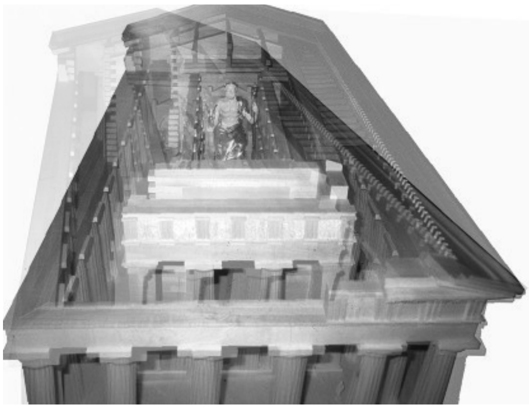

Figure 7: Current Heritage stereoview of the Zeus statue in Olympia (Greece), one of the 7 wonders of the world (author's 3D-image of a model)

3. International 3D-image Archives

3D-images are a particular key to the spatial past, a real treasure, still waiting for a rediscovery!
A synoptic overview over international archives, collectors and distributors with particular reference, but not limited, to the United States, see[W02]. The current main activity in the e-volution of Stereoview Technology is managed by Steve Thomas head of the CMP/UCR Keystone-Mast Collection, where approximately 50000 historic Heritage Stereoviews, of a total amount of 350 000 Stereoviews, will be digitized, see Figure 2 until Figure 5 for samples
The HAN 3D archive in Seoul (South Korea) is another sample of a very important archive for unique specimen of National Stereoviews.
Beside gaining some 10 000 recent international Heritage Stereoviews, the authors purchased a so far unknown historic collection of stereo-glass plates (unicats) from Switzerland.
To maintain the list of archives of 3D-photography, our international colleagues are kindly requested to continue in informing the authors under the email address as mentioned before, about so far unknown and/or not distributed collections of Stereoviews, "which show no www-presentation".
First attempts have been made, to define an optimum pixel size for the digitization of Heritage Steroviews (see Figure 8): In case of Figure 8 an original stereo pair of a conventional aerial photograph showing a 1:50000 scale has been interpreted with respect to different types of objects, like buildings, traffic lines, topographic objects, the DTM etc.. In addition this stereo pair has been digitized with ground pixel sizes ranging from 2,5 m until 40m. As expected, the stereo effect of the original model gives the highest interpretation aid. But it is liked to point out, the interpretation of the model showing 2.5m ground pixel size is almost like the interpretation of the original, while an increasing pixel size shows a decreasing confidence in the interpretation. From this the minimum digitization rate for a Heritage stereoview should be not less than 500 dots per inch, which here corresponds to the 2.5m groundpixelsize in 1:50000. Of course further practical research work in this field of e-volution is very welcomed and highly recommended, compare [FGM01].

4. 3D-niche-photography

It is the authors' concern, for documentation purposes, consequently to replace subjective manual sketches by objective (3D-) photography to the greatest possible extend,
To tackle this task, first time extremely high resolution low altitude aerial (3D-) photography from an 11m carbon telescope-rod, like in Figure 9 and from captive balloon (see Figure 11) successfully has been applied and will more and more become an objective tool for a huge range of documentation purposes, in particular in archaeology, see Figure 9 to 12. Depending on the height, the base length for the light digital SONY Cyber Shot 5 Mega pixel cameras showing and remote control has been varied. This"3D-niche-photography"is also well an 11m carbon

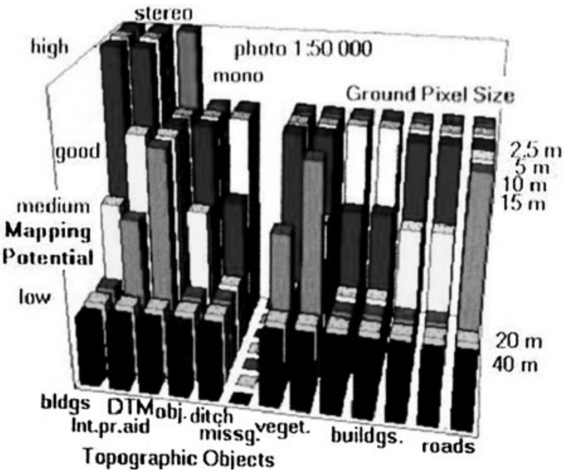

Figure 8: The optimum resolution for the "e-volution" of Stereoview Technology in Cultural Heritage

telescope-rod, like in Figure 9 and from a captive balloon (see Figure 11) successfully has been applied and will more and more become an objective tool for a huge range of documentation purposes, in particular in archaeology, see Figure 9 to 12. Depending on the height, the base length for the light digital SONY Cyber Shot 5 Mega pixel cameras showing and remote control has been varied. This"3D-niche-photography"is also well suited under expedition constraints and promises a great future.

As a matter of fact, in many cases Cultural Heritage Stereoviews can be obtained with single lens cameras, preferable showing in maximum 5 degree convergence angle for the directions of the optical axis., see also [SchK05].

It is highly recommended, to take a sequence of stereo mates with different baselines and to decide for the optimum stereo model afterwards, instead of believing in the a priori calculation of just one optimum base length, which might produce disappointing results regarding the expectations of the spatial perception.

5. Advantages of Heritage Stereoviews

3D-visualization Techniques are increasingly becoming state-of-the-art tools for recording, documentation and interpretation purposes etc., not only in CH.

The enumeration of the long list of possible applications of stereoviews in the areas of Arts and Science, Engineering, Economy, Information Technology, in the social as well in the daily life, ranging from, e.g., 3D-Newspaper to 3D-TV and from public 3D to the virtual museum, already exceeds this paper. Therefore in the following are highlighted some practical aspects in gaining and in applying 3D images, concentrating on CH.

3D imagery show particular advantages for the visual enhancement of spatial structures (e.g., relief enhancement), see Figure 11 and 12.

Heritage stereoviews become increasingly used in Rock Arts and in the field of inscription perception in CH (compare Figure 11) etc.

Figure 9: The digital 3D-Rod-Camera Lite with remote control doubtless becomes the most common sensor for extremely close range aerial photography (experimental study)

Figure 10: Sample for a low altitude Heritage stereo pair to replace out of date manual sketches (captive balloon 3D view of the Ecclesiasterion in Patara,Turkey; carried out by Dipl.Ing.St.Kiel)

The stereoview of a carved stone of the antique theatre in Tlos (Turkey) in Figure 12 is a sample, which, due to a proper choice of the base-to-distance ratio (here of about 1:2) clearly enhances near plan structures and is clearly superior even over so called expert sketches, compare [ABCL03]. Figure 12 also indicates the extremely high geometric and radiometric detail resolution of about 1mm pixel size and even better(!), which so far is superior to any

other 3D-medium- range surveying methods, including 3D Laser scanners, see also [AR05].
The combination of the left image of a stereo model from 1978 with a recent right image in Figure 13 stands for using Steroviews for Change Detection purposes.

Figure 11 Sample for Inscription enhancement by Heritage stereoviews in Tlos (Turkey)

Figure 12: Heritage 3D view enhancing the spatial structures of a carved stone of the antique theatre in Tlos (Turkey),

6. The completed list of virtual 3D-visualization methodology

For high resolution 3D-perception even historic stereoscopes like, e.g., of the Wheatstone and Holmes type etc., are still in use. Today, in the digital age, there seem to be tendencies, to create a kind of "digital stereoscope" for everybody, by suited software on a PC. In case, stereomates of an object are available, it is highly recommended, to process so called color anaglyphs for this stereomates. The perception of color anaglyphs in magenta and cyan allow an effective and cheap perception of digital stereo images in color. Yellow/cyan glasses instead of magenta/cyan glasses might even show a slightly better color perception. The Felix Solid State type 3D-screen even seems to be a candidate to replace the 2D-PC(-screen) generation in the next future, at least partly.

Figure 13: Multitemporal Stereoviews for Change Detection purposes near the Monument of Otto v. Guericke (Magdeburg, Germany)

7. Conclusions

This paper deals with new aspects of the e-volution in 3D-visualization Techniques as state-of-the-art tools for object recording and documentation,, as well as for interpretation and application purposes, with particular respect to CH. It shall convince not only professionals but also amateurs, to prefer 3D photography instead of still sticking to common 2D snapshots.
Summarizing, the popularity of 3D-Visualization Techniques, including samples and applications, still is not in coincidence with its importance [SchK00]. Though the progress in the field of 3D Technology recently increased enormously, there are still gaps for important practical as well as for research work, like, e.g.,
- to convince amateurs and professionals of the still underestimated effect in gaining a complete additional dimension. Beside others this holds for the enhancement of spatial structures by suited 3D-visua-lization Techniques, as well as for the achievement of extremely high detail resolution etc.
Though amateurs and professionals can gain own stereoviews even with single lens cameras, the 3D photography still is not very common and should be increasingly promoted.
- A survey for a systematic listing of existing international archives for stereo views, including the archives contents and access is highly recommended.
-A Peer reviewed and definitely complete synopsis of the virtual 3D-visualization Technologies with sufficient information content is still missing! Already from first systematic steps in this field the "DOWN UNDER" 3D-visualization method recently has been invented, by the authors, see Figure 5 and Table1.
- The authors appeal again to the professional community, to replace manual sketches for documentation purposes by at least 2D-, but preferable by (geometric adjustable) 3D-photography!

Table 1: The Complete list of Virtual Spatial Visualization Techniques (Status: October 2006)

1. 3D visualization of in minimum two overlapping stereo mates, vertical or horizontal arranged, but "projected without contact"; for "ortho" or "pseudo" as well as for normal and/or cross 3D visualization:
1.1 Autostereoscopic view of horizontal mounted 3D views, see Fig. 3, 11 and 15
1.2 MAGIC EYE / random dot
1.3 CYBER SPACE
1.4 Stereoscopes:
1.4.1 Lens Stereoscopes
1.4.2 Mirror Stereoscopes with lenses
1.4.3 Mirror Stereoscopes without lenses; vertical Mirror: PIGEON
1.4.4 Mirror Stereoscopes without lenses; horizontal Mirror: DOWN UNDER, see Fig. 5
1.4.5 Prism-Stereoscopes for horizontal mounted stereomates
1.4.6 Prism-Stereoscopes (with optical wedges) for vertical arranged stereo-strip and/or stereo-Panorama imagery: KMQ
1.4.7 Prism-Stereoscopes for vertical interlaced (even "multi")-stereomates: LENTICULAR LENSES (e.g,"3D postcards")
2.Methods for the virtual spatial visualization Technology based on stereo mates, "projected in contact", using alternate projection and/or different color
2.1b/w&colorANAGLYPHS:complementary color: green/red or blue(magenta)/red or magenta/yellow separation,see Fig1,4,6,7,10
2.2 CROMADEPTHS (spectral color separation)
2.3 POLARIZING FILTER Techniques
2.4 (Liquid Crystal-) SHUTTER glasses
2.5 NUOPTICS(PULFRICH):3D(-TV) for (relative) moving objects through "one-eye sunglasses"
3. Methods using **VIRTUAL** 3D MODELS:
(3.1 different types of mirrors)
(3.2 3D-crystals)
(3.3 3D CAD and CNC)
3.4 (FELIX 3D-) Rotating Screen
3.5 (FELIX 3D-) SOLID STATE
3.6 HOLOGRAM Technologies

- Intense dealing with "3D-niche-photography" based on telescope-rod and/or captive-balloon promises a great future.
- Receipts and samples for gaining, processing and applying Stereoviews are still required for different disciplines.
- There is still a gap for operational "stereoview adopted software".

It is liked to emphasize, the authors, who chair the RecorDIM task Group on "Collecting, Compiling and Sharing International Heritage Stereoviews", maintain the non-commercial website 3dsite.icomos.org, which is also prepared for contacts and cooperation.

Finally, to emphasize the great future potential of the 3D Technology it is expected, the FELIX Solid state type 3D screen is a real candidate, at least partly to replace the current 2D PC-screen generation.

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Short Papers

The Encyclopedic Concept in the Web Era

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Abstract

The paper deals with the online encyclopedias of historical and cultural content, attempting a reassessment of the encyclopedic concept for its web versions. It draws inspiration and examples from the encyclopedia under construction in FHW, dedicated to the Hellenic Civilization. The issues discussed include the content structure and the information organization, the ontological approach, the search and the information retrieval, as well as the hypertext and hypermedia issues, along with their content and form requirements.

Categories and Subject Descriptors (according to ACM CCS): H5.4 [Hypertext/hypermedia]: Architecture, Theory, User Issues, J5[Arts and Humanities]

1. Introduction

This paper focusing on the general methodological issues of the web encyclopaedias is the result of the theoretical research done in the frame of a project of the FHW, the online *Encyclopaedia of the Hellenic World* (www.egiklopedia.gr, 2006), and it owes much to the inspiring discussions with my colleagues, Cleopatra Ferla and Yorgos Tzedopoulos [FST03]. It benefited as well from an earlier study of the author on behalf of the ICS-FORTH, Creta, Greece [Sid05].

2. The encyclopedic concept in brief

The first encyclopedias have been conceived long before the word “encyclopedia” itself became of common use, as a result of the desire to organize the available information of a more or less defined knowledge field. Most of them have been thematic and saw the light in the inspiring and creative milieu of the Alexandrian library. They continued on for centuries with practically no other methodology than the alphabetical arrangement of their entries and some of theme became highly normative. They first raised claim for universality of the encompassed knowledge during the ‘century of the Lights’, through the famous intellectual movement named precisely “Encyclopedic”.

The main reason for any organizing or taxonomic action springs out from the constitutional cognitive qualities of the human being, his linguistic and intellectual consciousness, and frames his interaction with the physical and the social environment [Mor86]. From antiquity to present day, encyclopedias and similar projects justify their existence by the accumulation of enormous amounts of information and knowledge, non manageable by a single person’s memory and structuring capacities. Digital online encyclopedias do not innovate in this aspect, but they do follow the same pattern in their proper environment: the web. Web encyclopedias begun to appear in late nineties, when an already considerable amount of information –of highly varying reliability of course- made its way online. The web communities, foremost the academic, research and educational ones, felt their imminent need, although the institutional and public authorities have been for long, and partially they still are rather circumspect and reserved in encouraging such projects.

3. Content structure, organization and digitization

The main challenge all along the history of encyclopedic projects has been the validity and justification of the content organization. The conventional supports for the, up to now mainly textual, content being linear and of limited extend, they faced the unsurpassed barrier of the semantic isolation. According to the *Tarski’s Logic*, there is no semantic system, which can fully explain itself [BFF04]. The result was the choice of an apparently neutral criterion for the organization of the content, which in reality was only extremely arbitrary: the alphabetical lining up of the entries.

The application in the twentieth century of some mathematical principles on the knowledge organization allowed the creation of data bases, which represent far more complex and sophisticated types of relations than the linear juxtaposition of the entries [BC05]. Furthermore, the content itself has been substantially enriched with a multitude of non textual forms of information and knowledge, usually clustered under the generic and imprecise term of *multimedia*. These data bases, which have been and still are in use for online encyclopedias, are mainly relational, and although they offer much more flexibility in the content organization, they proved to be insufficient for the unquantified (or unquantifiable?) data of the humanities. In consequence of the *Gödel's Theorem*, according to which a complex standardized system cannot find in itself the proof of its own validity, various ideas are attempting to cure this self-cognitive insufficiency [Fra05]. They proceed so by developing and establishing a meta-system able to encompass and consider the semantic systems of the humanities (particularly those of history and culture) as system-objects [ZOM05].

4. Ontology

These ideas introduced the notion of *entity* as a self-contained and integral cognitive element to the field of the humanities. Each entity has a name, a description, some characteristics and qualities and it forms hierarchical, relational and/or dependential relationships with other entities. In the encyclopedic works under consideration here, these entities should be mostly understood as wider thematic units of geographical, temporal and/or cultural nature, appropriate to depict and include data, events and phenomena, their causal relationships and their usually divergent interpretations [GPCFL04].

From a practical point of view as an entity may be considered also each individual entry or its constituent parts. The ideal and strict conformity to this ontological approach should lead to object-oriented data and knowledge bases, which for the time being have no practical application in any web encyclopedia, mostly due to the lack of a properly elaborate model, wide and flexible enough to cover the semantic system of history and culture. A substantial step to this direction has been accomplished in the museology field by the elaboration of the CIDOC Conceptual Reference Model [CDGS*04]. However, many of the analytical elements of such an ontology may be preserved, such as structuring the information by using superclasses, subclasses, and/or related classes, establishing properties between classes, ranges and domains according to the inheritance instances and the property quantifiers, recognizing the subjects and objects in the discussed relationships, and distinguishing between abstract, specific, collective, endurant and perdurant entities (to randomly name some of them). Moreover, the characteristics of the entities may be maintained as close as possible to a formal ontology, with the qualitative characteristics unstructured and the quantitative ones following the standardization of the relevant discipline, while the examined depth of chained causality may remain limited.

A web encyclopedia, although still close to the conventional encyclopedic projects regarding its information morphology, may be open to modern knowledge theories and ontologies and may potentially adapt its form and structure wherever and whenever it seems necessary, thanks to its flexible digital character [TWR06]. The web encyclopedias may in sum inherit from the knowledge base systems theory the *Open World Assumption,* assuming precisely that the information stored in them is incomplete relative to the universe of discourse they intend to describe.

5. Search and information retrieval

Another innovation of the digital encyclopedias, which particularly applies to the online ones, is the possibility for search and information retrieval. The need for this effort- and time-saving feature becomes evident when one considers the growth rhythm of the available information on the web in general and in the online encyclopedias in particular. Some of them count already hundreds of thousands of entries, each entry consisting sometimes of several thousands of words and of abundant audiovisual items. The most widespread technique is based on the search of keywords, which are indexed and stored by the powerful search engines of the web [Cho03]. The same pattern is also in use for the encyclopedias. Most of these search facilities offer a refinement of the results by means of use of Boolean factors, but it seems that only one out of three users is able to formulate adequately his query.

The main challenge of this procedure is the consistency of the indexing. As long as it relies on the human factor it is unacceptably slow and hazardously inconsistent due to the age, linguistic, educational, cultural and ideological characteristics of each individual. Automated information retrieval systems have been called to cure this inconsistency, but the semantic multitude (polysemy and synonymy) of the words represent the main obstacle for the conceptual indexing. Two methods have been developed to overcome the obstacle: the Vector Space Model and the Latent Semantic Indexing [Kow97]. The first, practically already abandoned, used a *term-document matrix.* The second is based on the hypothetical *underlying structure* of the text [Suw06]. For the time being no conceptual indexing is available for a web encyclopedia, though it is already in use on the web, mostly through the development of the *Semantic Web* [GPE05] [Leu06] [DSW06]. The LSI emerges as the most promising alternative for the enrichment and precision of the search recall, especially in relatively defined and controlled domains of knowledge, such as the thematic encyclopedias [GPvB02] [GMvBM05]. The search for audiovisual content (not relying on keywords or other textual attributes) is still in embryonic state, even though some progress occurs in form, color, texture, and frequency sequences pattern recognition [RH05] [SK05] [KMS06].

6. Intertextuality and "Interknowledge"

In the conventional encyclopedias the notional relation of an entry to another was signaled in the former with a reference to the later, under the familiar form of "see entry …" This system could be effectively operational only with internal references. For the external references (bibliography) the reader was depending upon the wealth and updating of documentation of the library in which he was studying. Nowadays a huge variety of books, papers and research documents are available on the web in their full version, transforming thus the external references into a matter of course, and simultaneously raising questions about their choice criteria, their relevance, reliability, placement and commendation.

Furthermore, references may equally lead to an admirable variety of audiovisual material, ranging from pictures and graphs to geographical models, video and music files. The notion of intertextuality (borrowed from the literary theory, later transfigured to 'hypertextuality'), which has been crucial in early web years for the understanding of the new knowledge implementations [Tre03], proves to be poor for the description of the current situation, where the textual, verbal, and audiovisual information are tightly interwoven into an integral knowledge net. The absence of a satisfactory neologism for this phenomenon led us to coin provisory the otherwise unhappy term *interknowledge*.

7. Content requirements

The web encyclopedias of historical and cultural content (under which fall also most of the universal content encyclopedias) do not differ from the conventional ones in their scientific methodology. The issues of micro- and macrohistorical perspectives remain crucial, as well as the management of the sources. Nevertheless, the digital format allows more easily the narration of multiple or parallel historical discourses, records and compares more forms of event sequences, while at the same time different definition networks become visible, as well as different importance hierarchies and multiple fields of validity of the historical and cultural information are brought out.

The most ambitious of the online encyclopedias aspire to answer questions beyond the traditional «who? when? why? what?», such as which are the forms of cultural continuity and discontinuity, what are the components that constitute an event, what sort of serial situations can be traced, what criteria of periodicity should be adopted, what sort of relational systems should be emphasized (hierarchy, dominance, escalation, strict determinism, circular causality). For the purposes of such an analysis, the traditional tools of history are not sufficient and one should turn to methodological standards elaborated by the totality of humanities or even proper to the natural sciences. Some of the above questions have already affected - and have found satisfactory expression in - the data and knowledge base systems theory. The theoretically unlimited scale down or scale up of the time and space parameters, together with the rigorous chapter structure of the entries may produce a babushka-like effect, when an entire entry is included in another wider one, which in turn is also included in another even more wide. At the same time, comparable chapters of different entries may be brought together to build up an entirely new entry. Following this logic the same multimedia material may be integrated into various, apparently non related entries.

During such a process, it is anticipated that the question of sources will be posed. From the very beginning of history as a science, the sources were used, questioned and were the object of many discussions – not only on whether they are honest or deceiving, informed or ignorant, original or altered, but also for the role they can play regarding the reconstruction of reality, the organization and origin of the various versions and finally, the interpretation. A web encyclopedia should still rely on them, but keeping an especially watchful eye on the reliability of its online sources. It may express its critical concern for the scientific discourse while integrating the sources in the body of the historical narration, both as documentation (footnotes and references) as well as the object of the historical process (long quotes). This was an unimaginable feature for the conventional encyclopedias, limited by cost, volume and deadline boundaries. The sources in an online encyclopedia are not merely a "dead museum exhibit", but the objects that the editor is called to present, structure and elaborate in order to make them "history".

8. Form requirements

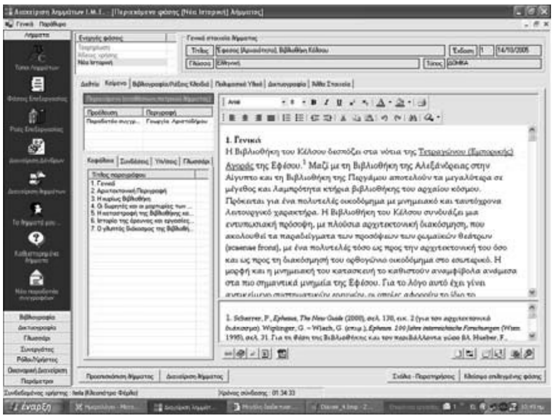

Figure 1: *A screenshot of the administrator's tool for the management of chapters, endnotes and internal links within the entry "Library of Celus at Ephesus".*

The electronic format and especially its online version introduced a series of requirements, which are totally independent from the content itself. The length of the presented texts in connection with the limited space of a computer screen may raise obstacles in the navigation and the simultaneous vision of related components of one or more entries (i.e. reference in the text and footnote content, image and caption, abbreviation and full length reference, link in the text and relevance of the linked document, number of clicks to reach the furthest component, etc.). Most of these obstacles have already found solutions in the general web documents with mouse-on pop-ups, “jumping” forward and backward, enumeration of the invisible pages or items to follow, and similar techniques.

Things are more complicated with the multimedia material, its accessibility and its copyright protection. Even today’s (2006) very fast connections and streaming techniques do not allow the transmission of high resolution video files nor do they support voluminous files of 3D models and 2D drawings. Yet it seems that this is only a matter of time to come up with the appropriate solutions. The copyright protection of the audiovisual material, as it is connected to the lucrative activities of various content providers, accomplished in recent years more successful steps. All the above issues however have limited interference with the operability of an online encyclopedia and they do not really affect its fundamental differentiation from a conventional version.

9. Administrator’s / editor’s needs

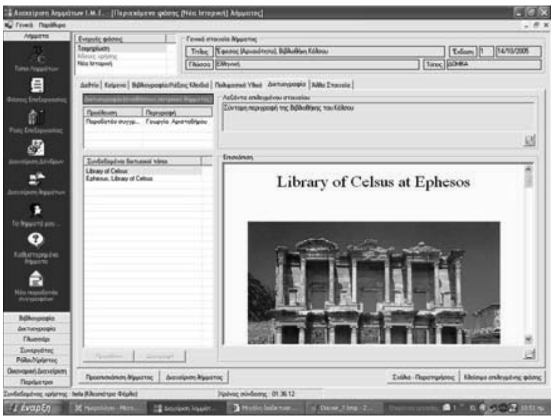

Figure 2: *A screenshot of the administrator’s tool for the insertion of web links in the entry showing a web page presenting the Library of Celsus at Ephesus.*

The first concern of the administrator, who most often identifies with the editor of the content, is the management of the incoming contributions. He needs to begin with an administrative tool, which will allow him to read, correct, complete, edit, validate and publish the contributions on the web, as in Figure 1. A more serene and more distant consideration will come later. He then will ask to modify the catalogues and the content, to update the aged information, to correct the factual errors, the syntactic and conceptual mistakes, to add new entries and complete the old ones, to establish or to suppress internal and external links, to publish and un-publish, to add new multimedia material, to produce finally new editions of parts or even of the whole work, as in Figures 2 and 3.

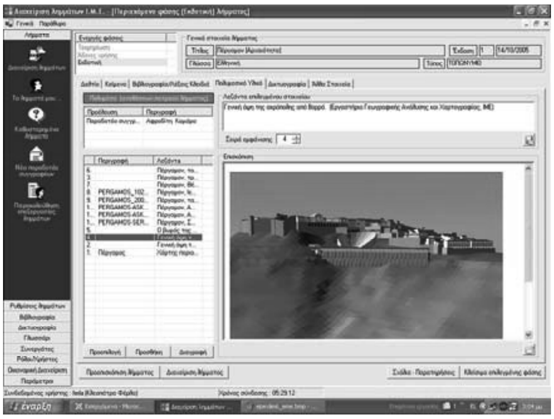

Figure 3: *A screenshot of the administrator’s tool for the insertion of multimedia in the entry showing a VRML model of Pergamon.*

This is the paradise of the editor! But it may be a very deceitful paradise, since both the eternal pursuit of the perfection and the exaggerate trust on an ulterior intervention may prove detrimental for the work itself.

Another concern of any serious editor is to attract numerous and qualified contributors, and in this direction may help an online reporting on which parts of the project are finished, which are under elaboration, and which are still unattributed and available to potential collaborators, as seen in Figure 4.

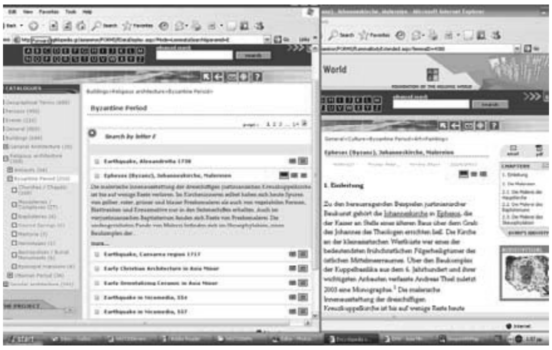

Figure 4: *A screenshot of the EHW site with an entry in German (summery and full text).*

Along with this last concern comes the need for online submission of contributions, for communication with the contributors, and last but not least for logistic management (Who has to submit what and when? Has he a valid contract? How much he has to be or he is already paid for? What has been applied for in various content providing institutions and at which cost? etc.).

At last a smart administrator / editor, who wants to facilitate his job, will ask for some basic reports on the global situation of the project, presenting entities, entries or items per phase of the workflow. And if he is really mean, he will ask to be allowed to modify these administrative tools according to his changing but anticipated needs. In an apex of peculiarity he may even ask to be allowed to control the access of users, as well as to modify the appearance of the user's interface in order to promptly respond to users' feedback. Then, if he wants to drive mad his system designer or supplier, he will ask his precious data to be stored in several servers, automatically updated and in formats and systems compatible with all current platforms and browsers, plus with their future development.

10. User's expectations

Any user of any encyclopedia seeks information and/or knowledge. And although nobody ever dreamed to judge a conventional encyclopedia by the compatibility of its volumes with the height of his own bookshelves, the user of a web encyclopedia expects it to be compatible with his hardware and his software!

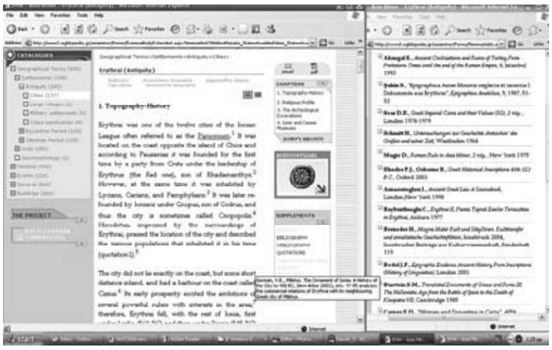

Figure 5: *A screenshot of the EHW site with the entry on ancient Erythrai showing the functions of endnotes and bibliography.*

He also expects it to be easily navigable and searchable, that is to say, with clear structure, unambiguous instructions and abundant orientation facilities. Furthermore, most users expect to find a printer friendly version, and those with visual or acoustic difficulties to find versions, which make the content available to them too.

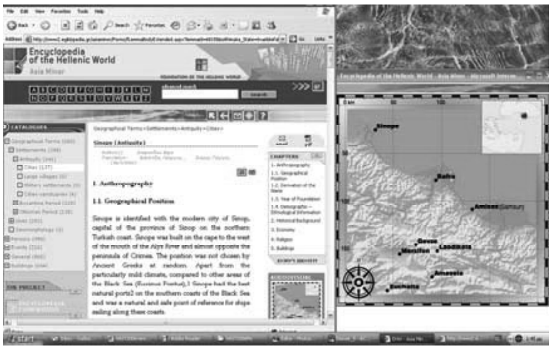

Figure 6: *A screenshot of the EHW site with the entry on ancient Sinope and its map.*

Figure 7: *A screenshot of the EHW site with the entry on the Artemis Temple at Sardis with its architectural redrawing.*

As far as it concerns the content itself, the user expects it to be up to date, of controllable accuracy and reliability, and easy for citation. That is to say, in each entry the author, the sources, the date in which it has been composed and the right way to cite it must be clearly stated. The user also expects the entry to follow the standards of the relevant discipline, to refer to other relevant and controlled resources on the web, and to document the subject with as much non textual material as possible, as in Figures 5-7. In multilingual encyclopedias whenever a verbal or a textual element appears in a multimedia object, it has to be translated in the language of the entry.

11. The encyclopedic concept in the web era

For the editor and the user of a web encyclopedia, there are several concerns beyond those, which apply to any conventional encyclopedia too (i.e. reliability, accuracy, density of information, multidisciplinarity in the approaches, novelty, wide range of scientific tendencies and internationally acknowledged contributors).

The way these concerns have been treated may serve as indicators of the encyclopedia's success. Among these indicators one should count the thematic clarity, the subject definition, the setting of the geographical and temporal borders, as well as the civilization and cultural focus. The content of a successful web encyclopedia is characterized by its integrity, originality, novelty, polymorphy, complementarity, and last but not least, its multilingual presentation. Both the editor and the user are bound to define the target group, but the experience on the web has already shown that "more is never too much". Thus web encyclopedias are expected to satisfy the highest academic and scholarly standards, and in the same time offer the necessary tools, which will allow the non specialist audience to take advantage of the gathered knowledge (glossaries, choice of basic bibliography, comments on webliography etc.). Web encyclopedias are expected to be really in the web and take advantage of the *interknowledge*, to refer to other resources with pertinence, to provide dating of their components and commendation of their links. From a more technical point of view one may expect an easy navigability and searchability, the adoption of the semantic indexing techniques, a print friendly environment, the compatibility with the current and upcoming platforms and software, the extendibility, the accessibility by volume and design, and the interoperability with other similar systems.

As for the EHW, which is essentially bilingual, Greek and English, in FHW we tried (and we are still trying) to implement all the above requirements as often as possible and we believe we succeeded most of the times. The work is now online expecting completion of the content and improvements in its function, which will be better targeted according to the comments of the users.

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Short Papers

Presenting uncertainty in archaeological reconstructions using possibility theory and information visualisation schemes

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Abstract

We present a prototype implementation of an alternative approach to visualising three-dimensional reconstructions of historical structures by taking into account archaeological uncertainty. The approach presented applies possibility theory to represent confidence levels in reconstructions. Feedback from an expert archaeologist is given to the system and results are integrated within information visualisation schemes, which vary according to uncertainty rankings. Changes in schemes are applied in real-time utilising X3D shaders and range from variations in colour, hue, opacity and saturation among others.

Categories and Subject Descriptors (according to ACM CCS): J.2 [Physical Sciences and Engineering]: Archaeology I.3.7 [Computer Graphics]: Color, shading, shadowing, and texture; I.2.3 [Deduction and Theorem Proving]: Uncertainty, “fuzzy,” and probabilistic reasoning;

1. Introduction

Three-dimensional reconstructions of cultural and archaeological structures have become more prominent during the last decade. Virtual walkthroughs and photo-realistic rendering are now the norm and are employed in site visualisations, museum kiosks [3DK06], digital archiving [ARC06] etc. However, archaeology as a discipline is inherently uncertain; it is a destructive process used to gather what available evidence remains in order to better understand ancient cultures. Since an archaeological site is never recovered to its exact ancient proportions, it is safe to say that archaeological hypotheses and interpretations also contain the element of uncertainty. Virtual reconstructions of such sites do not usually display the uncertainty inherent in archaeological interpretations. It is more often the case where the user is able to navigate through virtual structures that make no distinction between the real and the reconstructed parts.

The archaeological community has stressed the need to acknowledge the availability of other possible hypotheses as well as the difference between what was found and how it is interpreted [MR94]. As a result, new approaches have come forward that take these alternatives under consideration, and attempt to contain them in a virtual reconstruction. Recovered remains are differentiated from their interpretation by using a dividing line and different colour in [Eit98]. In [SMI99] the reconstructed portions are displayed as sketch-lines and transparent overlays. Methods to present uncertainty are introduced in [KD05] where the use of colours, transparency and rendering are suggested as ways of representing ambiguity. A more technical approach is given in [ZCG05] which compares different information visualisation schemes to display uncertainty through time.

In [HN04] fuzzy logic is introduced as a basis for quantifying reliability in virtual reconstructions. A reliability number is assigned, ranging from 0.0 (low reliability) to 1.0 (highest reliability), for each reconstructed part of the structure. By combining the values using a fuzzy logic union, an overall reliability index of the reconstruction is calculated. Our approach differs in that it uses *possibility theory* combined with perception-based information visualisation schemes in order to calculate and visually represent the uncertainty in reconstructed buildings. We define uncertainty as the hypothesised factor and the extent of expert knowledge included in the visualisation of an archaeological structure. Archaeologists piece together available information from evidence of excavated features, artefacts, ecofacts, comparisons and ancient texts into a speculative version of the past. This version becomes more certain as the evidence increases.

This paper presents work in progress on the visualisation of archaeological uncertainty using possibility theory in combination with information visualisation. Section 2 introduces possibility theory and how it relates to elicitation of human judgement. Section 3 describes the methodology adapted in this research, the use of possibility theory and information visualisation schemes. Section 4 presents the prototype application while section 5 concludes with a discussion on further work.

2. Possibility theory

Possibility theory handles uncertain and incomplete information. Initially, an extension of fuzzy sets, it was first introduced by L. Zadeh [Zad78] and further developed by Dubois and Prade [DP88], into a calculus of uncertain logic. Like fuzzy logic, possibility theory has its roots in the theory of fuzzy sets. However, while fuzzy logic reasons about vague knowledge, possibilistic theory mainly deals with uncertain and incomplete knowledge [DP94]. More specifically, fuzzy logic is concerned with statements having truth values; in other words, to what extent a statement is close to the truth. In fuzzy logic scenarios, fuzzy set rules are used to describe the gradual nature of properties, e.g. to what degree a fragmented tile belongs to the family of Roman tiles. Possibility theory has uncertainty degrees and does not model truth values but expresses the fact that the truth value is unknown. The uncertainty degrees support assessment of the most *plausible* truth value. Consider the following example: an archaeologist has recovered a fragment of a column, x. The available evidence suggests that it is Ionic or Doric, these options are represented in the set $\Omega(x)$ which contains all possible interpretations (ω) of the column. If $\omega = Ionic$, a possibility distribution $\pi(\omega) : \Omega \rightarrow [0,1]$ expresses the extent that the actual value of x is ω; e.g. the possibility that the column part belongs to an Ionic column.

Let us suppose that A is an interpretation of the above scenario: $\Pi(A)$ represents the level of possibility that the column belongs to an interpretation from the above group. As a result: $\Pi(\Omega) = 1$ and $\Pi(\oslash) = 0$. The possibility that the column belongs to at least one of these two types is equal to the value of the most plausible of the two: $\Pi(A \vee B) = max[\Pi(A), \Pi(B)]$. This contrasts with probability theory where the same equation is additive. Additionally, possibility has a dual measure: necessity. This represents the possibility of the contrary event, e.g. $N(A) = 1 - \Pi(\neg A)$. As a result $N(A \wedge B) = min(N(A), N(B))$. A final important difference from probability is that in possibility theory, $\Pi(A)$ and $\Pi(\neg A)$ are weakly dependent. In other words, possibility theory allows us to state: *while I am quite sure that the fragment belongs to an Ionic column, I accept the slight possibility that it may be Doric* thus $\Pi(A) + \Pi(\neg A) >= 1$. Similarly, for duality $N(A) + N(\neg A) <= 1$. This illustrates that possibility measures can flexibly express partial ignorance.

A crucial issue about possibility theory is that the range [0,1] can be described in a purely qualitative way and is not restricted by a numerical representation-such as an ordered scale from uncertain to certain. In [RNM03] possibility theory, with qualitative ordinal values, is successfully used to describe human judgement in medical scenarios where doctors express their belief on the interpretation of a medical diagnosis. It also has been shown that it is difficult to elicit separate necessity and possibility measures at the same time from the expert due to the close nature of both scales. As a result, a Ψ scale is used which combines Π and N to $\Psi(A) = 1/2[\Pi(A) + N(A)]$.

For the purposes of our research we are adapting the above-mentioned Ψ scale to describe the uncertainty an archaeologist has on a specific reconstructed part.

3. Methodology

Our approach is focused on 3D reconstructions of archaeological structures. Our goal is the implementation of a visualisation system where the archaeologist, by describing their uncertainty on every part, influences the appearance of the reconstruction. Uncertainty values are directly related to the information visualisation scheme chosen. As a result, there are two distinct components in the system: the possibility calculations and the visualisation. These are now explained more analytically.

3.1. Possibility theory and archaeological uncertainty

We have identified three categories through which uncertainty could be expressed:

1. Expert judgement: the archaeologist goes through each reconstructed part of the building and selects how sure they are about the interpretation from a list containing linguistic expressions of uncertainty. The simplest form for these expressions can be described as a Likert-style scale [Lik55] (Totally uncertain, Fairly uncertain, Somewhat uncertain, Neither certain/uncertain, Somewhat certain, Fairly certain, Totally certain).
2. Expert judgement with influencing factors: this second category asks the archaeologist, to supply expert judgement and also identify any evidence which may influence judgement for the specific part-these influencing factors gathered so far from archaeologists are discussed in 4.2.
3. Influencing factors: it would be interesting to observe whether by solely identifying available evidence one could estimate the uncertainty of each part.

3.2. Visualisation schemes for displaying archaeological uncertainty

Information visualisation techniques encompass a wide range of approaches developed to help people visually interpret data. Colour visualisation schemes [War04] are of importance when visually interpreting uncertainty levels, especially ordinal perceptually-ordered pseudocolour sequences. Pseudocolouring is a technique for representing varying values using a sequence of colours. In archaeology it is mostly used in Geographical Information Systems (GIS) representation. Ordinal perception means that colour grading follows an order (black to white, hue/saturation increase, etc); the crucial requirement is the change towards opponent colour space. If a data value Y lies between X and Z, in an ordinal pseudocolour sequence the colours should have the same ordering scheme to allow for the visual perception of the ordering of values. Fig. 1 illustrates commonly used pseudocolour sequences. For the purposes of this research, once an archaeologist has assigned values to the parts, the results from the possibility model will be fed to the information visualisation scheme.

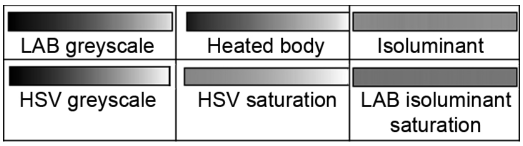

Figure 1: *Commonly used pseudocolour sequences*

4. Implementation

A Romano-British building [MR05] located in the area of Fishbourne, East Sussex, UK has been chosen as the first case study of the research (Fig 2). The structure, referred to as Building 3, is located near the grounds of Fishbourne Roman Palace. Building 3 nencompasses little evidence besides its foundations. Currently there are two interpretations related to its past form: one suggests its function was of a military nature, while the other attaches a religious purpose.

4.1. System prototype

A 3D model of the building is composed of different parts (hypothetical and recovered) such as the various walls, roofs, etc. The model is displayed using X3D [X3D06], which is an open format for communicating 3D objects using XML. The system prototype, illustrated in Fig. 3 is divided in two interacting components: control (A) and visualisation (B). The control component allows the user to select different parts of the model through a user interface (1) and assign uncertainty values (2). Once all the values have been assigned, the user can choose from a set of visualisation schemes to be applied to the model (3). These schemes are implemented

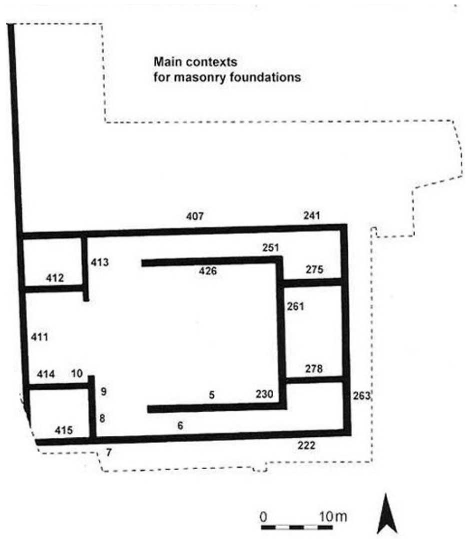

Figure 2: *Plan of Fishbourne Building 3*

using X3D shaders [dCGP04], which support real-time adjustment of textures, opacity, colour, position and direction of the object. The use of X3D shader nodes allows us to embed GLSL/HLSL shaders in our scene, and as a result swap between different visualisation schemes. The use of shaders opens up possibilities of visualisations such as a combination of texture maps with varying colour overlays. Finally, the visualisation component displays the model that supports user navigation and interaction with the scene. The system provides bidirectional information transfer between the control component and the scene.

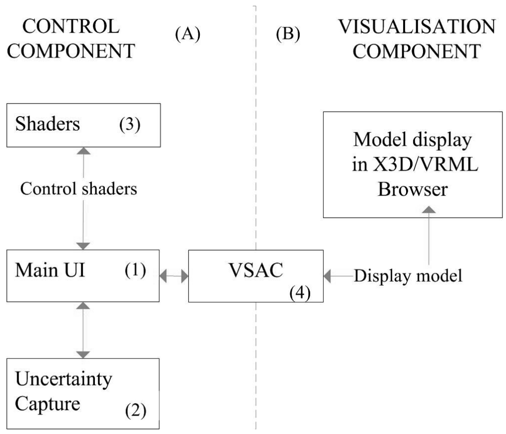

Figure 3: *Diagram of the system*

The underlying visualisation and communication services are supported by VSAC (Visual Simulation Attribute Connector). VSAC (4) is an author-friendly, runtime configurable X3D interaction system; it utilises its own X3D/VRML prototype node, VSAM (Visual Simulation Attribute Messenger). VSAM provides all input and output events for all data types supported by VRML/X3D browsers (Octaga, Cortona, Xj3D among others). All VSAM fields are optional at design time; the fields can be configured dynamically at runtime if required. As a result, objects in the scene are identified by this prototype and can be manipulated in real-time. Fig 4 shows the building with varying transparency; the visualisation window is to the left and the controller to the right.

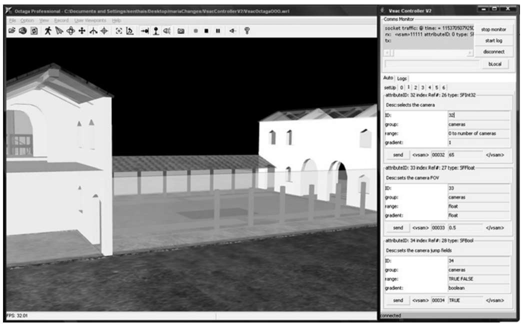

Figure 4: *Fishbourne Building 3 in the prototype application*

4.2. Influencing factors in interpretation of archaeological structures

As briefly introduced in 3.1, in order to create a reconstruction, archaeologists piece together available evidence. Through discussions with archaeologists we have identified the following categories of evidence:

- Features: any non-portable remnant of human activity
- Artefacts: objects made or modified by human culture
- Biofacts: objects located in a site but not altered by human hands - seeds, bones, wood, etc
- Topography: environmental layout and information
- Textual material: references from ancient texts
- Absolute comparisons: comparison of building with similar buildings of the period
- Contextual comparisons: comparison of the building in its context with similar buildings and their contexts
- Peer influences: discussions with peers, outside advice

We suggest that according to the evidence available for each part, the certainty of the archaeologist will increase or decrease. By using questionnaires and interviewing archaeologists, we are currently evaluating whether certain types of evidence (stand-alone and in combination) are considered *stronger* than others. For example, we investigate whether archaeologists often consider structural evidence more significant than biofacts.

It is understood that for different archaeological periods, respective archaeologists may place importance in different evidence types. For example, an archaeologist studying the Middle Ages may place more importance on textual evidence (a wide range available), than would an early Anglo-Saxon one (almost no textual evidence available). This leads to the development of varied setup schemes for the possibility engine.

For this reason, the questionnaires mentioned above, are focused on Roman period archaeologists, which is the era relative to our case study. However, any preference in evidence that may be derived can be easily changed in the system.

5. Discussion and further work

In this paper we have described an approach for visualising archaeological uncertainty in ancient structures by combining possibility theory and information visualisation. Possibility theory provides us with a means to model human uncertainty; in its simplest form it expresses the degrees to which a statement should be considered possible and plausible. Changes in the uncertainty of an expert are visually represented by ordinal, perceptually-ordered pseudocolour schemes. We analyse the design of a prototype application that controls the visualisation. Models are displayed in X3D, and visualisation schemes as well as uncertainty values, can be manipulated in real-time. The schemes are implemented with X3D shaders, offering the possibility of a wide range of visual transformations. A Romano-British building is selected to serve as a testbed for an initial case study, modeled in X3D and manipulated through the application.

We are using formal questionnaires to determine whether influencing factors, such as a preferential order in different evidence types, can affect an archaeologist's uncertainty. Integration of influencing factors in our prototype will incur weight factors in the calculation of uncertainty, hence acquiring statements which could be less or more plausible. The next step would be to test how the resulting visualisations would reflect the calculated uncertainties and whether the perceived uncertainty based on the visualization scheme would match the impression of the archaeologist. The ultimate goal of this system is to identify visualization schemes which are able to reflect uncertainty levels based on complex information, thus offering a technological tool which would aid archeological discovery.

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Short Papers

Beauty or Beast?: A Review of the CIDOC-CRM Applications and Thesauri in Archaeology

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Abstract

The CIDOC-CRM may be a growing standard within the museum and cultural heritage sector. In fact, some museum experts and technicians are almost spell-bound by it, particularly because it is now in the process of receiving ISO standard. Without doubt it is an interesting and well-organized idea, but is it that popular? Have we agreed to use it as a world standard? This paper reviews some applications of the CIDOC-CRM and explores the issues about thesaurus. Although many examples of the theoretical uses of the CIDOC-CRM are found on the web, not enough practical implementations have yet been undertaken. In addition, consideration should be given to the conceptual gap of domain experts, the uncertainty of the area of domain, the interpretation and explicitness of the CIDOC-CRM, and the lack of its dissemination. It is not the aim of this paper simply to criticize the CIDOC-CRM, but to provide a better understanding of it and offer possible solutions for several problems, from an archaeological point of view.

Categories and Subject Descriptors (according to ACM CCS): H.3.7 [Information Systems]: Standards

1. Prologue

The CIDOC (the International Committee for Documentation) of ICOM (the International Council for Museums) has developed a domain ontology called CIDOC-Conceptual Reference Model (CRM) in order to provide a framework for the exchange of cultural information especially within museum community [Cid06]. The ontology does not define descriptive schema for the cultural domain, and also does not mention any issues related to technical implementation. It rather provides a common ground for information exchange and integration by conceptualizing the domain of cultural heritage. The CIDOC-CRM encourages cultural specialists to clarify semantic structures and relationships among information they deal with, by means of an object oriented approach. This object-oriented model facilitates the harmonization of maximum details of information, and the extension for more specialized fields of application would be performed without semantic loss. The first version of the model was published in 1998. Subsequently, the version 3.2 has been submitted to the International Standard Organization (ISO). For these reasons cultural professionals including museum curators, information specialists, librarians, archivists and archaeologists have started to use the CIDOC-CRM.

In spite of the fact that there are several on-going projects using the CIDOC-CRM, few have overviewed its applications in the cultural heritage arena. It seems that approval for this standard overwhelms the opposition, yet the number of critical reviews has hitherto been quite limited. Since the CIDOC-CRM may soon acquire an ISO standard (ISO/PRF 21127, current stage on 2006-06-06: 60:00 international standard under publication), an overall analysis and critique are long overdue. It is understandable that the CIDOC-CRM is appealing and attractive, particularly taking into consideration the state-of-the-art technologies such as Semantic Web and object oriented model. These technologies are clearly giving some sort of impact in the world of information management. However, the potential and the risks of the CIDOC-CRM are also not well known in the same way that existing international documentation standards have not yet become widely known and used. With a view to understanding the CIDOC-CRM better, the author has undertaken a web-based survey for its applications and available thesauri. In particular the focus is placed upon the current state of the development from an archaeological point of view. This paper, thus, will evaluate some applications of the CIDOC-CRM in archaeology, and give some suggestions for the future of the CIDOC-CRM, in relation to archaeological thesauri probably required for its practical use.

2. CIDOC-CRM applications

It is not the purpose of this paper to review all projects related to the CIDOC-CRM, rather it outlines the intentions of some projects as well as their problems and potential.

From the early days of the CIDOC-CRM, some papers have been available online. Most of them tried to test the validity of the CIDOC-CRM by mapping existing standards/metadata schemata into it. They include Dublin Core Metadata Element Set (DCMES), Art Museum Image Consortium (AMICO), MDA SPECTRUM, Research Libraries Group (RLG) Cultural Material XML Schema and DTD, Encoded Archival Description (EAD), Functional Requirements for Bibliographic Records (FRBR), ABC Harmony and OPENGIS [CDG03]. These results have convinced the CIDOC-CRM inventors that the ontology functions perfectly for a wide range of cultural subjects. This is natural, because the CIDOC-CRM can express cultural phenomena in a much richer way than other metadata schemata. [Doe00] argued that the mapping from the CIDOC-CRM to DCMES was tedious due to the richness of the CIDOC-CRM path. Indeed, the validation for the compatibility with cultural standards is probably enough. But, as a result of these formal mappings, not so many examples of practical implementations are widely available. It is really high time to move from a theoretical validation to a practical one.

More recent developments can be seen in different projects particularly all over Europe. The SCULPTEUR project involves the Uffizi, the National Gallery and the Victoria and Albert Museum, the Musées de Cherbourg and the Centre de Recherche et de Restaration des Musées de France (C2RMF) [SGL*05]. The rich data of these museums were mapped to the CIDOC-CRM, and the project achieved interoperability using a Z39.50 search and retrieve web service (SRW). The concept browser is an idea of grouping concepts by theme (people, art objects, events, and techniques etc). The semantic relationship among the themes will be hyperlinked by the CIDOC-CRM ontology, and a visualization tool called TouchGraph enables users to navigate such concepts easily. mSpace was also adopted in order to avoid the visualization of complicated structure by filtering concepts. One of the key functions of SCULPTEUR is a content-based retrieval system for 2D and 3D objects. The performance of such retrieval would be slightly disappointing; however, with the help of metadata and ontologies, more and more sophisticated data retrieval systems will be constructed in the future. The project is innovative and the use of the CIDOC-CRM is clearly described, but the application is not available on the web. In addition, a similar example of content-based search in the field of cultural heritage is seen in the website of the Hermitage Museum (http://www.hermitagemuseum.org/). As [SGL*05] pointed out, since the assistance of a CRM expert was required to complete and validate the mappings, some problems rely on the validity of mappings.

Norway seems to be one of the most active countries in the use of the CIDOC-CRM and the Semantic Web. [JHOO04] tackled a task to map unstructured data into a CIDOC-CRM compliant model semi-automatically. The case study used old reports, acquisition catalogues and grey documents from different types of museums in Norway. The project used XML and DTD as a mark-up language and schema to encode unstructured running texts. An event-based approach was adopted and experimented in order to validate the potential of the CIDOC-CRM.

The use of unstructured data in relation to the CIDOC-CRM is interesting, compared to structured databases which are relatively easy to map. Arising issues—if not problems—here are intensive labour force and selection for digitization. All encoding works to extract the meaning of the information have been done manually. Although [JHOO04] stressed that manual mark-up is an unavoidable process, even if automation is worth trying, the intensity of human involvement is subject to the users needs for such unstructured information. Similarly this issue is applied for the ideas of how to create a digital summary of contents for newly published books, in order to make a content-based search of modern publications. Basically the task is unsolved. For example, the BOOK Database developed by several Japanese publishers has 720,000 entries of tables of contents, yet all were input manually [Sug06b]. From those examples, it is evident that the selection for digitization is an important aspect.

On the other hand, MuseSuomi archived a type of semantic web portal in conjunction with the National Museum, Espoo City Museum, and Lahti City Museum [HJK*04]. A search engine, Ontogator, enables users to execute a view-based multi-facet search. The nine views of facets system are underlaid by seven ontologies including artifacts, materials, actors, locations, times etc. Some of them are the subset of widely used cultural thesauri in Finish museums. This search interface is an easy way to navigate the whole complicated database. In addition, a semantic recommendation system allows users to explore hyperlinks of both explicit and implicit knowledge of a collection they choose. RDF triples and collection domain ontologies realized a powerful knowledge base. Moreover, a prototype implementation was made for the use of MuseSuomi in WAP 2.0 compatible mobile phones. It is planned in the future to accomplish the functions of accessing to objects related to the users' current geographical location. It has to be noted that the CIDOC-CRM seems not to be used for the ontology of this model, but this is one of just a few applications of Semantic Web in cultural heritage actually working on-line. Despite the absence of the CIDOC-CRM, MuseSuomi is an excellent showcase to understand how powerful an ontological approach is in the cultural domain. The on-line documentation/publications of the project are also extremely helpful for those who would like to develop a similar system. It is a pity that the project is one-country driven, without much consideration to international standards and thesauri of cultural heritage.

So far museum-oriented projects have been discussed as they are the primary concerns of the CIDOC-CRM, but the Centre for Archaeology (CfA) in English Heritage aimed to reveal the basic structure of archaeological data and projects [CGF*04]. This is one of the rare examples of the CIDOC-CRM applications for field archaeology which should require the extension of the CIDOC-CRM. Therefore, the author would like to mention rather some specific points about its application.

In the model, "context" is a focal point for the webs of archaeological services. Archaeological context is very important since it contains the nitty-gritty information about excavation. The concept of time and all semantic relationships among finds and features are structurally formed by contextual records. However, maybe because of the focus upon museums in the CIDOC-CRM, there are not so many properties concerning the geographical position of physical thing (context). For Physical Object entity, properties such as P46, P58, and P59, and for Place entity, P5, P88, P89, P121, and P122 are available. Apparently, this is not enough to conceptualize all relations of the different layers of archaeological data. Thus, it is not easy for archaeologists to map the data of archaeological stratigraphy into the CIDOC-CRM straightforwardly, and there seem to be big discussions about how to map such complicated data. Similarly, this complexity should apply for buildings and monuments that have three dimensional data in geographical space. The CfA project team tackled to solve this problem by the use of temporal properties known as Allen's operators (CIDOC-CRM Properties from P114 to P120). These temporal properties make it possible to describe the semantics of archaeological context. For instance, if X is stratigraphically above Y, archaeologists actually imply that X occurred some time after Y. Expanding this transformation of spatial information into temporal information, it is possible to encode all of the semantics of an archaeological matrix [CGF*04].

However, as [CGF*04] pointed out that the unfriendly CIDOC-CRM terminology is a barrier for domain experts to communicate with information experts, thus the transformation of archaeological contextual information would be a risk for the use of the CIDOC-CRM. Some sort of automatic toolkit would be required for the practical use of future applications. This project certainly succeeded in providing a knowledge representation of practical operations of an archaeological organization.

A new inter-European project has been launched for the use of the CIDOC-CRM in various stages of archaeological operations (from field recording to museum documentation). The AMA (Archive Mapper for Archaeology) project attempts to create a semi-automatic toolkit for the mappings of different archaeological resources including structured and unstructured data to the CIDOC-CRM [EPO]. Such collaboration work may solve some of the problems of the use of CIDOC-CRM in a wide range of archaeological documentations.

[ERV05] have developed a system for virtual exhibition using XML data processing. This framework of museum systems fosters the administration and management of virtual exhibitions, so that this can be regarded as the development of a museum framework by expanding the idea of the CIDOC-CRM. An object-oriented methodology provides an integrated system for museum management, exhibition management, web service and user management. UML (Unified Modelling Language) was mentioned to use for the robust design model. This is a good example of designing museum data-flow particularly from user's point of view (e.g. visitors and curators). When cultural information is incorporated, it is easy to assume that the information management will fall both within and outside the scope of the CIDOC-CRM. In fact, the role of the CIDOC-CRM is not well described in this paper, simply because this system especially deals with a framework of museum exhibition management rather than the contextual contents of museum collections. In this kind of management-level system, control and security issues will be increasingly important. By far, there have been few debates on copyright and security for the semantic net of cultural heritage information. More attention should be also paid to an authorization system which facilitates data quality control.

3. Thesauri

Some forms of domain specific dictionaries such as taxonomy, thesaurus, controlled vocabulary, and terminology are essential elements for the development of the CIDOC-CRM applications. There are different views on the distinction of those terms, however the common idea is to control the use of data in order to improve performance of matching different data in a standardized way. In this paper, a word, thesaurus, will be used for a representation of this general concept, to its convenience. As a review, several examples of thesauri with regards to archaeology will be discussed.

The Paul Getty Trust has played a leading role for art history. It has developed three famous thesauri called the Art & Architecture Thesaurus (AAT) and the Union List of Artist Names (ULAN), and the Thesaurus of Geographic Names (TGN). Without doubt, these are extremely useful for some areas of cultural heritage. In terms of archaeology, TGN (and maybe AAT) is the most relevant thesaurus. In spite of a wide range of and a great amount of thesauri found on the web, archaeology-specialized thesauri are not competitive. England would be the best place to look at. There are Archaeological Object Thesaurus by former MDA (Museum Documentation Association), Monument Type, Object Type, Material, Warfare, Maritime, and Aircraft Thesauri by the

National Monuments Record in England and English Heritage. The British Museum has also created Object Name and Material Thesaurus. Obviously these thesauri are heavily dependent on English archaeology, so that it cannot be generalized in world archaeology. However they are disseminated through websites and they seem to be good guides for practice. It is assumed that there are a large number of archaeology specific thesauri, but a lot of them are often not widely available and are developed and used in-house. It is also said that site specific vocabularies have been developed in archaeology, so that it seems extremely difficult to incorporate such various thesauri. Consequently, a survey for archaeological thesauri is needed to understand the distribution and the diversity of the domain thesauri. In the meanwhile, an interesting work has been done by [DKS05]. They provide a formal methodology for the creation of multilingual thesaurus of historical periods. Based on the CIDOC-CRM model, the combination of the ontological and terminological approach tries to clarify the concept of periods.
Multilingualism is another topic to be considered. MINERVA has recently published a report on multilingualism in European heritage [Min06]. It carried out a survey for multilingual websites and thesauri, targeting libraries, archives, museums, and other cultural sites. According to the survey, it seems local and national-level thesauri have been developed and international thesauri are used in some members of the EU countries, however they vary in size and purpose and multilingual thesauri are still not popular and not widely used. The trilingual UNESCO thesaurus aims to provide a controlled and structured list of terms used in the area such as education, science, and culture. The HEREIN (European Heritage Network) thesaurus specializes in national policies, architectural and archaeological heritage, and offers a help in obtaining various national reports. A multilingual vocabulary has been built by the NARCISSE (Network of Art Research Computer Image SystemS) project, describing works of art, technical data of photographic archives, restoration and study reports. It is now available in eleven languages [Min06] [LAS*]. ICONCLASS is a famous classification system for iconographic description, currently available only in English, but the translation into French and other languages is underway.

By having a careful look at those thesauri, it is envisaged that geographical and temporal terms have to be created in the first place. Even though there are various discussions about the definition of terms in cultural heritage, it should be much more straightforward to create these thesauri than the thesauri of classification of archaeological potteries. Regardless to say, geographical and temporal terms are foundation stones of a huge area of the heritage sector, therefore, the construction of those two thesauri exemplifies very basic human perceptions of the world, time and space, which is unavoidable when creating a common understanding of cultural semantics. It is, however, better not to build a complete version of the thesauri, because a perfect thesaurus is not possible and it can be modified later if necessary. Whilst the TGN could be one of the strongest candidates for the geographical standard, a chronological thesaurus needs to be developed sooner or later. Although [DKS05]'s new methodology opened a new possibility of thesaurus, problems rely on the complexity of the creation and the use of such model. Unlike the CIDOC-CRM, which leaves the issues of domain-specific knowledge, the development of terminology/thesaurus is time-consuming and will cause a considerable controversy. The potential candidates for a chronological version also exist inside history textbooks. If the chronology of world history can be merged into one framework, the thesaurus will be created. At this stage, the problem is not a cultural but a political. Historians in different countries (and politicians and citizens) may have to agree with one single thesaurus. But the TGN should also confront the problems of territorial conflicts in the political world. In conclusion, it seems better for cultural experts to develop a chronological thesaurus for their own needs of information exchange without any problematic political discussions. As soon as two thesauri are constructed, only one question will be left: Who controls the thesauri? It is obviously not possible to answer this question.

Maybe building up international-level thesauri is not the only way forward. For example, software like the IKEM toolkit (http://www.vartec.be) might be a good starting point. This software allows users to construct and manage their own thesauri based on the ISO 2788 and 5964 standards (monolingual and multilingual thesauri). The thesaurus management software supports to merge personal/local thesauri to generate corporate thesauri, and the function of web-based group-discussion enables users to exchange ideas of thesaurus terms over the internet. This is an extremely useful feature of the software to develop and maintain thesauri through web collaboration. The IKEM seems to offer a bottom-up approach for the creation of thesauri with more interactivity and flexibility. This approach seems a bit slow, but considering the future development of automatic assemblages of information by highly intelligent computer robots, this approach could be quicker in the long run.

4. Summary and conclusions

In this conclusion, the author would like to highlight several problems with some suggestions of solutions.

1 Conceptual difference (Different mapping model)
Many cultural professionals now try to conceptualize their own data in different ways. As there was a discussion in the CfA to map archaeological contextual data into the most appropriate CIDOC-CRM entities and properties, even the same data could be mapped differently by different people. But it is not known how to solve the problem of such conceptual differences. In addition, it seems that nobody knows if a consensus for the best way of mapping should be made in the same domain. These problems may be caused by the

implicitness of the definition of the CIDOC-CRM. In the CIDOC-CRM, there are definitions of entities and properties with scope notes and examples. However examples are sometimes very few and either too specific or too general. Probably the definitions are quite clear for the inventors of the ontology, but, to some extent, they are not explicitly described and explained badly. In order to avoid misunderstanding, better manuals, possibly in several languages should be published.

2 Lack of thesaurus and standard

Thesauri and domain standards are indispensable elements for the development of the CIDOC-CRM. However the reality seems rather chaotic. There are no established thesauri which could serve across the different documentations in different archaeological communities. A survey for archaeological thesauri is needed. For instance, [Sug06a] executed the Digital Data Survey for Japanese Archaeology (JAD2) in order to figure out the current situation of archaeological data and its use and archaeologists' expectations, taking into account the needs of the CIDOC-CRM. This kind of perspective is vital as a further step to standardization.

Practically speaking, the incorporation of existing thesauri, particularly temporal and spatial ones, would be a solution. In terms of archaeology, the successful creation of an archaeological dictionary at a national level should result in the integration of such dictionaries at an international level, since most of countries have some sort of governmental control over the protection of cultural properties. This is an ideal approach particularly because this form of information management can be related to national laws and regulations of cultural heritage. The plan for national thesauri is also underpinned by the fact that international co-operation for the illicit trade of cultural items is crucial. On the other hand, locally-specific dictionaries cannot be underestimated. The value of local identity—which has to be central to the idea of the CIDOC-CRM—should be preserved well. These local vocabularies could be assembled automatically by the use of software like IKEM, then the expanded vocabulary will be more practical because it is based on actual data used, not on a top-down creation of vocabulary from scratch. It is very difficult to say which approach would be suitable for the future, but it seems significant to maintain both approaches considering the diversity of cultural vocabularies. Although the CIDOC-CRM is translated into several languages, multilingualism is also essential in terms of thesaurus. The lack of proper multilingual thesauri may cause problems of the international use of the CIDOC-CRM. It is also not too much to say that the validation and implementations of the CIDOC-CRM have been mostly confined within Western cultural communities. The collaboration with Asia, Oceania, Africa, and the Americas will become more necessary.

3 Utopia: Encyclopedia of archaeology

The ultimate goal of the CIDOC-CRM would be to construct the semantic structure (encyclopedia) of all subjects in cultural domain, however, there is no clearly-defined concept of archaeology as an academic subject. Obviously archaeological theories exist, but nobody has ever described the semantic framework of archaeological data, services and systems. This is, apparently, not only the case in archaeology but also in other disciplines. It may be a good occasion for every domain expert to discuss all of the theories and practices, but it seems a long way to archive such a huge encyclopaedia. The question then becomes whether the CIDOC-CRM will last until everything is clarified semantically.

4 Lack of experiment and dissemination

The experimentation of the CIDOC-CRM is still not sufficient. Although there are many projects related to the CIDOC-CRM, it is hard to find practical examples of its application on the web. In addition, in contrast to the acceptance of the CIDOC-CRM within international museum community, many cultural experts still do not know of its existence. For instance, the JAD2 survey shows the most of Japanese field archaeologists are unaware of the CIDOC-CRM [Sug06a]. Therefore, it is uncertain whether there could be some opposition to this more-or-less ISO standard ontology.

It also appears that many applications remain at the theoretical level, and the implementations are also conducted only in-house. The problem is that the results of such applications are not well disseminated. If a goal of the CIDOC-CRM is information exchange at the detailed level that cultural specialists request, it is vital to show the results in a proper way. However there still seems to be hesitation among cultural professionals to open their ideas and resources to a wider audience. What is missing is a widely available publication on the details of the applications. Web-accessible contents of the applications are also fundamental. Cultural experts should discard old fashioned ideas like "My data, my idea and my application" which are completely opposite to the intention of the CIDOC-CRM, and try to follow the idea of "Open Source" developed in the information domain.

5 Too broad scope

The definition of "domain ontology" is quite uncertain, as is the definition of cultural heritage [CDG03]. Museums are its initial targets, but libraries and archives are also included in the Intended Scope. Formal mappings have also been made for various fields of cultural heritage. In reality, the boundaries of the domain are only defined by the exclusions of administrative and management works such as personnel, accounting and visitor statistics. Having said this, as far as entities and properties are concerned, the range of the domain is museum collection oriented. All of this implies that the CIDOC-CRM is, in fact, not a domain ontology but a core ontology of curatorial knowledge in cultural heritage. Therefore, a series of agreed extensions of the CIDOC-CRM could lead to different domain ontologies such as ethnological ontology and library ontology. Similarly [Doe00] stated that the CIDOC-CRM could inspire a good metadata, which is a knowledge representation of a specific domain. At the same time it is also possible to consider the "core ontology" which merges existing ontologies developed in different disciplines. [CGF*04] and [JHOO04] mentioned that one of the strengths of the CIDOC-CRM is its event- based approach, and the core entities for this approach are E5 Event, E39 Actor, E52 Time-span, E53 Places, and E77 Persistent Item (or E70 Things). These event-centred relationships could serve as general purposes. In fact, some effort has been made by [Hun03]. She proposed the ABC model to improve semantic interoperability among different genres of domains by means of multimedia. This top-level ontology is also based on an event aware model, attempting to facilitate the harmonization of different ontologies of MPEG-7 and MPEG-21, CIDOC-CRM, and ON9.3.

In order for the CIDOC-CRM to be widely used in practice, it seems better to attempt to archive a de-facto standard first, rather than an ISO standard, since top-down approaches are sometimes to be avoided. Having said this, it is also interesting to see what the ISO standard means to cultural experts. There seems to be very few ISO standards in this domain, thus this top-down method might be a good opportunity to conquer the problems of bottom-up standardization methods we have tackled for many years.
As the CIDOC-CRM becomes the ISO standard, cultural professionals seek perfection, but it is a compromised format of expressing cultural data that most of them agree to use in order to integrate fruitful cultural data as much as possible. The extensible function of the CIDOC-CRM allows all cultural experts to be involved in one framework. The elegance of the CIDOC-CRM is that it is a conceptual model leaving complicated issues such as domain vocabularies and technologies behind. However, precisely because of this conceptual elegance, the practical level of implementation poses numerous questions as discussed above. Is the CIDOC-CRM the beauty or the beast? The answer is in your hands.

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Short Papers

Surveying Monuments by Who's Standards

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Abstract

During the last decades many monuments have been surveyed in Greece for several reasons, all those works have been carried out under different standards and circumstances. Surveying methods varies from classical ones up to photogrammetric, 3D laser scanning, architectonic and all the combinations of the above. Even though there are so many methods there are no standards at all for doing all those works. There have been some efforts for setting standards for monument surveys but none of them has ever been accepted. The author, having a multiyear on site surveying experience, is trying to propose some specifications for the survey of monuments, concerning all methods in use. At least a minimum of standards for such works is pointed out.

1. Introduction

Last years we have seen many monuments, all over the world, which have been destroyed from several reasons. Therefore, and also because of the great interest of all people nowadays for the cultural heritage, we need detailed plans and registration for every monument if possible. As a result of the above many scientists are involved in surveying monuments. Their specialization varies widely and a common language is needed but more over is needed their close collaboration. So the archaeologist, the architect, the conservatist, the engineer, the phogrammetrist, the surveyor, and others are requested to work together as a team. And generally, I believe that, we are leaded in a new century of teamwork, because of the excess and very fast development of technology.

Registration for a monument is needed each time we want to deal with it. For example whenever we have to study, or to repair, or to reconstruct, or to conserve a monument its plan is necessary. There is no possibility to do anything on a monument or archaeological site without drawing its present accurate situation on a plan. Also in some cases we have to survey the monuments just for registration purposes only, because there are monuments which are invaluable and we own to register them at least in detailed archives. This becomes more obvious for all classical ancient monuments all over the world.

As well obvious is the necessity of surveying the monuments and the archaeological sites. As a matter of fact scientists with a variety of specialization are involved in that field and all of them are trying to develop better methods for surveying. According to the above mentioned the classic method of surveying applied by architects is modernized and automated with less people and time needed for similar or sometimes better results. New techniques are developed that give various methods for the survey and editing of the final plans. Even more when we need detail surveys in large scale we need better accuracy in measuring thus we apply special surveying methods.

Whenever a detailed plan is needed in great scales we have to apply different methods in surveying. If we choose the photogrammetric one, we need better accuracy in control points. Another factor we have to face is that we need very high resolution in shots; therefore we use large format cameras. Usually we use control points for the survey which are permanent marked on its surface in a way that they can easily be used for further densification of the details in future surveys. In this way we succeed to have higher accuracy and connectivity of the measurements between different measuring epochs. Last years emphasis has been given in detail surveys as a major tool for studying the monuments. Also detailed plans are used for 3D reconstruction in a computer graphic environment that is valuable for restoring the monuments.

On the other hand the cost that concerns both time and money has been eliminated in the modern methods of surveying. This is because of the automatism in many steps in both field and office work. Even though the cost of the initial instrumentation is higher it is worthy because you have the payback much more soon. Many new techniques have been developed for surveying monuments during the last years. There are at least four reasons, which cause this fact:

a. The development of instrumentation in surveying
b. The development of computers which automated most of the work
c. The development of photogrammetric instrumentation from analogue plotters to the digital plotters
d. The remarkable acceptance of archaeologists for the new technology

The new techniques depended upon the size of the monument, the scale of surveying and the required accuracy. Most of the new techniques are based on photogrammetry, even though surveyors have yet the responsibility for target control point establishment. Photogrammetric surveys are depended on the accuracy of control points, which are observed with classic surveying methods using total stations or GPS. The density of control points depends upon the scale. The accuracy of the control points depends on the method of their determination and the accuracy of measuring instruments. Another applied classification deals with the type of the used camera, which could be metric, semi-metric or non-metric and also digital camera. The number of required control points depends also on the type of the camera and the method of solution for extracting the final results.

Apart from all of the above we use many types of platforms to take the proper shots, such as kites, balloons, grains, model helicopters etc. in order to carry the camera at the appropriate distance from the object we want to survey [Miy96]. After that we have the choice to manipulate the images in many different ways with several programs in order to obtain the final results. The conclusion is that more easily with fewer hours and less people we can have valuable results, which have much accurate information.

2. Surveying monuments

It was in 1978 when many monuments in Thessaloniki were damaged from an earthquake and there was an urgent need for supporting and restoring them. At that time there were no plans at all for those monuments because they had passed several centuries since they had been built. Facing that challenge some engineers from the city started to survey those monuments and draw their basic plans. At that period it was obvious that every engineer was doing his own best work to answer all the needs of all the specialists who were involved in the restoration process.

In 1982 when Prof. Manolis Andronikos discovered the theatre at Vergina, he asked me to make the plans of the excavation. At that time, it has been used a Di3S by Wild for distance measurements combined with an optical theodolite for measuring the angles, while data were registered manually. It took about three hours in the field and a few days in the office to draw the plans of the site. When the plans delivered to him, he informed me that when his professor discovered the palace of Vergina in 1965 at that time some surveyor was measuring for 15 days to survey the site, so he was surprised from the speed, the accuracy and the low cost. Since that time, even though it is not so far ago, the development of instrumentation for surveying purposes has been changed dramatically.

Apart from those efforts many other surveys have been carried out in several monuments but none has ever oriented in establishing standards for such works. This fact results works that most of the times are incompatible. On the other hand during all these years an excess development has happened in surveying methods due to new instruments. Nevertheless, in my opinion, it is necessary to establish specifications for the monuments surveys in order to have a common reference for all engineers and specialists they deal with the monuments.

The real problem of non existing specifications we faced occurs when we start to measure the monument and finally we have to create a plan on which we present the current situation of it. At this point everybody is free to follow his own thoughts concerning the methods, the instruments of surveying and the presentation techniques. This causes a variety of results that have no uniformity or compatibility. Another fact is the development of 3D surveys the last decade which gives many advantages for the final result, such as rendering, texturing, visualizations, 3D representations and virtual applications.

As we have been engaged all these years in surveying monuments we observed the needs of the users in scales, details, information etc. For example in the survey of Tholos in Delphi (Fig. 1) they wanted an accuracy of 2mm and we succeed it. In another case the architect wanted the section of the church of Saint Andrea in Mount Athos in order to prepare his restoration study and we did it (Fig.2). In a third case the Municipality of Thessaloniki wanted to survey for registration purpose the Gallery of the town and we did it (Fig.4). While the list goes on the experience gained from all those surveys lead us in specification quest.

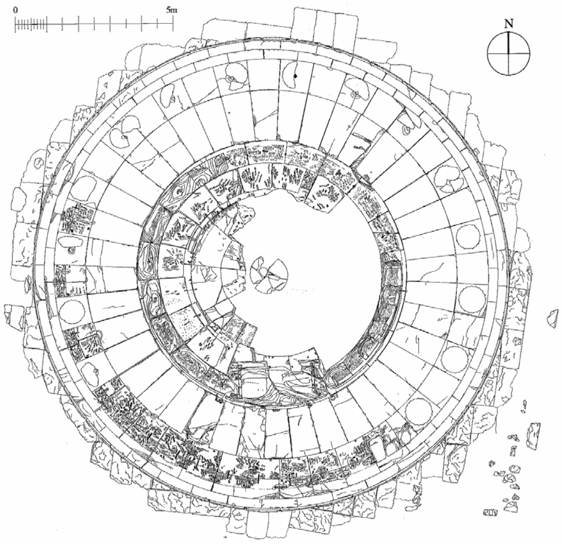

Figure 1: *Plan of Tholos in Delphi*

Figure 2: *W-E section of St Andrea's church in Athos*

3. Surveying methods

The development of the methodology has been changed a lot since the first surveys in the '70s. During the last two decades we passed from the optical theodolites to the electronic ones and after that to the total stations. Then data collectors have been developed which made easier the fieldwork. From simple total stations with external data collectors we have passed in less than 10 years in total stations with built in memory for data registration. And more over now we have motorized total stations that can be used by one man only. And also the last achievement of technology is the reflectorless total stations, which can measure without a reflector.

Figure 3: *Measuring in the Acropolis of Athens*

Now with such a total station (Fig.3) is possible to survey easily inaccessible points situated on ceilings, roofs and on high buildings. The methodology in surveying had changed because several years ago there was a cost per detail point, which was based on the method of surveying the point. If it was inaccessible the cost in time and money was very hight. But today with such instrumentation the cost for some more detail points is meaningless. We have just to sight the point and press the measuring button. The instrument has also a built in laser pointer so we can easily view the target point.

The techniques and the methods in surveying have changed due to this development in the technology of surveying instruments. Surveying has become easier in the field in action and mistakes do not occur very often as in the past. The instruments are computerized and this causes the rapidly development in their technology. The next step will be to have the ability for printing the plan in the field, which is coming very soon. It is possible today with a laptop connected to the total station and via special software that you can manage the measurements from the mouse of the laptop directly in CAD environment. Then the operator must sight to the target and just click the mouse so the instrument will measure and the new point will be plotted on the screen. By this way we can connect the laptop on a plotter and have the drawing of the day in the end of the measurements.

Now concerning photogrammetry in addition to the powerful CAD programs we had the development of the stereo plotters which lead photogranmmetry into the "digital darkroom" [Pat91]. Today both hardware and software in this section are developed and is subject of changing very often towards better solutions. Using CAD programs we can easily produce 3D plans of the buildings and findings in the excavation as mentioned for city plans [Gru98]. This is a powerful tool for architects when they wand to visualize the site [ITM98]. Such 3D drawings can have several applications. But accordingly to the huge development of technology in all areas there has observed a difficulty in following and learning all the changes. Hardware and software is changing and developing every day. This will lead to new young people who have a better efficiency in the modern technology and a greater level of understanding it.

As mentioned above the development of computers caused in a way the development in surveying instruments. But moreover this caused the ability of designing and drawing plans in the computer environment. The CAD programs are of a major help for all specialists dealing with the cultural heritage. Those programs have been renewed and their abilities became extremely helpful for the surveyor. For example several years ago there was not possible to define a volume between two not similar surfaces, now this is possible due to the CAD programs development. That fact was causing the impossibility to create sections of the surface automatically.

Recently it has been easily succeeded to draw 3D models of the monuments and sites because of the H/W and S/W development. A 3D model of one site is useful for four reasons:

- Better viewing of the site as it was
- Understanding of the site and its functionality
- Studying the shapes of the site
- Plan out the reconstruction

It is obvious the fact that the 3D model gives us the ability to recognize the typical basic building blocks of the monument and their location in the site; in a way to predict their original connection with the monument. Having this information architects face a much easier problem than it was in the past. Towards this direction lead also the 3D laser scanning instruments even though the programs for manipulating the point clouds are yet in the very beginning.

4. Specifications for surveying monuments

In the past there have been some propositions for standards but none has been accepted and applied yet. The best effort of establishing standards is the one by English Heritage under the title Metric Survey Specifications for English Heritage in 2000. A copy of this was given to me by Paul Bryan for which I thank him. Then our effort has been developed by the author and it concerns surveys in scales from 1:50 up to 1:10. It concerns also topographic, photogrammetric and architectonic methods. According to the standards all measurements should be referred in a common reference network. Such networks composed from control points for horizontal and vertical control. Also control points for the densification of the information and the photogrammetric surveys.

Concerning photogrammetry the standards give details about cameras, films, scanners and all the consequence work. They give details also about orthophotos and digital cameras. They give specifications also about DTM extracting from photogrammetric surveys, about rectified images and digitization of old surveys. They give details concerning the product plans for its content, types of lines, layers, details and the structure of CAD files.

Concerning architectural surveys the standards give all the details about what to do, how to do and what to present. They give details for scales, plans, sections, façade plans etc. They give details what to survey, utilities surveys, dimensions, heights, areas and volumes. They give details for the accuracy of the plans and the digital drawings. They describe the contents of the plans, lines, layers etc. They propose a uniform codification for the layers and the plans. They describe the format of the plans concerning editing and contents.

Another fact that the standards propose is the final control of the plans that have been produced concerning their accuracy, their completeness and their exactness. All those controls take place in the field by partial control of the plans before the final acceptance of the whole survey. For the time the only problem is that all those specifications are available only in Greek language at http://web.auth.gr/e-topo

5. Conclusions

We can observe today a trend for standardization in every work. This fact leads towards uniformity and a common perspective for every work. After so many years been engaged in surveying monuments we reach the necessity of establishing standards in this field in order to have a better result in the team work around the monuments. At least we can establish specifications for the final plans of the survey and in the "how to do" some of the work because many specialists insist that every monument is something different and special and so we can not apply standards on the work with them.

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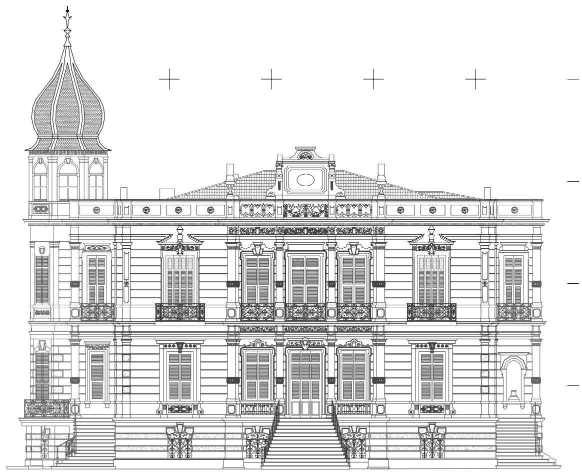

Figure 4: *Facade of the Gallery in Thessaloniki*

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Short Papers

Realtime intrasite documentation from above: the case of balloon-mounted wireless photography

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Abstract

During an excavation the archaeologists need to document the excavation area in multiple instances during the entire duration of the investigation, to add necessary notes and remarks and to do that quickly. Digital technology offers several possibilities for instant documentation and real time reuse and elaboration of the documents. The present contribution reports of an experiment carried out to apply balloon mounted intrasite scale remote controlled aerial digital photography to the process of acquiring real time photographs of the excavation work for annotation and archival. The emphasis of the approach was on the usability of the configuration by a non-technological expert, its unintrusiveness and low cost. The experiments revealed problems related to the image quality and the sensibility to the wind experienced with the present configuration. The usability of the concept is, however, promising and the benefits of the real time photographing became apparent.

Categories and Subject Descriptors (according to ACM CCS):
B.8 [Hardware]: Performance and reliability; J.5 [Computer Applications]: Arts and humanities; I.4.1 [Computing Methodologies]: Image Processing and Computer Vision, Digitization and Image Capture

1. Introduction

An archaeological excavation might be described as a paradoxical function of limited time and expected comprehensiveness. The development of field methods is important in order to cope with this unsatisfactory yet unavoidable state of affairs. Both techniques and technology may help to speed up processes and release staff from manual labour to the more profitable intellectual work. The present contribution discusses the itself already established technique of balloon-mounted aerial intrasite documentation with the novel prospects opened by wireless networks and digital photographic technologies. The focus of the discussion is in the capabilities of the new technologies to speed up the cycle of taking photographs and using them real-time in cartographic documentation. A further emphasis is placed on the aspect of packaging the technology in a form, which may be used by a technologically untrained archaeology professionals. The observations and conclusions are based on field trials conducted during the spring and summer 2006 on several sites located in southwestern Finland.

2. Background

One of the central features of the documentation of archaeological excavations is a need to record repeatedly individual objects and physical locations in their different states of visibility during the project. This means that an archaeologist needs to record information on a daily basis, or sometimes even several times during one day, on a single unit, feature or structure.

Another typical feature, which relates to the currently prevalent paradigm of conducting excavations is that an average excavation site is seldom in an especially photogenic state in any moment during or after the excavation. The strive for efficiency especially in the case of rescue excavations makes it very difficult to acquire clear compositional images. The pacing of the excavation of the different units in a manner, which would keep the excavation surface relatively flat, would significantly slow down the excavation process. The requirement of efficiency together with the unit based stratigraphical excavation method leads to the removal of the layers and structures one by one, instead of an orderly maintaining regular surfaces, distinct layers and levels. A complete picture of the site, analytical layers and levels come about often first in the post-excavation analysis after the digitally acquired cartographic material has been compiled and revised for publication and archival.

The postponement of the completion of the picture of the investigation site is not entirely problem-free. At the present, the units and structures are typically measured by using a total station. The measurements result in a level drawing containing relative altitudes of the various layers and structures as a key element of the document. The individual measurements reside in a three dimensional space, but the resulting aggregate of the lines and points is basically two dimensional map unless the measurements are interpolated to form truly three dimensional objects. Measuring with a total station is very accurate, in fact, to an extent where the need for such a precision becomes debatable. In practise, it might be more essential to consider the relations and interpretations of the units than to strive for a microscopic precision. In any event, an overly accurate measurement increases needlessly the amount of the measuring work.

The challenge of producing rapid, precise and analytically informative information has been met in the field work by using digital image overlays alongside with the measurements. The aim of the using the digital images is to superpose the total station data with a series of a photographs of the actual layers and thereby combine on location the measured data and images with a verbal report, clarifying remarks and sketches in a single document.

The main problem with the approach is that it is rarely possible to position the photographer straight above the object of interest in order to document the units and structures from a direction, which corresponds with the vertical angle of the aggregate of the total station measurements. Angled views are also helpful as complementary documentation, but significantly more difficult to combine with the measurements in real time even with the current georectification packages. The angled views do also leave often significantly large blind spots in the rugged and irregular excavation surfaces. In trials, we have found out that the precision of these photographs is far less an issue than the accurate angle of the images and the straightforwardness of the process, which both contribute to the easy orientation and focussing on the analysis instead of technical details.

3. Documentation from above

Photographic documentation of the investigation area has been a cornerstone of the field documentation almost throughout the entire history of archaeology [Ree36] [RB96, 78] [Bew03]. The tradition can be separated in two practises: documentation from a scaffold or tower and documentation from higher in the air. These two practises differ in the way that photographing from a scaffold is used for documenting details (units and structures in the contemporary terminology), whereas the aerial photography has been used primarily to document large areas, special features and images for publication [RB96, 78-80]. Examples of intrasite aerial photography have been published on several sites (e.g. [Mye78]), but they are in minority compared to the surveys and large scale documentation [Cam03, 76-77]. Close range aerial photography has been used also in related disciplines, such as in the documentation of vegetation patterns [MYN*04],

Erecting a scaffold or tower above or adjacent to an excavation and the efficient use of one has at least in Finland been set aside as a result of changes in excavation documentation techniques since the 1990s. The inauguration of digital imagery has first replaced the colour film images used for note purposes and gradually also the archive-grade B/W film images (cmp. [Tak98]). Digital images as part of field documentation have increasingly been used for various photogrammetric imagings, but seldom in excavating archaeological layers. Digital imaging and photogrammetry are more common in documenting vertical objects and profiles.

4. Developing the tools

The issue of developing new functioning means for from above documentation was taken into a consideration in early 2006. The pondering started with an idea of constructing a modern photographing tower for positioning a digital camera above an excavation. The basic requirements were the repeatability of the documentation work flow and, within reason, the possibility for all-weather shooting. Motivation for the premises were the practical needs: an average excavation can not wait. Things need to be done in schedule. The basic requisite was to be able to take images from the air in the same conditions it is on the ground. Few archaeologists take pictures in extreme weather and lighting conditions. Rain smudges and deforms the excavation site to an extent, which reduces the usability of the photographs. Similarly the limitations of the photographic technology limit the quality of the images. In Finland, the darkness of the autumn is yet another a challenge for the field work. Therefore the aim was set to be able to work in normal Finnish archipelagial conditions during the summer: within the +10 to + 30 centigrade temperature range and in less than 5 m/s light wind. It was also considered that the research areas are mostly free of additional problems, such as strong, turbulent or divergent winds.

Another prerequisite was the ability to have the acquired images very rapidly available, preferably in real time, in digital form. As discussed earlier, the objective was to combine the images during the field documentation with the measured data and unit forms. For the practical reasons in order to be able to work real time, it became evident that the photographer needed to have a real-time viewfinder for panning, zooming and cropping the image. These prerequisites led to the applying of wireless local area network (WLAN) between the camera and the ground station laptop operated by the photographer.

Considering the aims of documenting the excavation process, feasible scale of the photographs was established to a few excavation squares, which means that the area covered by the photographs area should be approximately 2 X 5 metres or larger. In Finland the highest free flight altitude is 30 m above ground level (AGL). The preliminary plan was to stay below that level to avoid the need of special permissions for scaffolds or flying devices.

The technical usability of the system was compared to that of a regular scaffold:

- Any archaeologist should be capable of using it after 1-2 hrs of practical training.
- All of the equipment should also be manageable by only one person and two people should be able to master the task to perfection.
- The system may under no conditions present any danger neither to its personnel nor the environment, and should not require any special permits or skills to operate, but be easy to use for every archaeologist.
- The system needs to be usable in typical weather and wind conditions (+10 - +30 centigrade, < 5 m/s wind).
- The vegetation, foliage and man made structures often limit the open air around the excavation site. Therefore the system should require as little horizontal space as possible.
- It was acknowledged that the system should also be as quiet and unintrusive as possible, given the fact that excavations often take place in locations of sensitive ecology and in areas, where the current everyday functions need to be taken into account. This applies to a variety sites of from tourist attractions to the graveyards and sites of heavy traffic.

The traditional photography scaffold or tower with its height of 5 to 6 metres was considered to be too low and rigid. The established criteria ruled out also dirigible planes and helicopters, kites as well as hot air balloons (cmp. e.g. [STG04]). The most promising device seemed to be a large refillable helium-filled balloon (ref. [MPK03]). It is light, relatively small, simple, inexpensive and unintrusive (ref. used to survey sensitive wetland areas [MYN*04]). The balloon was decided to be equipped with a high-quality surveillance camera for the remote pan, zoom and crop capabilities.

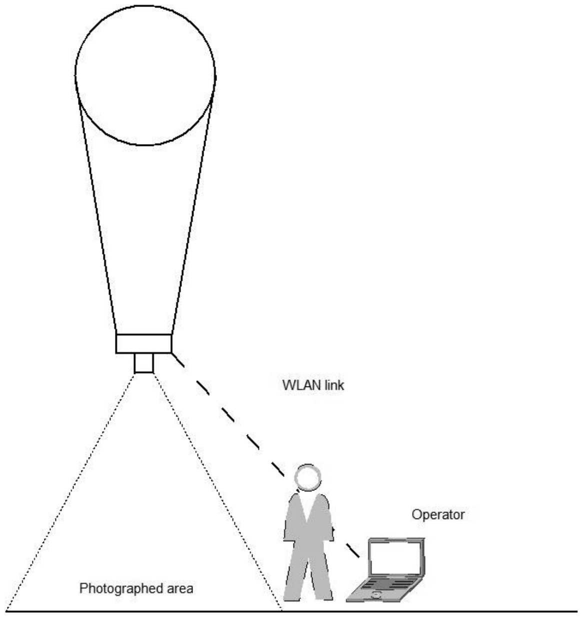

Figure 2: *SkyCam 2006 system*

5. Development results: SkyCam2006

The SkyCam 2006 aerial documentation system (shown in action in Figure 1 on page 4) was developed jointly by the workgroup in order to create an easy-to-use, ecologically sound system for aerial photography at a reasonable cost. Existing balloon carried systems were considered to be prone to technical errors and not suitable for real time documenting.

The solution was to rig a high-performance computerised surveillance camera (presently a Sony SNC-RZ25N dome-camera) attached with a WLAN-card to a 3 m diameter (appr. 10 feet) polyurethane, helium-filled balloon (see). The balloon, filled with helium, is strapped to the ground by four tethers (present length max. 75 m / tether, or 246ft), which ideally leaves the lines outside the area under viewing. In order to keep the balloon in place even in heavier than moderate winds, counterweights were made by pouring cement in plastic pails (weight/pail appr. 15 kg or 33 lbs.). The tethers are fastened to these weights to ensure the stability of the construct. The currently used balloon is an advertising balloon made of polyurethane. A 3 metre diameter balloon requires 15 m3 or 525 cbft. of helium gas.

The balloon mounted camera is installed with a software allowing real time remote viewing, and controlling of the device. The camera is powered by a 10-piece set of 12 V DC rechargeable batteries, which currently gives approximately 5 hours of operating time. The Sony dome-camera has a 30 FPS frame rate giving good flexibility to the remote viewfinding and an additional possibility to shoot video

Figure 1: *SkyCam 2006 aerial photographic system in use at the Kuusisto Castle in Southwestern Finland*

if necessary. The device requires only 0,7 lx illumination, which enables viewing and shooting in poor lighting conditions. The lens provides the user with 18 x optical zoom, which is assisted by a 12 x digital zoom. Panning and tilting the head provides limitless angles to view any research area. The possibilities of using IR or UV filters is under research.

The camera and power source are fitted securely to a stainless steel plate, which in turn is fastened to the supporting device, in this case the balloon, at each corner. A weatherproof IP-box with built-in fan and protective lens cover was also designed to enable viewing in poor weather. The SkyCam is not, however, safe to use if there is a danger of lightning. A suitable viewing height for the average excavation can be anything from 10 to 30 metres above ground level, depending on the documentational needs.

Pictures are transmitted by a built-in SNCA-CFW1 wireless LAN interface (802.11b) to a laptop on the ground, where the operator can pan, tilt and zoom the viewing area at will. The images are named and stored immediately in JPEG-format. The principal benefits of using a WLAN based connection instead of e.g. a video connection (as e.g. in [KO98] [ACKT04]) anticipated before the project and confirmed by the trials are the

- Flexibility of the connection and data transfer. The photographs may be edited, used and archived as a part of the excavation documentation instantaneously using the same workstation, which is used to control the camera and to take the pictures (cf. [KMM*99]). The operator can use an ordinary image editing tool or a specialised documentation system to add labels, notes and draw on the images.
- Wireless connection. The lack of wires simplifies the construction and frees the operator to work at the best possible spot on the site, even inside a building if necessary (cf. e.g. [ACKT04]). Moreover the wires do not interfere with the angle of view (cf. Fig. 2 in [ACKT04]).
- Seemless integration to the general network infrastructure used at an excavation and to the internet. The images may be shared on an excavation wide WLAN network between all workstations and used simultaneously by several ar-

chaeologists in a variety of documentation and annotation tasks. The pictures may also be transmitted directly to remote users for e.g. consultation by email or using an FTP-server, if available.

- Use of standard technology. The WLAN capable cameras and workstations are relatively inexpensive (in comparison to proprietary systems) and easily interchangeable (e.g. in case of a technical failure or in need of a higher resolution camera, video capabilities, etc.).

The total cost of the complete system is about EUR 2300-3300 without a computer. The helium balloon costs between EUR 700-1000, the helium gas 600-700 EUR per season, the SNCA-CFW1 camera EUR 1000-1500 and a WLAN base station EUR 50-100.

6. Discussion of the first test results

So far the experiences show that one complete fill and later complementing fills are sufficient for one summer of activities. This means savings in gas costs and very little ecological traces. Leakage problems reported in earlier experiments conducted with hydrogen filled rubberised silk balloons could also be avoided [Mye78]. The balloon and its accessories are transported to each site on a trailer.

Both the balloon and the attached camera have been subjected to rigorous tests in the archaeological investigations at the ruins of the medieval Kuusisto Castle near Turku, in southwestern Finland during the passing summer. After some training, the balloon and its accessories have been set up ready to use from the transportation package in 15-20 minutes. The system is manageable by one person with a reasonable physique. The pull of the balloon is quite strong although quite manageable in moderate weather conditions. The longest distance for the WLAN between the ground station and the camera measured to work properly, seems to be about 150 metres with the present configuration.

Some tentative issues were recorded. The balloon has a slight problem with its sensitivity for wind. Stationed over an excavation it can only stand for winds in the range of 1-2 m / s. Besides the general sensitivity to the wind, the low altitudes at about tree-top level seemed to be especially problematic due to the strength of turbulence. The balloon attached with a camera has obviously a mass, which moves around very rapidly and rather compellingly in sudden winds. The balloon is capable of moving even the 15-20 kg counterweights on the ground. Further, the estimated lift of the balloon was not sufficient to make it possible to apply a completely weatherproof harnessing.

The greatest challenge proved, however, to be the resolution of the camera and especially the JPEG compression of the current software version. The 640x480 px resolution with a high compression rate renders images in calm weather conditions, which are suitable for a limited use in popular presentation and on the Internet. Even a very subtle swinging of the balloon and camera have, however, a deteriorating effect on the image quality, which renders them useless for research purposes. The image in figure 4 is taken in nearly ideal conditions (only slight breeze), although the low sun height causes some problems in form of shadows. The figure 3 on the other hand, illustrates the low resolution of the present camera and the deterioration of the image quality in somewhat heavier winds. It is expected, however, that the stability and image quality issues may be solved by adjusting the balloon configuration and by using a different, higher resolution camera.

Figure 3: *A detail of the ruins of Kuusisto castle, southwestern Finland. Foto: Kari Uotila.*

Figure 4: *An undated, Bronze Age grave mound in Parainen, southwestern Finland. Foto: Kari Uotila.*

7. Conclusions

A few months of testing has shown, that a helium balloon, WLAN and digital camera offers a relatively easy and technically feasible method to take real time aerial images of archaeological sites. The current configuration is cheap, easy to use, unintrusive, allows suitable angles for photographing and permits working sessions of up to 5 hours. Therefore the balloon needs to be taken down only once in a middle of a day for the change of batteries. The objectives of real time stratigraphical documentation and notetaking may be met with ease.

The present technical problems relate to the relatively poor image quality of the surveillance camera technology used in the current configuration. The problem is easily solved by finding and installing a more accurate camera.

The sensitivity to the wind, which is a special problem with the round balloons, may be worked out if a cigar shaped 'airship' or kite balloon is used instead. The currently known issues with the approach relate primarily to the increased size, weaker lift and higher cost of the cigar shaped balloons compared to the round ones. Also, the earlier reported problem of the relatively narrow window of suitable winds for the kite shaped balloons has to be taken into consideration [Mye78]. Another possibility would be to use of two or more balloons (as in [MYN*04]), even though that would definitely decrease the controllability and the ease of handling. In spite of the reported successes, the need of additional training and equipment decreases also the feasibility using a combination of kite (in moderate winds) and balloon (in low winds and windless conditions) (cf. [Ahm04]).

8. Future prospects

The work will continue with the issues of image quality and the sensitivity to the inoptimal weather conditions. The quality of the images is under research and several new camera models with WLAN connection are being tested including both the surveillance cameras and the relevant consumer products. A further issue under consideration, is the sensitivity to wind related to the round balloons. Possible solutions, including the changes in the shape and size of the balloons are tested to reach an optimal configuration.

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Short Papers

Integrated methodologies for data elaboration and real time: Villa of Livia (Via Flaminia project)

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Abstract

The CNR ITABC (Institute for the Technologies Applied to the Cultural Heritage), through the Virtual Heritage Lab, develops integrated methodologies for data elaboration and visualization and for the creation of virtual archaeological landscape.

The Via Flaminia's territory (Rome, Italy) is a composite setup of buildings, terrain and vegetation. Its virtual reconstitution requires the acquisition of architectural and topographic data and the development of a methodology to consolidate all data into a unique real time modelling framework.

Gathering data about the current status of the various elements of the territory requires to draw on a broad spectrum of instruments and techniques. Each technique should indeed be adapted to the morphology and scale of the entity that is surveyed. The instruments used to acquire data are: laser scanners, photogrammetry, computer vision, Total Station and differential GPS.

Using an advanced technology such as the laser scanner (for example in the case of the Villa of Livia) we obtained three-dimensional sets of points. The level of resolution is 6mm, or about 30,000 points by square meter. A total of 7,000 square meters were surveyed. Points were then triangulated (using Rapidform) and a first model produced decimated.

The preparation of a real time model requires such raw and bulky models to be optimised, and especially to reduce the number of polygons and ease the texture management. Two approaches were tested in this respect.

The optimized models are finally integrated in the virtual reality system, together with other models, prepared using different technologies, such as photomodelling (applied to regular geometries) that produces low-poly models with textures.

Through the 3d reconstruction of the architectural heritage and its real time display, we obtained an accurate and communicative interpretation that both suits research purposes and can transmit the importance of conservation to the general public. It is perceived as an effective way to divulgate and publicise an information that is often only accessed by the scientific community.

I.3.6 [Computer Graphics]: Methodology and Techniques

1. Introduction

Processing information from the archaeological fieldwork to the communication medium is complex and requires assumptions and interpretations to be made at various stages. In addition, surveyed data has to be selected and simplified in order to lighten information files and provide a clear representation of reality. There is thus a risk of displaying distorted and incomplete information and thereby inducing bias in interpretation and research. Against this background, the Virtual Heritage Lab (VHLab) based at the CNR ITABC (Institute of Technologies Applied to Cultural Heritage), develops since 1999 an integrated methodology to acquire, elaborate and visualize archaeological landscape, through virtual reality systems.

In autumn 2005, CNR-ITABC signed a research agreement with ARCUS (Art & Culture Society), in collaboration with the Archaeological Superintendence of Rome and the participation of the UPM (University polytechnic of Catalunya), for the "reconstruction of the archaeological landscape of the ancient Flaminia with virtual reality systems", building a digital ecosystem that individualizes two levels of perception: the first one represents an holistic vision of the road from Rome to Rimini, based on historical maps, information on the archaeological excavation, technical cartography and aerial and satellite photos able to support the realization of a web gis; the second one, which dips into a micro-space vision that focuses the attention on four sites represent and contextualize the local entities within the "ancient landscape" entity.

In this paper, we introduce how we developed a specific approach for data gathering, incorporation in unified models and optimization protocol oriented towards real time desktop DirectX 9.0 applications, in order to reconstruct an archaeological landscape based on surveyed scientific data.

2. The study area

The ancient via Flaminia represented in the ancient times the road axis of fundamental importance for the connections between Rome and northern Italy and towards Centre-oriental Europe, joining Rome and the Umbria with the Latin colony of Ariminum (268 a.C.). The road followed the ancient transhumance ways and has been used during the Romanisation of the area. In II sec. a.C., Sempronio Gracco was restored, and it is supposed that the Interamna-Spoletium-Trebiae-Forum Flaminii section was renovated in the same time, following a pre-existing Umbra's road (important for the connection with the colony of Spoletium, 241 a.C.).

The road and bridges were renovated under Augusto. One of the main objectives of the road was the conquest of the Padania Valley and the Gallia Cisalpina. Along the road were found numerous burial sites and some important urban centres. Nowadays, the ancient Via Flaminia is still visible in few zones and important archaeological rests are conserved, scattered in a modern peri-urban context. The transformation of landscape and degradation of vestige make them hardly visible and appreciable.

The topographical knowledge of the Via Flaminia is disjointed and therefore the first problem in the virtual restitution is the contextualization of the sites able to be relieved and reconstructed in a unique VR frame.

Gathering data about the current status of the various sites of the territory requires to draw on a broad spectrum of instruments and techniques. Each technique should indeed be adapted to the morphology and scale of the entity that is surveyed. The sites that interest the project are very dissimilar, the necropolis of Grottarossa; the bridge Ponte Milvio, on Tevere river; the ancient arch of Malborghetto become nowadays museum, and the Villa of Livia at Prima Porta. The cognition of the actual state of the sites is based on the possibility of using advanced technologies for the data acquisition that is intimately connected to the typology and the particularities of the entities to examine. The instruments used to acquire data are: laser scanners (Villa of Livia), photogrammetry and computer vision (Grottarossa), photomodelling, Total Station and differential GPS (Malborghetto and Ponte Milvio). Nowadays the project is still in progress and if the relief of Villa of Livia and Malborghetto are already finished, for the other sites the work is started in this days.

2. 1. The villa of Livia

The Villa of Livia is the most important and complex component of our project (fig.1). The great archaeological complex is situated in the IX mile of the Via Flaminia, traditionally identified with the villa of Livia Drusilla, wife of Ottaviano Augusto, The villa was built between the 30 and 25 a.C., using the rests of a previous republican construction, and was occupied until severian age, when important restoration works were made, especially in the thermal area. Four construction's phases are identified, the last one in the III century B.C. The Villa was discovered in 1863. Unfortunately, the villa was bombed and damaged during the last world war. Damages are still visible in the room 15 and in the thermal area.

The villa is designed in a terraced structure, supported by opus reticulatum's structural walls. It has two visible floors, with an underground floor for services, and probably a second floor in many areas of the Villa. On the main central terrace of m. 160 x 80, the residential rooms were opened towards south, placed around a small porticus with a garden of republican age; towards the North, a complex of rooms and gardens was developed with an atrium tetrastilo with impluvium with private access from the Via Flaminia.

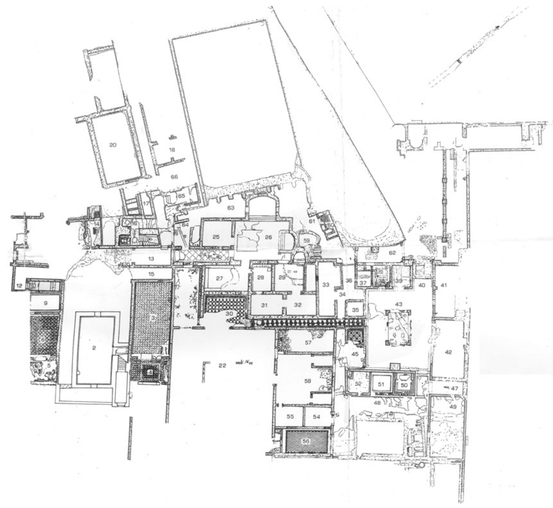

Figure 1: *plan of Villa of Livia*

North-west of the atrium, the present thermal zone corresponds to severian age but the original structure is datable between age Claudius-neronian and domitian. In the South-West sector of the villa there was the representative zone, perhaps used for receptions, and various dependences of service, of augustea age modified until severian age. Under these rooms, there is the underground triclinio with the famous frescoes of the garden, now kept in the national Roman museum.

3. Methods and results

A completed digital 3D processing of acquisition and representation will be the best basis of knowledge according to an integrated approach in order to minimized the risk to lose scientific data (Forte, 2003). We interpreted what we perceived, a VR system is able to show all the phases of the digital processing in a 3D domain. The dynamical interaction in a VR system can multiply the faculty of interpreting archaeological data, monitoring the digital ontologies of all the process of research.

To start the relief of the Villa we found out different problems: First, a fixed shed built in 1986 completely covers the site (fig.2), preventing any overall vision of the building and thus precluding the site survey from any zenithal point of view (e.g. aerial photographs). The second problem relates to the complexity and great dimensions of the Villa, and thus to the need for methods that compromise surveying time and accuracy. Moreover, another question was how we could manage the big 3D model file of the entire villa for the real time.

Figure 2: *view of the Villa of Livia*

The design of a reliable and verifiable reconstruction begins with collection of quality and comprehensive data, both by a thorough survey of the vestiges (“bottom up”) and the collection of texts drawings and other archives (in close collaboration with the Superintendence of Cultural Heritage), relative to actual places and on study cases morphologically and temporarily comparable (“top down”).

The importance of starting from objective and accessible data, in the case of the Villa of Livia has turned out even more necessary, due to the complexity of the architectonic system and the insufficient and partial credibility of the planimetry in public archives and of scarce information caused by incomplete excavations.

For the great archaeological complex of Villa of Livia, we had selected two different surveying techniques. The first is based on the laser scanner and targets for the “representation zone” rich of important traces of painting in fresco and for the thermal area. With this technique we acquire high resolution and accurate data on volumes, at the expense of intensive surveying time The raw data collected with this technique is also too bulky for real time system. The second techniques is photomodelling, used for “the private” areas. In these simpler areas, photomodelling allows to rapidly acquire low polygon resolution with an high metrical accuracy data easily used in the 3D model.

The laser scanner technology represents a substantial technical step towards the availability of publishable, up-to-date, accurate data. In addition data is georeferenced, which is fundamental for an archaeological contextualization of the buildings in their territory. The acquisition of 3D data with the laser scanner generates a high resolution point cloud able to support the development of 3d models with a resolution of 6mm or about 30,000 points by square meter (Cyclon by Cyrax Technology). Because of the heavy files generated by the scanner, the relief Villa was made room by room, delaying the problem of merging all the files in a unique model. The second step of the point cloud elaboration relies on the RapidForm software developed by Inus Technology, which functions and algorithms for the construction of the mesh seem to be still more powerful in this moment. The result is a 3D model based on exact data, with generated and interpolated faces. The same technique is used to detect both the architectonic compound of the Villa of Livia and the hill on which it exists. In fact, to contextualise the villa we used the scanner laser to survey the hill. This produced 4.379.590 points cloud that was process with the software RapidForm to produce a mesh. The processing of the cloud was complicated by the high level of noises and could not reach a satisfactory result. GRASS was thus used as an alternative software, importing the dxf file of the point cloud from Cyclon, and a geo-referenced model of the hill could be generated, using also some reference points measured with the Total station. (Fig.3).

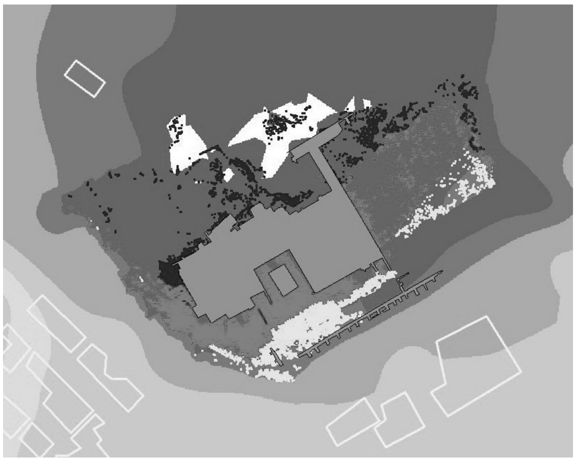

Figure 3: *Digital Elevation Model reconstructed through the interpolation of GPS data and the laser scanner point cloud of the Villa of Livia*

This approach allows both the creation of complex archives and the use of these data to reconstruct archaeological landscape in virtual reality applications for DirectX 9.0 environment.

The preparation of a real time model requires such raw and bulky models to be optimised, and especially to reduce the number of polygons and ease the texture management. Two approaches were tested in this respect. (Rapidform and 3dsMax software).

The first consist in mapping the surfaces using a specific algorithm dedicated to generate textures. This fast, but accurate method produces images composed of series of triangles that could not be edited with photographic software. Moreover, the algorithm of rapid form introduced a monochrome background to the unused zones (fig.4), thus causing an annoying puzzle effect to the meshes (fig.5). More importantly, this method does not allow to apply the “multires” modifier, which is the most important tool we have used to obtain a low polygon 3D model .This first method was thus abandoned.

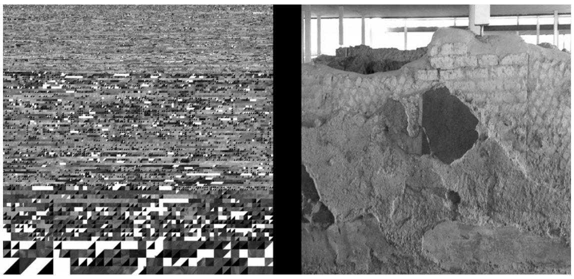

Figure 4: *Texture applied to the mesh in RapidForm, detail of the puzzle-effect*

The second method is based on 3dsMax software. A special mapping tool was used ("unwrap"), that allows to directly apply the image on the mesh.

This technique allows to roto-translate the projection plane to the same position as acquired with the digital camera. The possibility to manipulate the textures after the processing allows to fine-tune every single image of the total scene (e.g. brightness, colour, contrast), conferring realism and quality to the model. The ulterior optimization of the mesh is made using the modifier "multires" of 3dsMax, which, unlike the modifier "optimize" (previously used), allows to have a great control on the reduction of the number of polygons without modifying the perception of the model (fig.6). This second method thus reached a satisfactory compromise between the level of detail and the fluidity of the model.

Figure 5: *Texture by rapidForm*

Rooms were then modelled and texture added to the mesh. Merging the models of each of the single room within the general model was finally done using the 2D Autocad relief in DXF format obtained from the Total Station and imported subsequently in 3dsMax (Fig.6). In order to obtain a unique realistic model, it was necessary to equalize colours, contrast and brightness of the textures of the single rooms, using Photoshop.

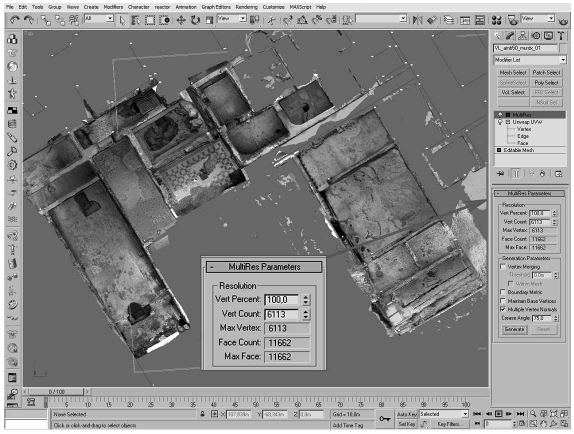

Figure 6: *Merged rooms with 3dsMax*

Photomodelling was first applied to three of the private rooms of the Villa. This easy, but not so fast, technique generates a very low poly model, readily textured. Comparing the two different way: (1) laser scanner with RapidForm and 3d Max (2) Photomodeller, it is evident that the first method is more accurately and detailed than second. Because the time needed to prepare the two optimized 3d model was more or less identical, we decided to drop the photomodelling technique and survey the whole villa with the Scanner, in order to achieve a uniformly accurate and detailed mode.

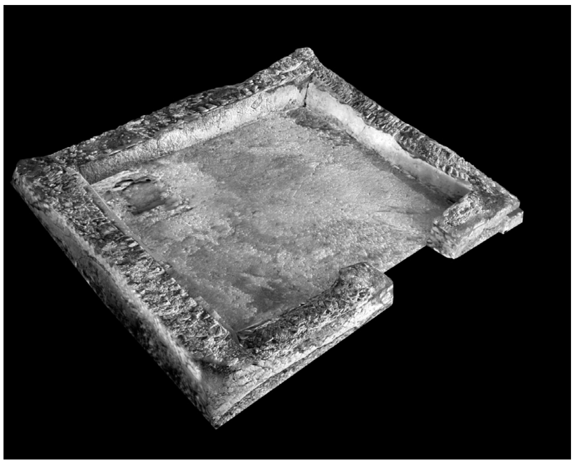

Figure 7: *Room 52 with photomodelling*

In fact, to realize the 3d model of the room N°52, for example, (fig.7) with the Photomodelling takes one mission of one person on site to make the pictures and four to five person-days to (1) realize first the 3d model with the software Photomodeler 4.0, (2) import the vrml or dxf format files in 3d Studio Max and (3) correct geometry (checking with 2d cad layout), (4) create "mappe in bump", and (5) lights and rendering to texture.

For the same room, instead, it takes one mission of three persons with Laser scanner to realize n°19 ScanWorld. One person day is the required to process data with the software Cyclone by Cirax Tecnology and realize a point cloud composed of 965.017 points that cover an area of 378 sqm (where the room in object is just 35 sqm). The post processing with RapidForm (to construct the mesh and make a first optimization) and 3d Studio Max (for texturing with "unwrap" and optimize with "multires" tool the model) takes then three days of one person (fig.8). For the whole Villa, the Laser scanner was used to survey of total 7,000 square meters in about forty person-months.

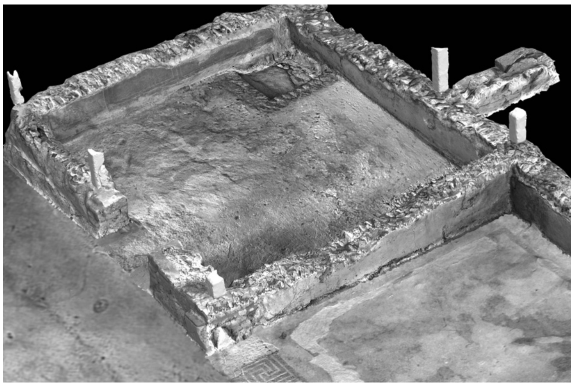

Figure 8: *Room 52 with 3ds Max*

Photomodelling was still a useful technique to survey the Malborghetto, an area of 204,68 sqm with very simple volumes. Together with the acquisition of reference points using the total station and the GPS, it supported the reconstitution of the site and its landscape.

4. Conclusion

The Via Flaminia project is still in progress but the work done up to now already allows to draw methodological conclusions for the creation of a virtual reality system based on a unique model (example of integration of spatial data, different technologies and methodologies) with high accuracy and detailed data (fig.9).

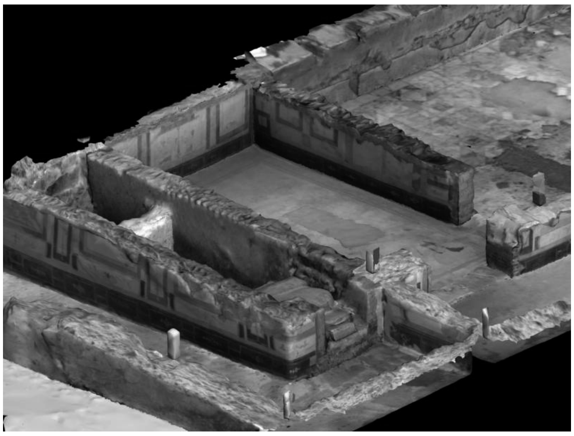

Figure 9: *Rooms modelled with RapidForm and textured with 3ds Max*

The method can also generate low polygon resolution version of the meshes without modifying the perception of the model, keeping the frame rate of the application higher than 25 frame/sec. With this modelling approach, we obtain a fluid navigation through the mesh. The reconstruction of the virtual site is later realized trough an application in Virtools Dev 3.5, which allows to obtain a final version. This last version is not editable but the previous version is editable and could be upgraded at every moment if required. Through the 3D reconstruction of the architectonic heritage supported by real time applications, we approach an accurate and suggestive interpretation (using also the avatars reproducing historical and non-historical characters) that involves the public and transmits the importance of cultural heritage and thus of its conservation. Such models allow to disseminate data and information that often belong to the scientific ambit and that are not accessible or comprehensible to the majority of the unspecialized public. The interpretation increases the experience and vice versa: the possibility to interact with the cultural heritage increases the respect and the understanding of the public, transmitting the importance of the conservation, knowledge and the sharing and exchange of data and contents.

The cultural wealth at our disposal and the application of advanced but freely shared technologies give the possibility to make the common heritage accessible to everyone, in its historical, artistic and scientific dimensions.

5. Acknowledgements

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Short Papers

VR Modeling in Research, Instruction, Presentation and Cultural Heritage Management: the Case of Karanis (Egypt)

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Abstract
Since Fall 2005, a team at the Experiential Technology Center of the University of California, Los Angeles (UCLA), and archaeologists from the UCLA and the Rijksuniversiteit Groningen (RUG) expedition to Fayum have been creating a Virtual Reality model of the ancient town of Karanis. The model has multiple purposes, perhaps the most innovative being its future use as a management tool for the archaeological site. The model will aide in monitoring the decay of the town since the early 20th century, and in reconstructing the buildings, but it will also be used to study aspects of routing and the use of space, as well as a way of explaining architecture, principles of stratigraphy, and life in the ancient town to students. These seemingly disparate aspects of the VR model all aid the compilation of a site management plan for Karanis. This short paper presents a work in progress, envisioning the full potential that 3D technology implies.

Categories and Subject Descriptors (according to ACM CCS): J.3 [Arts and Humanities]: Architecture

1. Introduction

In the late 19th century three British scholars, Grenfell, Hunt and Hogarth visited the Fayum oasis in search of scholarly treasure (Figure 1). They were after Greek papyri, which were found in great quantities by the so-called *sebakhin*, farmers who were excavating ancient settlements to use the mud brick on their fields as fertilizer. The papyri and other antiquities were a lucrative by-product of these activities, and became a focus of the antiquities trade. The three British gentlemen had no interest in architecture, or archaeology, although they did remark on the exceptional preservation of wooden objects at the Fayum sites, in particular at Karanis. After two thousand years agricultural tools, doors, windows, roofs, textiles and baskets were still found intact and in amazingly good condition, but their focus was the papyri [GHH00]. The architecture was left to be cut away by the *sebakhin*. In 1924 the University of Michigan started excavations in Karanis, after a complicated battle with the *sebakhin*, who by that time were well organized and had a little rail line running from the center of the ancient town towards the edge, so that the mud brick was harvested on an industrial scale. The maps and elevations of the Michigan expedition show at least six major occupational phases, but also a large area, encompassing the entire center of the town, marked ominously “Area Entirely Destroyed By Sebakhin”.

From 1924 to 1935 the University of Michigan excavated a large part of Karanis, concentrating on the town’s central quarter. The excavations revealed a large mud brick town, with two stone temples, multiple storied houses, granaries, dovecots and ample evidence of grain and olive processing [Boa33; BBP31; Hus79]. The excavations were a race against time, with the purpose to save and document as much of the town remains as possible in the little time they had, before the *sebakhin* would excavate all. Before the Michigan excavations finished, the destructive work of the *sebakhin* was brought to a halt, by urgent claims that the site represented an important historical monument. The excavations cleared a wide area, to enable an in-phase overview of the different strata. Late Roman layers (dated to the third to fourth centuries CE) were removed to understand the earlier periods of occupation. After excavation was finished, in 1935, the mud brick monuments were mostly left open to the elements.

2. Present situation of Karanis

The town of Karanis was probably founded in the third century BCE, during the efforts under Ptolemy II Philadelphus to bring the Fayum under cultivation. These earliest (Ptolemaic) levels were not reached by the Michigan excavations. A recent re-interpretation of the archaeological remains puts the end of Karanis to the sixth or seventh century CE [Pol98]. These nine

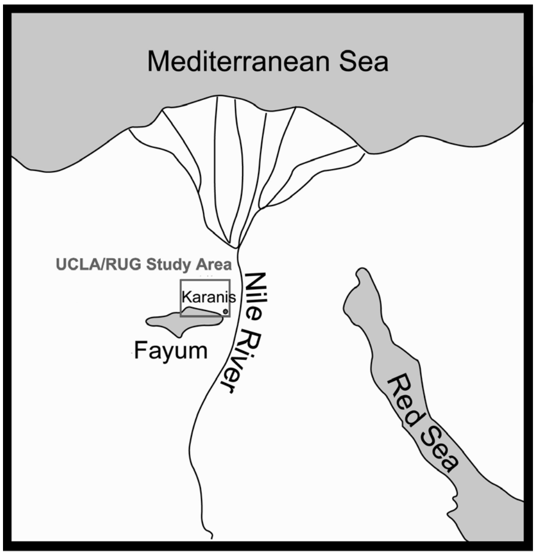

Figure 1: *Location of the Fayum, the study area of the UCLA/RUG excavation project and the ancient town of Karanis.*

centuries of occupation have created a depth of deposit which in some places is over ten meters. The large area excavated by the Michigan team, and the part destroyed by the *sebakhin* still cover no more that 25% of the entire site. On satellite photographs it is clear that the unexcavated parts of the town extend to the north, south and west, and continue at the west side of the main road from Cairo to the Fayum (Figure 2).

The site east of the road is open to the public and offers tourists an open air exhibit (the excavated part of the site, Figure 3), and a small museum which boasts antiquities from all periods of Egyptian history, from pottery dated to the Predynastic (3000 BCE) to the porcelain of Egypt's last King Farouk (1950's CE). The museum does not focus specifically on the Fayum, although several objects on display have been excavated in the Eastern part of the Fayum (Hawara). The museum was established in the 1960's as part of a philosophy to give all Egyptians the opportunity to find a broad overview of their national history in locally accessible museums.

At present, the open air museum at Karanis is a bewildering experience for the visitor. Sand-filled pathways lead through the excavated areas, and in many places run over underlying structures, exposing older, vulnerable mud brick walls. To the uninformed eye, an enormous deep vacant space in the center of town, flanked by two stone temples, seems to represent a curious type of inversed agora. Without knowing the history of exploitation of the site, the town's fabric is incomprehensible.

The mud brick buildings, excavated by the Michigan expedition, show evidence of rapid decay:

Figure 2: *Google Earth photograph of the ancient site of Karanis, with the approximate boundaries of the ancient remains, the cemetery west of the Cairo-Fayum desert road, and the destroyed central part of the site between the North and South Temples.*

Figure 3: *Center of Karanis looking south west towards the South Temple. The low lying area between the mud brick building and the stone temple is the "area entirely destroyed by sebakhin" (see also Figures 2 and 4).*

severe undercutting by wind erosion, dissolving of the plaster and bricks by rare but occasional precipitation. Conservation efforts of the Supreme Council of Antiquities and a French team in the 1970's have concentrated on a few buildings: the North and South Temple and a bath house in the west part of town.

3. Environmental archaeology in the Fayum area

In 2003 an excavation team of the University of California, Los Angeles (UCLA) and the Rijksuniversiteit Groningen (RUG), started a landscape project in the northwestern region of the Fayum. The project focuses on land and water use in the development of agriculture, from prehistory to present. The project's concession area includes extensive Prehistoric remains and three Greco-Roman settlements: Qaret Rusas, el Qarah el-Hamra (discovered in 2002), and Kom Aushim / Karanis.

The Prehistoric remains provide information on the earliest agriculture in Egypt, the cultivation and storage of wheat and barley. A study of Karanis is undertaken to augment information provided by the Michigan excavations. Many of the botanical remains have been shipped to Michigan and are now in the Kelsey Museum in Ann Arbor. Another portion of the Karanis finds (botanical remains, but also agricultural implements) are on display in the Agricultural Museum in Cairo. The botanical research, headed by the co-director of the Fayum project Dr. René Cappers, studies these finds, but also tests rigorous sampling methods in new excavations, to determine how representative the present Karanis botanical collections are.

Archaeology has seen a development in recent years, from purely research based projects, to an approach that takes much more responsibility for site preservation and presentation, as well as information to the general public. It is in this context that the UCLA/RUG Fayum project, directed by Willeke Wendrich and René Cappers, started to collaborate with Jolanda Bos, from the Dutch archaeological company Past2Present-ArcheoLogic, to investigate the possibilities of site management. The project has received support from the Antiquities Endowment Fund, administered by the American Research Center in Egypt for the first phase of the work: the initial evaluating phase of the management to be summarized in a position paper.

4. Karanis site management plan

The remains of the ancient town of Karanis were not adequately protected, through backfilling after excavation was finalized. Since the excavation of the University of Michigan, the mud brick town has been exposed to the elements. A rough estimate of the decay in the last century leaves the impression that more than 50% of the exposed remains have eroded in the past seventy years. For the UCLA/RUG expedition it was apparent that the monuments needed to be dealt with in some way. Excavation is not the main focus of the team, which feels a responsibility to aid the preservation of the remains of Karanis for future generations. As became clear from an initial survey, complete conservation of the site would be an impossible undertaking, both technically and financially. Difficult choices need to be made regarding the conservation of this vast area. To provide well founded grounds for these decisions, the site needed to have a management document. A team, headed by Jolanda Bos, is developing a site management plan to safeguard the preservation of the remains, at the same time enabling well substantiated decisions regarding access, information, conservation and future research. For this purpose the determination of the value of the Karanis monuments and the site as a whole will be assisted by developing several management assessment tools. These will also provide a toolkit for the archaeologists working at the site, in relation to site and heritage management in Fayum. Instruments, needed to determine the direction of the archaeological heritage management, will be developed in a bottom-up approach. At the core will be the archaeological remains and the interests of the different stakeholders, in contrast with an approach in which ‘best practice’ is implemented without a thorough analysis of a site’s potential.

One of the main assessment tools for (future) archaeologists and heritage managers of Karanis is a survey of the state of conservation and rate of decay of the mud brick buildings. Important elements in the study are the publications, maps, excavation notes and other documentation of the previous archaeological expeditions. During our initial year at the site, it became apparent that one of the sources to assess these issues are the photographs taken over seventy years ago by the Michigan expedition. Comparing these with documentation of the modern state of preservation should facilitate answering questions such as: How fast does the mud brick deteriorate? What has disappeared during the past seventy years after exposure of the buildings? What are the processes that are causing this? To aid us with the assessment, and to enlarge the impact of our findings, we decided to make use of the results of a parallel project, the creation of a virtual reality model of Karanis for use in the class room at UCLA.

5. Virtual Reality model of Karanis

In Fall 2005 a start was made to create a real time Virtual Reality model of the town of Karanis (Figure 4). With funding from the Office of Instructional Development at UCLA, three graduate students of the Department of Near Eastern Languages and Cultures at UCLA, Kandace Pansire, Eric Wells, and Carry Zarnoch are rendering the plans and elevations of the Michigan publications into a three-dimensional model of the town. The work is done in the laboratory of UCLA’s Experiential Technology Center, and greatly assisted by the center’s Associate Director, Lisa Snyder. The rendering program used is Multi-Gen, which enables the creation of a real time model, which is generated on the fly. The model is created in such a way, that it serves multiple purposes, five of which are highlighted below.

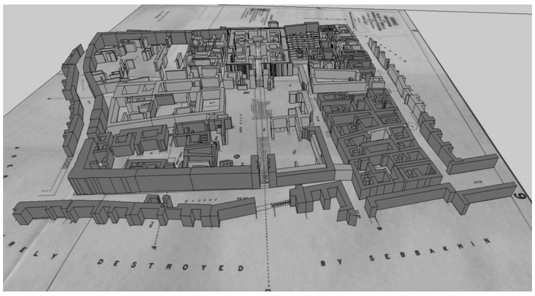

Figure 4: *First stage of the Karanis VR model (in development), based on published maps from the University of Michigan publication. In the forefront the map indicates the “area entirely destroyed by sebakhin”.*

5.1. The Karanis VR model as an instructional tool

The values of VR modeling in archaeology is generally recognized [Bar00]. Students of architecture or archaeology learn how to read maps, plans and elevation drawings. Students of history, art history, or ancient languages often do not have this background and show great reluctance to study information in a non-linear or non-narrative way. Understanding an ancient city, the activities of its inhabitants, the role of neighborhoods, location of industrial quarters, routing, social gathering spaces and all other aspects that are part of a town’s fabric, requires a spatial approach to the subject. By creating the VR model, the plans and elevations are translated into a three dimensional representation, familiar to a generation accustomed to computer games. Perhaps the most important aspect of the instructional model is the display of phasing of the site. Rather than painstakingly studying a series of eight large fold-out maps, the student can toggle between phases. This enables an understanding of urban development, re-use of buildings, re-definition of city quarters, and concepts of growth, decline and abandonment.

5.2. The Karanis VR model as a research tool

The potential of the Karanis VR model as a research resource is as enormous as that of the teaching tool. Complex phasing of individual buildings or even segments of buildings, can be integrated in the phasing of the site as a whole. The model can be used to summarize and integrate micro-analysis into an overall stratigraphic overview. Secondly, the virtual reconstruction of buildings or entire sections of the town will enable testing of hypotheses ranging from building methods, to inside light levels, temperature control, storage capacity and lines of vision. Architectural reconstructions have an important heuristic function, because decisions on, for instance, wall height, roof lines, and stair wells require decisions on very specific structural details. Each choice has consequences which are difficult to foresee when made on paper, while the virtual reconstruction translates each alternative into a very specific set of delimiting conditions. A third example is a research project starting in Fall 2006 in which the model will be used to represent the spatial distribution of grinding stones and olive presses. The site of Karanis is littered with large round limestone milling stones, smaller granite hand mills, heavy half-rounded press weights and large stone press foundations. Although not all of these are in situ, a study of the distribution is expected to result in the identification of centers of activity of grain processing and olive oil production. In combination with a detailed study of each grinding or mill stone and the wear marks on these, reconstructions of the different production types will be made. By connecting the VR model to a GIS, full use can be made of the three dimensional spatial analytical functionality.

5.3. The Karanis VR model as threat monitor

During the Fall 2005 field season, Bastiaan Seldenthuis, the photographer of the project systematically recorded the wall faces marked on the old University of Michigan Karanis site plans. This time consuming project, which will be finalized in the Fall 2006 field season, enables us to correctly project the wall faces on the Karanis VR model. By underlying the 2005/2006 photographs with those made in 1924-1935, the VR model will enable us to visualize the wall decay during the past seventy years. Similar photographic recording of all, or part of the standing walls on site in future years will provide one method of documenting the state of preservation and an instrument to monitor further deterioration.

5.4. The Karanis VR model as presentation tool

The VR model will be part of an exhibit that will elucidate the function, appearance and history of the town. Similar functionality used to teach the ancient urban fabric to students, will be used to guide tourists through the virtual town as preparation of a visit to the actual remains. Stills from the model will present reconstructions of particular quarters on site, so that the extant remains can be compared to the recreated model. Such on-site information panels also aid the visitors in understanding how the bewildering mud brick landscape ahead represents different phases in town use, partly dug away by excavators and looters. The use of VR models has been applied with success for this purpose at for instance the sites of Ename and Luang Prabang [PCK*00; Let99].

One of the aspects underdeveloped in archaeological information allocation to the general public is the methods archaeologists use. Popular on-site presentation of archaeology often still focuses on artifacts, rather than the archaeological context. The public is, therefore, often not aware of the potential information to be gained from an archaeological site, and the modern excavation and scientific methods used to do so. In addition to explaining the history and development of the town, the VR model can be programmed to show the visitor a glimpse behind the scene: it will present the research potential of Karanis as an archaeological site, the vulnerability of the remains, the efforts to preserve the site, and the importance of public awareness and participation. The model will, therefore have a prominent role in the Karanis site information center.

5.5. The Karanis VR model as an assessment and management tool

At several stages the VR model for the site will serve in the management of the ancient town. Its function as threat monitor and explanatory aid were outlined above. In addition to the educational aspects, the model will be used to design the routing for visitors. At present tourists are allowed to roam freely on site, while there is no discouragement to climb on buildings. Assessment of areas under immediate threat can be monitored closely, and the results conveyed to the public version of the model, to be used as a vivid illustration why the vulnerable mud brick should not be touched. Based on the detrimental stress, selected visiting highlights and routing, a selection will be made of areas which require immediate backfill, or other consolidating interventions.

Not all remains of the town of Karanis were excavated by former expeditions. In fact a considerable part of the site still lies hidden in its protective matrix of sand. These unexcavated areas which are not under direct threat of deterioration by natural or human factors, should be preserved *in situ,* rather than endure *ex situ* conservation. The results of surveys with non-destructive techniques, such as a magnetic survey to be done in Fall 2006, will be added to the VR model to extend the town to its full former size. At that stage, the model can be used to implement a site zoning as a management tool for the different potential usages. Areas that are completely off-limits, public areas restricted to tourist routing, increased access for guided specialized trips, and research areas are some of the potential zones to be defined.

6. Conclusion

Originally designed as an instructional and research tool, we are just now exploring the full potential of VR modeling technology by making it accessible to all the stakeholders of a multi-faceted project such as the Karanis site. The model's instructional value can be utilized as a wake-up call for policy makers when threats and decay are made shockingly visible by overlaying photographs from different periods; visitors, when confronted with this evidence, may comply more willingly with limited access if they understand that the rules are designed to preserve what previously was invisible to them. Research results feed into public information as well as management decisions. Assessment of the current situation, aided by a three-dimensional spatial representation can go hand in hand with a representation of the foreseen improved state of affairs after specific interventions. The VR model can be used as a record, a representation, a prediction, and a test of previous, current and future situations. The potential of VR in cultural heritage resource management is vast, but it is our task to envision the new capabilities it gives us, i.e., its potential to enable research to proceed, while preserving the site itself. Most importantly we must avoid designing our projects and predicting our results based on existing technologies rather than taking into account the full potential that this new 3D technology implies. The Karanis VR model, with its easy accessibility, may become the center of focus for students, archaeologists, visitors, local population, government oversight officials and policy makers. It will bring together the important stakeholders of the Fayum heritage and cover the multiple angles of the Karanis heritage management.

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Short Papers

Photogrammetry in Architectural Study: A message from architect to surveyor

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Abstract

Photogrammetry is nowadays one of a prime technology for architectural drawing. This paper aims to report an architectural survey by using photogrammetry. The authors discuss not up-dated technique of photogrammetry but what is the problem when the architect makes drawing by photogrammetry. The authors had an opportunity to participate in the fieldwork of the architectural remains of Ancient Messene and a Byzantine church in Messenia, Greece. We used photogrammetry to make drawing and visualize the Classical monuments and the Byzantine church. In this paper, we make it clear the problems of photogrammetry as a visualization tool for architectural survey.

1. Introduction

Photogrammetric techniques with digital camera are quite proceeding in these years. These techniques are suspected to simplify the fieldworks in the archaeological sites. The method of photogrammetirc techniques with digital camera has advantage in its conveniences: the surveyors just take pictures on sites, and analysis them by laptop computers.

It is very important to record the data for the architectural research or archaeological survey, because the excavation aims to protect the cultural heritage, not to destroy the ruins. For architectural studies, especially, drawings and measuring data are quite important. Thus, architects and archaeologist has to make drawing and to take photographs in order to record the data and to analyze them. Most of the historical monuments have complicated shape, such as sculptures or architectural members with decorations. It is suspected the photogrammetry make easier these architectural field works. In addition, 3D modeling data will be useful for presentation sources, virtual museum and making replicas, etc.

The authors had an opportunity to use photogrammetric techniques in Ancient Messene in Peloponnesus, Greece (the excavator is Prof. P. Themelis, Society of Messenian Archaeological Studies), and a Byzantine Church near Messene in 2004. This project conducted by Architectural Mission to Messene of Kumamoto University (leader: Prof. J. Ito), collaborated with Topcon Corporation. EOS Kiss Digital (Canon, 630 M pixels) and software PI-3000 were used for this photogrammetric survey.

2. Systems

Topcon PI-3000 is application software for 3D measuring, 3D modeling and 2D pictures, so this system also enables us to make Digital-Ortho-photo (image of orthogonal projection). It is possible to analyze various kinds of target with various sizes, from few cm to 100 meters. Moreover, this system is useable in laptop computer so that we could analyze data on the sites. The principle of PI-3000 system is based on stereo method: combination of more than two pictures from different viewpoints (see Fig. 1).

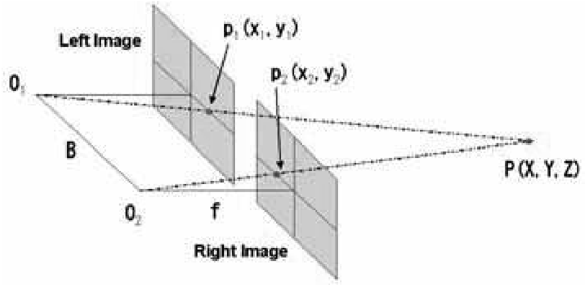

Fig. 1 *Basic Principle*

Measuring work is as follows (Fig. 2):

1) To calibrate your digital camera, before taking photos (you may can calibrate it after taking photos). It is necessary for camera calibration by selected lens and digital camera and obtains the interior orientation parameters (focal length, principal point, lens distortion).
2) Put picture data in your laptop and open it in the PI-3000 software.
3) Make orientation. Orientation is to calculate the photographing position of cameras, based on the image coordinates of the corresponding points on the left and right images. More than six corresponding points should be correlated.
4) Determine the common measuring area of two pictures within one model. We determine this common area on the stereo-images, rectified to become visible in 3D from the required parameter by the orientation. We can also determine easily on the two images displayed simultaneously at right and left on the same PC display.
5) Once the common area is determined, we make automatic measuring (stereo-matching). Through this automatic measuring, we can process thousands of points altogether at a time and obtain the 3D coordinates.
6) After the work of 3D measuring, you can make 3D model in automatic and manual. It is also possible make rendering image, texture mapping image as well as contour line image by making a wire-frame out of the 3D point clouds.
7) Finally, we output the data of reconstructed. Since this can be output as DXF, PDF, CSV and VRML data, so we input them into CAD to make drawings or bonding other data, etc.

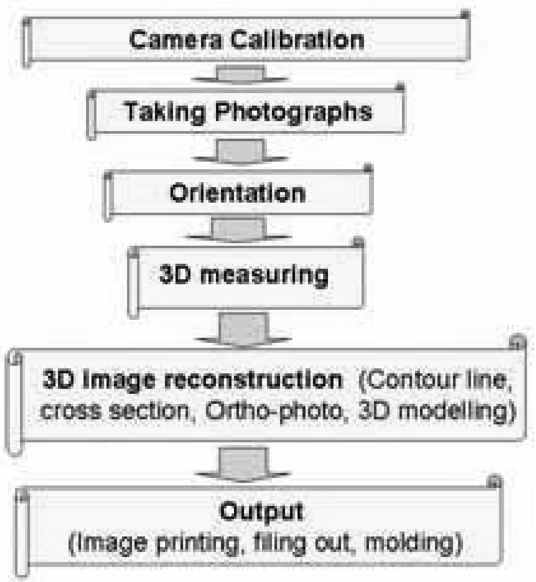

Fig. 2 *Flow chart*

3. Examples of 3D measuring and modeling

3.1 Ancient Messene

The ancient city of Messene, one of the most important classical sites in Greece, is located around 20 km north of Kalamata, Peloponnesos (Fig. 3, 4). Messene, an ancient city in Peloponnesos, Greece, was founded by Epaminondas, the Theban hero, in 369 BC. The Sanctuary of Asklepios (or the Asklepieion) was the main sanctuary of the town and located in the center beside the Agora. The sanctuary was excavated by A. K. Orlandos during the years from 1950s to 1970s. However, he passed away after that, leaving the research uncompleted. The investigated the Stoa of the Asklepieion, the Grave Monuments of Gymnasium, and the Byzantium Church, which is about 5 km south form ancient site of Messene.

3.2 Corinthian Capitals

The Corinthian Capital is an architectural member of the column, which support the upper roof structure of the colonnade of the Asklepieion. It shapes bell-like with spirals with acanthus leaves around its (Fig. 4). The Corinthian capitals are used in stoas (colonnade) of the Asklepieion. The Corinthian Capital, which we measured, was about 70 cm (in length), 50 cm (in height), 70 cm (in width). Firstly, we put seven target seals on the Corinthian capitals to measure 3D coordinates by electric total station (Topcon TS), and then took photo by the digital camera (EOS Kiss Digital, Canon). The environment of taking pictures are; object distance was

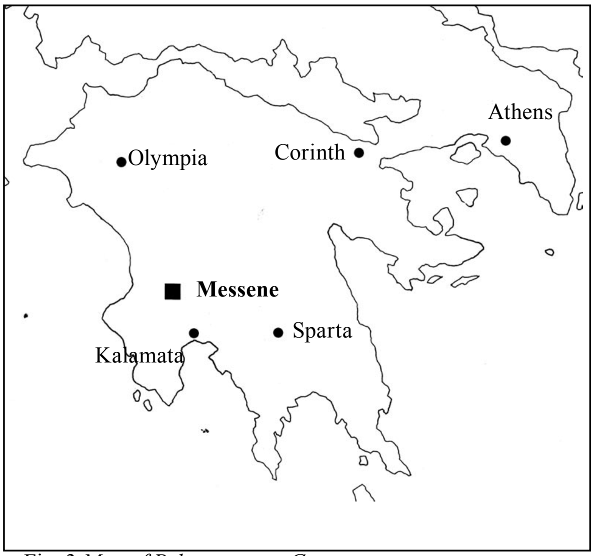

Fig. 3 *Map of Peloponnesos, Greece*

Fig. 4 *Aerial view of the Asklepieion (below) and the Stadium (above) from Acropolis*

Fig.5 *Corinthian Capital, Messene*

Fig.6 *3D model of Corinthian Capital with texture maching*

around 65 to 70cm, distance between viewpoints was around 0.3 m, focal length was 18 mm, and 11 photos were used. In this environment, one pixel is equal to about 0.3 mm in horizontal direction, about one mm in vertical direction. As a result, we got texture-matching picture with contour lines (Fig. 5, 6). The contour lines will be helpful for measure vertical height and make architectural drawings. It took 10 minutes for taking photos and one day for making 3D mode.

3.3 Architrave-Frieze Blocks

The Architrave-Frieze block is timber block putted on the columns and support the roof of colonnades. The block was consisted with two parts of the Order; architrave and frieze. There are decorations three steps of facia (horizontal bands) in architrave part, and buclanie (bull-heads) and phialae (sacred dish for worship) combined with festoon in frieze part (Fig. 7). The targets were 3 Architrave-Frieze blocks, which was about 7.3 m (in length), 0.75 m (in height) and 0.35 m (in width). For taking photos, same as Corinthian capital, put 22 target seals on the blocks to measure 3D coordinates by electric total station (Topcon TS), and then took photo by digital camera. The environment of taking pictures are; object distance was around 1.1 m, distance between viewpoints was around 0.4 to 0.75 m, focal length was 18 mm, and 16 photos were used. In this environment, one pixel is equal to about 0.4 mm in horizontal direction, about 1 mm in vertical direction. Working hours was 30 minutes for taking photos and 5 day for making 3D model. As a result, the authors succeed to make 3D model with clear texture mapping: the 3D model with texture is so enough clear to see three steps of facia, bull-head and phialae decorations that the architect will be able to use for basic sketch or layer to make final drawings.

The authors made comparison of Digital-Ortho-photo from

Fig. 7 *Architectural drawing of Architrave-frieze Block with relief of buculanii and phialae*

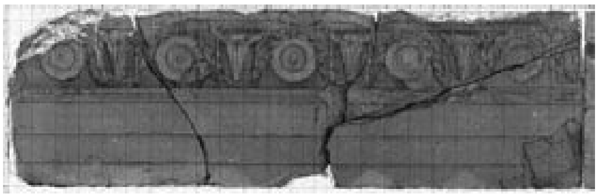

Fig. 8 *Digital-Ortho-Photo of Architrave-frieze Block*

3D model and architectural sketch by hand measuring (Fig. 8). Fig. 7 shows architectural sketch one of the Architrave-Frieze blocks (the length of which is about 2.4 m) in original scale 1 to10. It took seven days for the architectural sketch by hands; two days to detailed measuring (because the block is too heavy to rotate by human power), three days for general sketch and two days for decoration part. Fig. 8 shows comparative pictures the Digital-Ortho-photo and the hand made sketch of the same block of PI-3000. The hand made sketch are digitalized by scanner and adjusted to have same pixel per inch as the Digital-Ortho-photo. With comparison, there is 1 mm difference between these two pictures in the edge and clacks of the block. The cause of this might be from the difference of definition of facade of the block, that is, there is difference of viewpoint. It is also suspected that scan machine and camera lens make distortions. Secondly, the shape of difference between these two pictures of frieze decoration. It might be caused from using template when we make drawings by hand, not because of distortion of camera lens. As an evaluation, the Digital-Ortho-photo is enough collect (under 0.5 mm in generally) as an architectural sketch or basic layer for final architectural drawings. In addition, photogrammetry can make decoration drawings quicker than hand drawing.

3.4 Lion Statue

The lion statue was founded from Grave Monument K1 in Gymnasium complex buildings and now you can see in the Archaeological Museum of Messene. The lion is hunting a deer from its behind (Fig. 9). This lion statue is considered

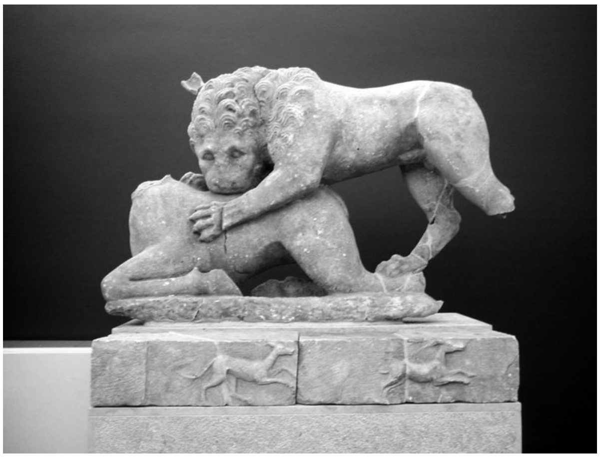

Fig. 9 *Lion Statue from Grave Monument I, Archaeological Museum of Ancient Messene*

Fig. 10 *3D model of Lion Statue with texture mapping*

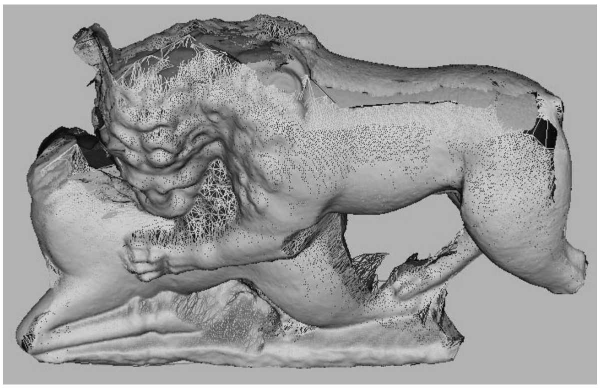

Fig. 11 *Rendering Model of Lion Statue*

that it was on top of the Grave Monument roof. The authors succeed to make 3D model of whole of the statue. More than 20 photos were used to make 3D model. Unfortunately, the brightness of each photo is different because we could not change the lighting in museum. It took half of a day for taking pictures but 10 days for analysis. For archaeological research, in generally, it is required only the facade part drawing of the statue, so we will be able to shorten working hours for the drawing.

3.5 The Church of Agia Samarina

The Byzantine church of Agia Samarina is located 5 km south of Ancient Messene (Fig. 12). This church renovated from ancient building (probably a kind of temple) to Byzantium church, so big limestone blocks were used in the lower part of the church. In generally, it is necessary one week at least to make architectural drawing for such a big building. We tried to use photogrammetry, and it took a half of one day for taking photos, five days for making 3D model. The environment of taking photo was: object distance was about 11 m, distance between viewpoints was av. 4 m and 34 photos were used to make 3D model. In this situation, one pixel equal about 4.5 mm in horizontal direction and about 15 mm in vertical direction. Fig. 13 shows 3D wire flame model with texture mapping, and Fig. 14 show Digital-Ortho-photo of 3D model.

As you see in these pictures, the authors successes to make Digital-Ortho-photo s of the elevation of this church (unfortunately, we could not measure the roof). In this time, the author made just 3D model, but it will be possible to make simplifies of site working, if we have more detailed photos and measuring data.

Fig. 12 *Byzantium Church of Agia Samarina, Mssenia*

Fig. 13 *3D model of Churuch of Agia Samarina*

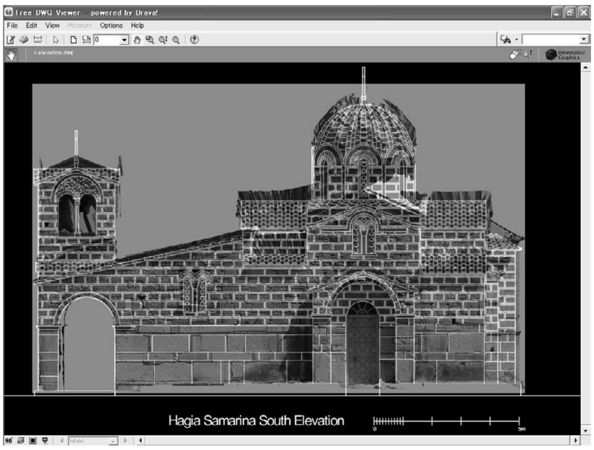

Fig. 14 *Comparision of ortho picture and hand drawing elevation, south elevation of Agia Samarina*

4. Summaries

In summing up, the authors succeed to make 3D measuring and modeling by use of market on digital camera and software (Topcon PI-3000). This system can measure various kind of object from small to big: a small object such as lion sculpture in the museum, and big object like Byzantium church. This system need not big instrument or electric sources in the site, so it is easy to use in the site. In addition, the authors could make Digital-Ortho-Photos with well correctness to use as architectural drawing, or basic sketch for the final drawing. Although, the authors, as architects, could not satisfy enough of the result: the architectural member of Classical period made high accuracy less than few millimeter, so at this moment, we will not able to use the Ortho-Photos for architectural drawings directly. In Byzantine Church, there is a distance error in the length of wall more than more than 20cm; this irregular is unacceptable as architectural drawings. In this case, the Ortho-Photo is only useable for layers on the part of upper small stones of the facade of church. The laser scanner will have advantage for such a round material, like the Corinthian capital, but we have to carry up such heavy stones, which is more than 150 kg. We have to take care the required accuracy is depending on the kind and size of the object. Additionally, this system requires well-trained operator who have not only operating skills but also architectural or archaeological experience, because the final purpose of the architectural survey is to make drawings with collect measurements. In our case, the working hours for making sketch by photogrammetry are approximately same with it by hand. Thus, if the photogrammetry has enough accuracy for architectural requirement, there is big possibility to make the filed work simply and easily. For example in measuring work in the church facade, it will be not necessary to put up scaffolding for measuring the roof of church. It is possible to solve this problem by using Picture TS (Topcon GPT-7000i), which can measure the points without reflector, and can take photos with each point. It is also more safety for surveyor and proper for sensitive object like sculptures.

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