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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.

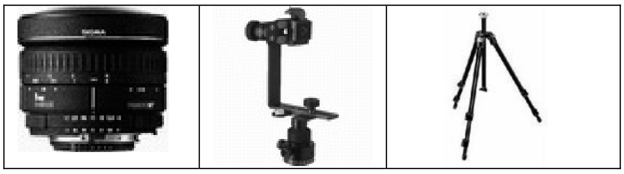

Figure 4: *360º panorama equipment: fish-eye lens, pano head and tripod.*

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.

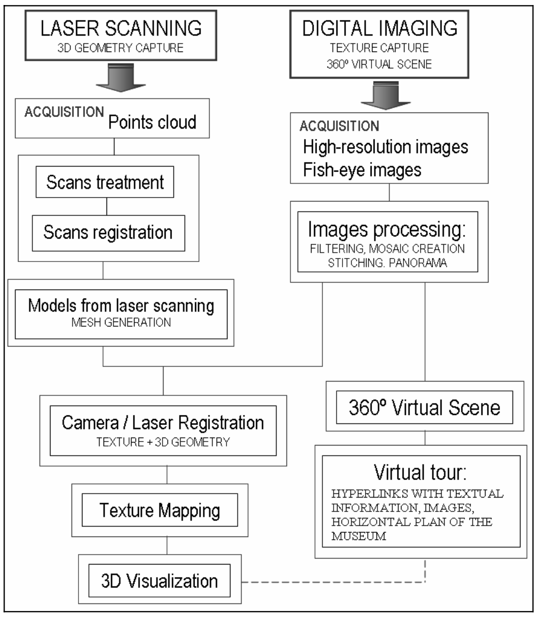

Figure 5: *Laser Scanning methodology.*

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).

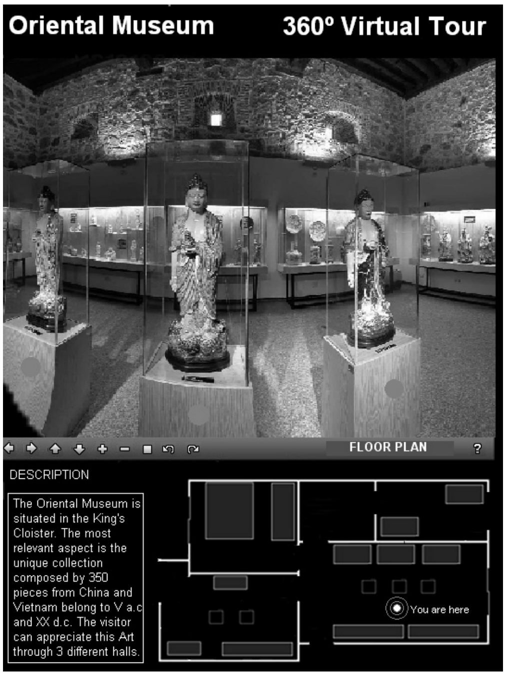

Figure 8: *360º virtual tour through the Oriental Museum.*

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.

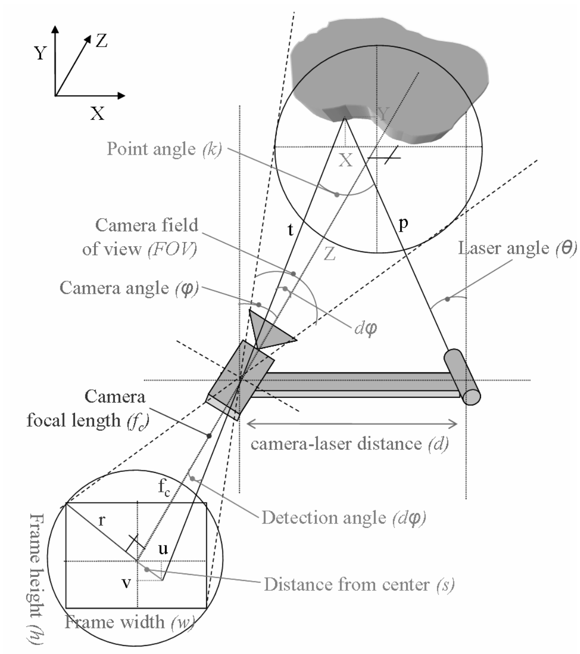

Figure 1: *The proposed system and the process of triangulation for a point in space*

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:

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

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

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

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

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

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.

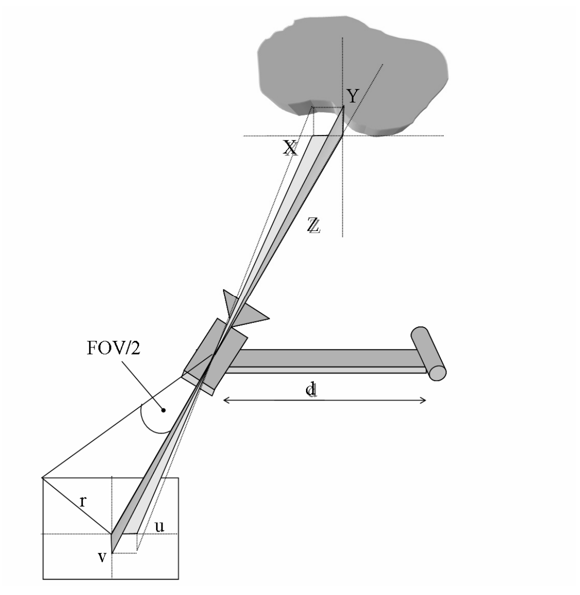

Figure 2: *A more practical approach to the estimation of the unknown coordinates of a detected point*

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

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

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:

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

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.

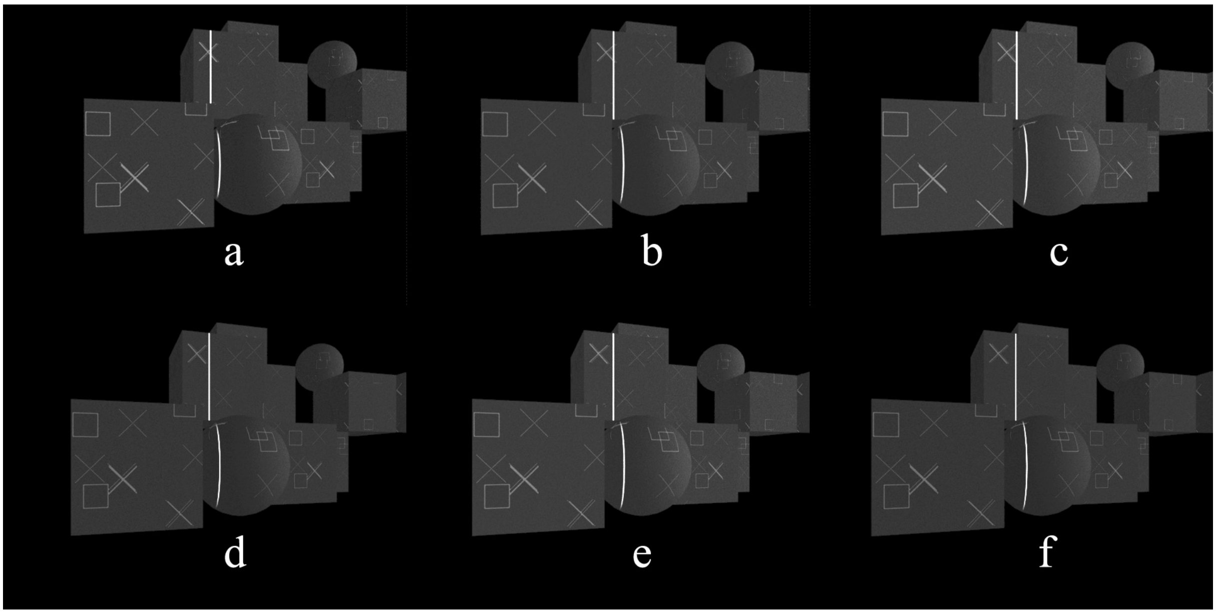

Figure 3: *Six (a to f) consecutive images (with a step of two images) from the test data set. The bright vertical line is the laser projected on the object.*

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.

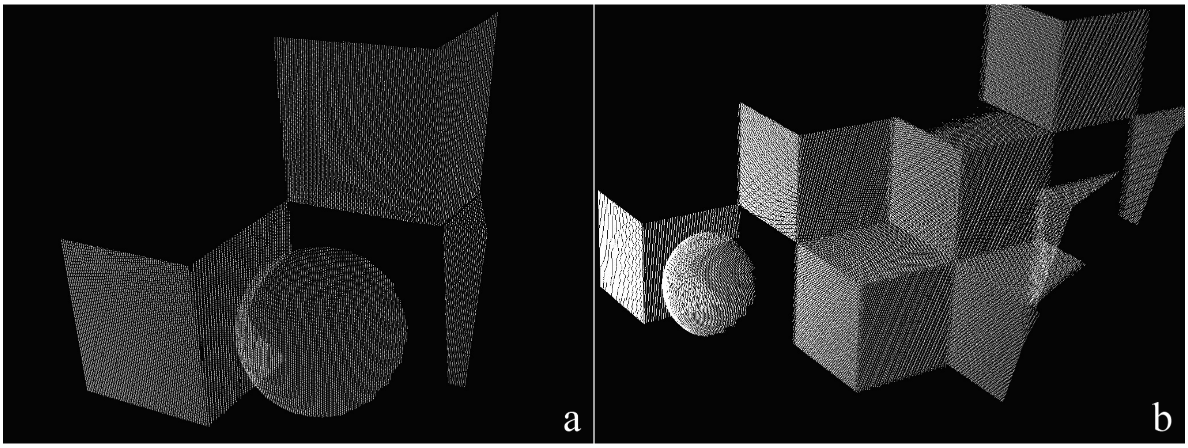

Figure 4: *The result of the digitization process (point cloud) at different time instances.*

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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.

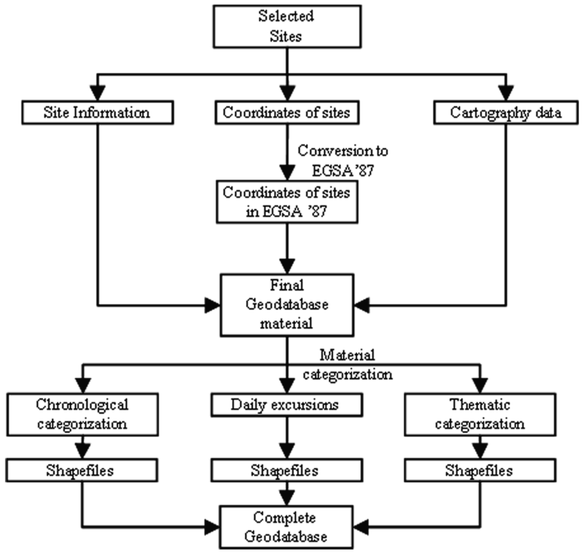

Figure 1: *Tasks during the Geodatabase construction*

- *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.

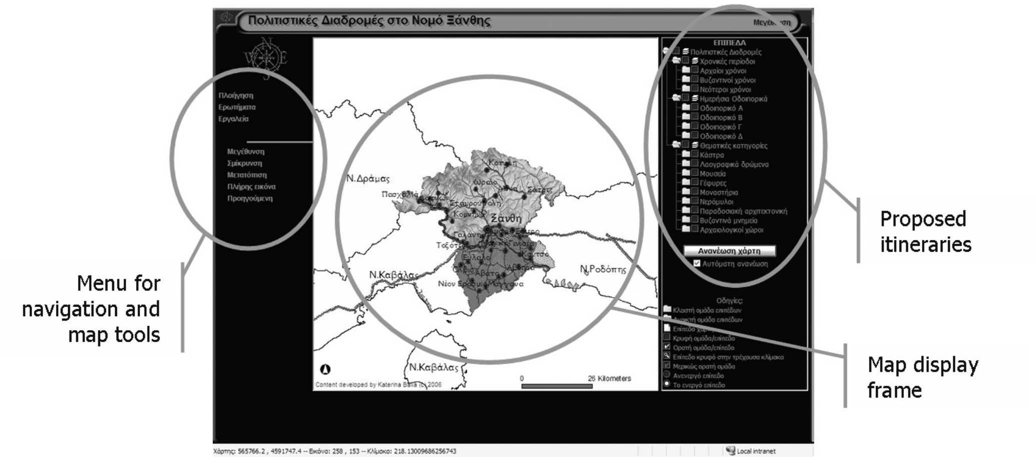

Figure 2: *Screenshot of the web application (in Greek)*

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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"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).

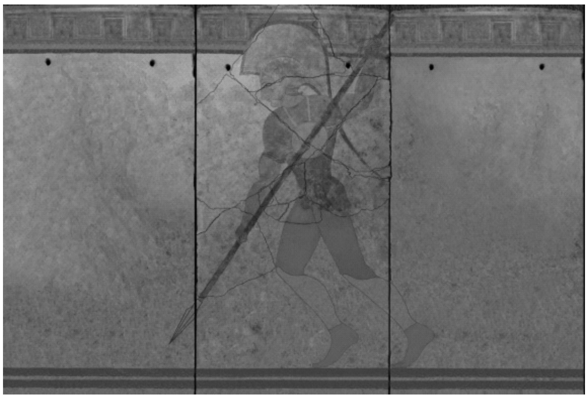

Figure 3: *Virtual reconstruction of the slab.*

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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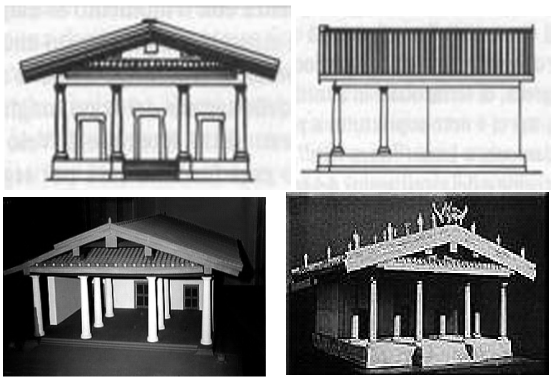

Figure 5: *The geometric model of theTemple*

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.

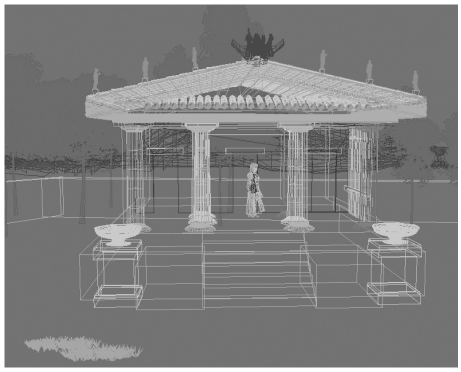

Figure 7: *Firts phase of modeling and reconstruction of the architectural space.*

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:

$\mathbf{r_u = r_d + k_1 r_d^3}$ 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.

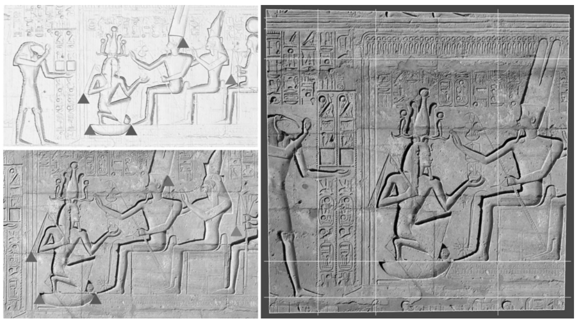

Figure 3: *User-supplied correspondences between scan data (top left) and photo data (bottom left); rectified image region via POSIT with lines added for reference (right).*

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.

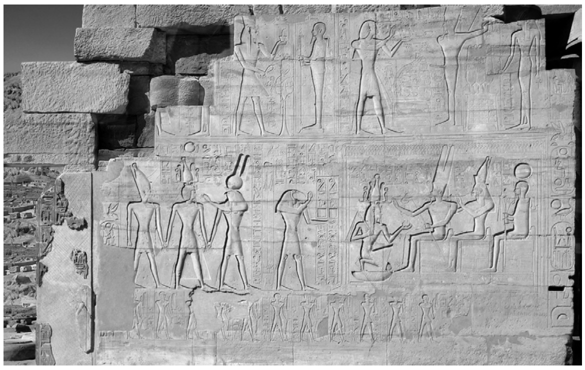

Figure 4: *A completed orthographic mosaic. Note that cast shadows from separate input photos are shown to closely align as images were acquired within ~20 minutes.*

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].

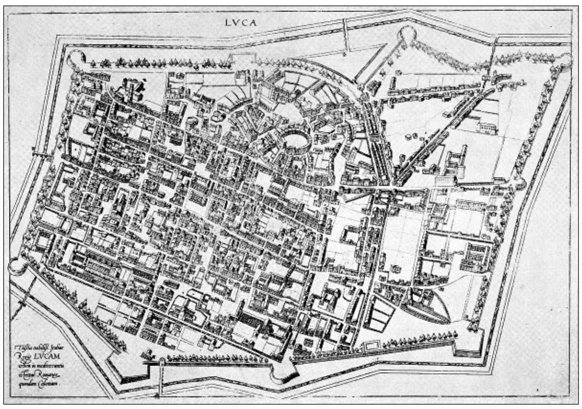

Figure 1: *Lucca, Birdview sight, (Braun, 1576)*

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.

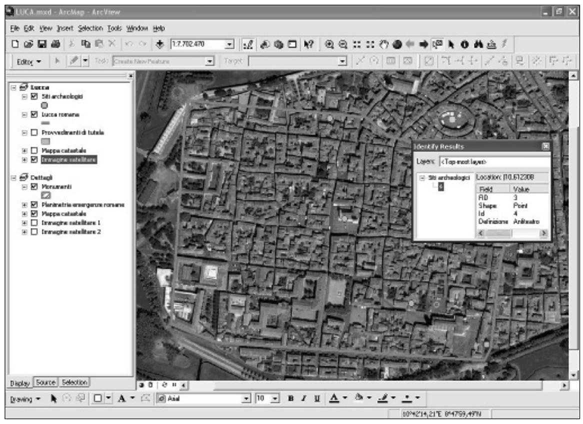

Figure 5: *GIS environment. Perimeter of roman Lucca with example of Info Tool query*

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].

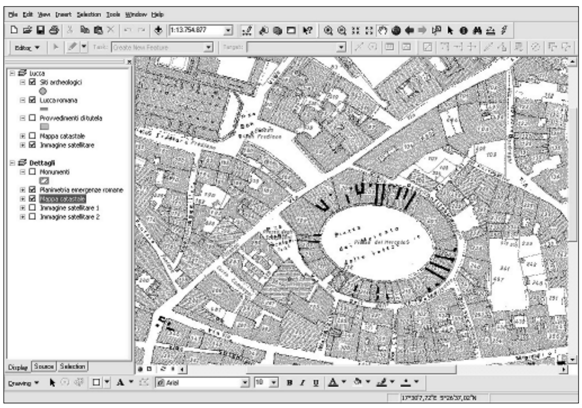

Figure 6: *GIS environment. Cadastral map with in black the remains of roman Amphitheatre*

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.

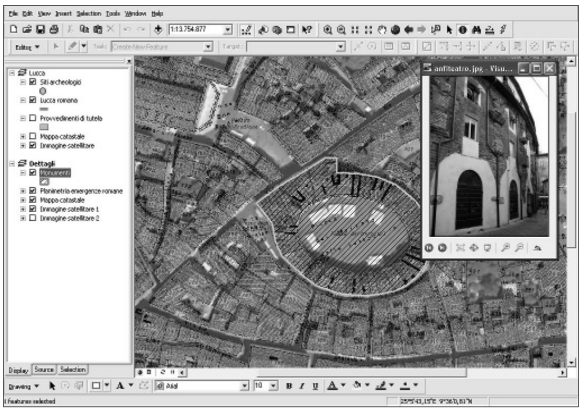

Figure 7: *GIS environment. The roman Amphitheatre in evidence, with the superimposition of an image*

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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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 $r = \frac{p_2 - p_1}{\|p_2 - p_1\|}$ and $n_t = \frac{(p_2 - p_1) \wedge (p_3 - p_1)}{\|(p_2 - p_1) \wedge (p_3 - p_1)\|}$ 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

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

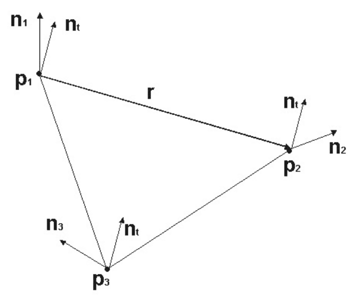

Figure 1: *Triplet with associated normals*

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).

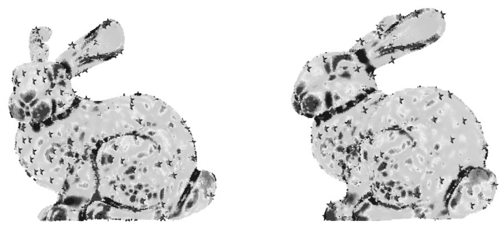

Figure 2: *Gaussian Curvature of two scans* (0° *and* 45°) *of the Bunny set.*

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

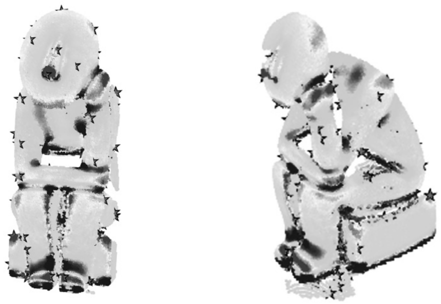

Figure 3: *Gaussian Curvature of the front and left scans of the Thinker.*

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.

Figure 4: *The Thinker.*

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

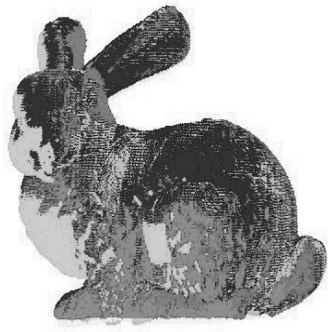

Figure 5: *Bunny coarse registration.*

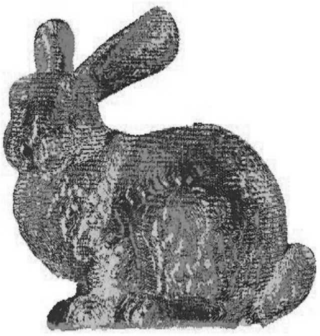

Figure 6: *Bunny fine (ICP) registration.*

Figure 7: *Thinker coarse registration .*

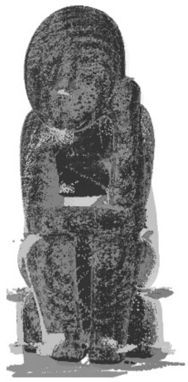

Figure 8: *Thinker fine (ICP) registration .*

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.

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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.

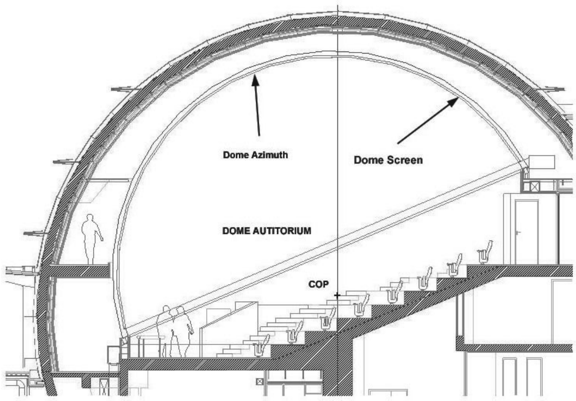

Figure 1: *The Dome Theatre of FHW. 132 seats, 14.4 m dome diagonal, 20 º of dome surface.*

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.

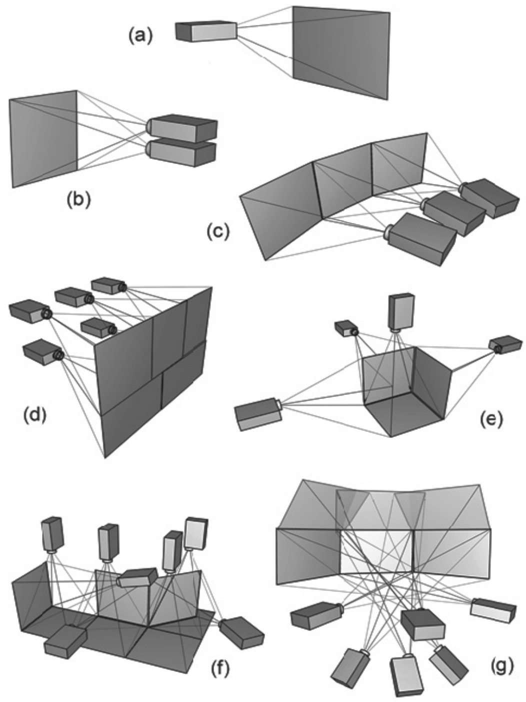

Figure 2: *Examples of display tile configurations possible with TiDE: (a) planar active stereo, (b) planar passive stereo, (c) curved-screen reality center, (d) large video wall, (e) CAVE like, (f) arbitrary topology, (g) dome.*

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.

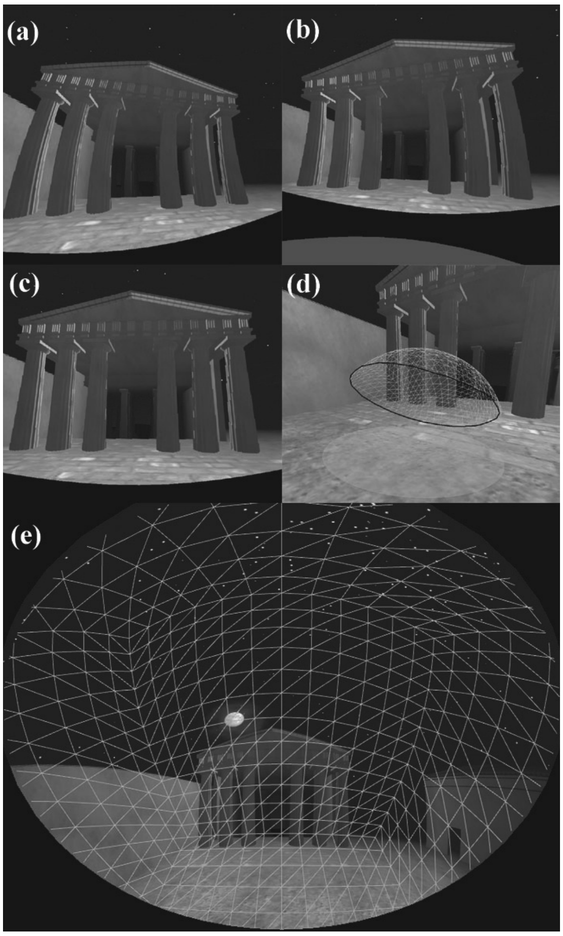

Figure 3: *The dome simulator (d-e) and resulting distortion tests. (a-b) Vantage points away from the center of projection. (c) View position in the vicinity of the center of projection.*

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.

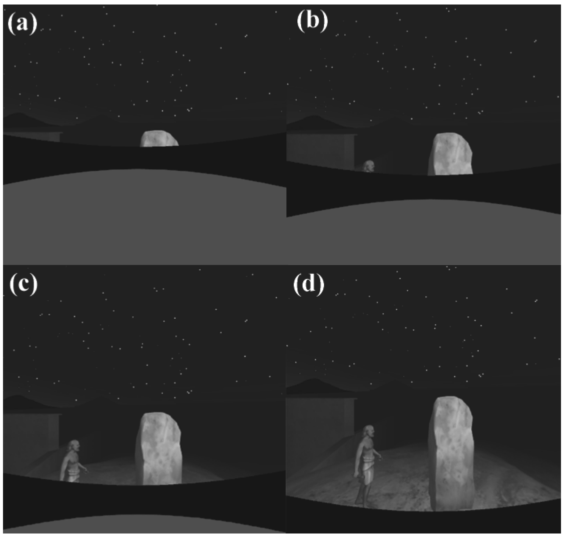

Figure 4: *Vertical Field of View, shows how much of the ground is seen by the visitor. (a) Using no tilting at all. (b) 10° tilt. (c) 20° tilt. (d) 30° tilt.*

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.

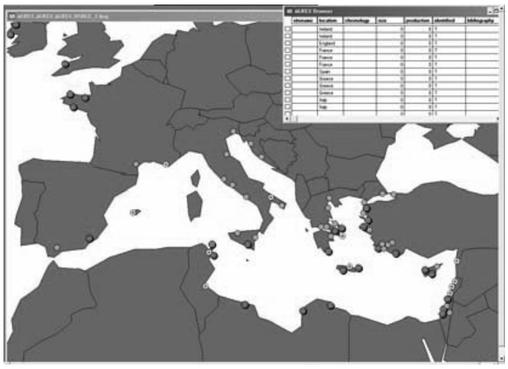

Figure 1: Purple dye production centres.

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.

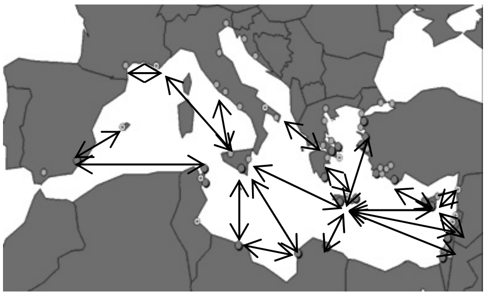

Figure 2: Establishing Trade networks - mapping sea routes.

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).

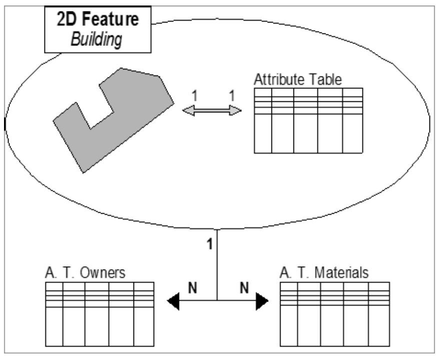

Figure 1: *Classical model of 2D feature.*

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].

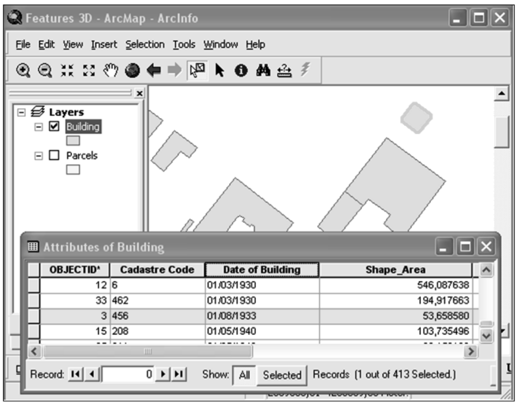

Figure 2: *The case of study.*

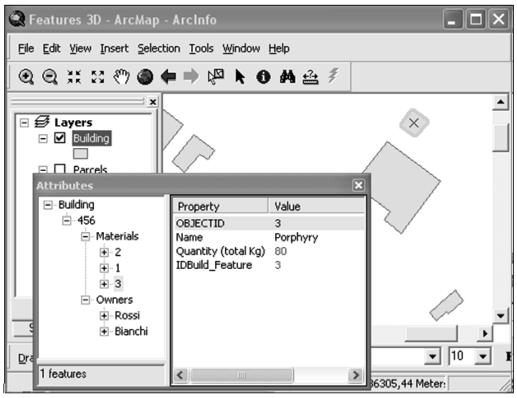

Figure 3: *Match of the feature with external tables.*

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

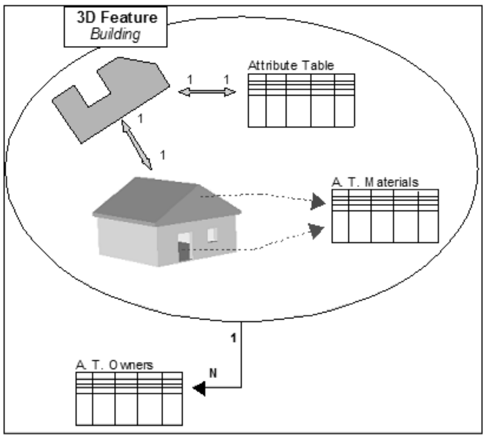

Figure 4: *Sample of 3D-extension of feature.*

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.

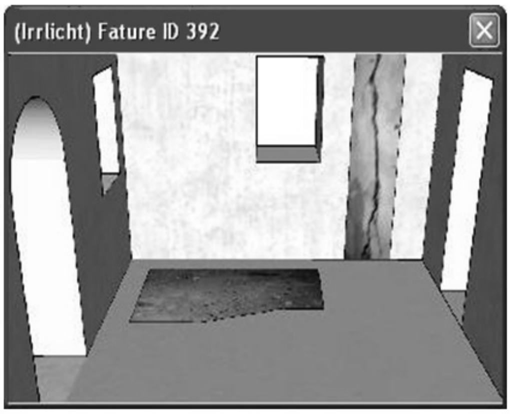

Figure 5: *Texture obtained by a picture of a cleft.*

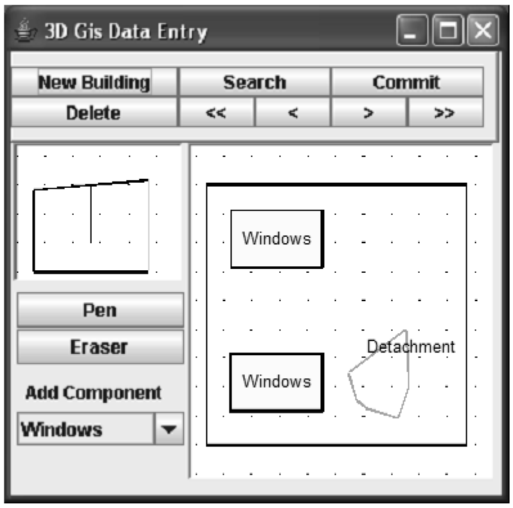

Figure 6: *Data-entry software.*

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

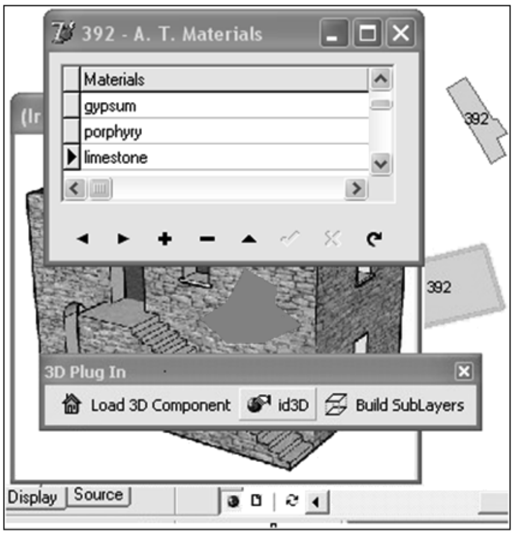

Figure 7: *3D features in ArcGIS.*

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)

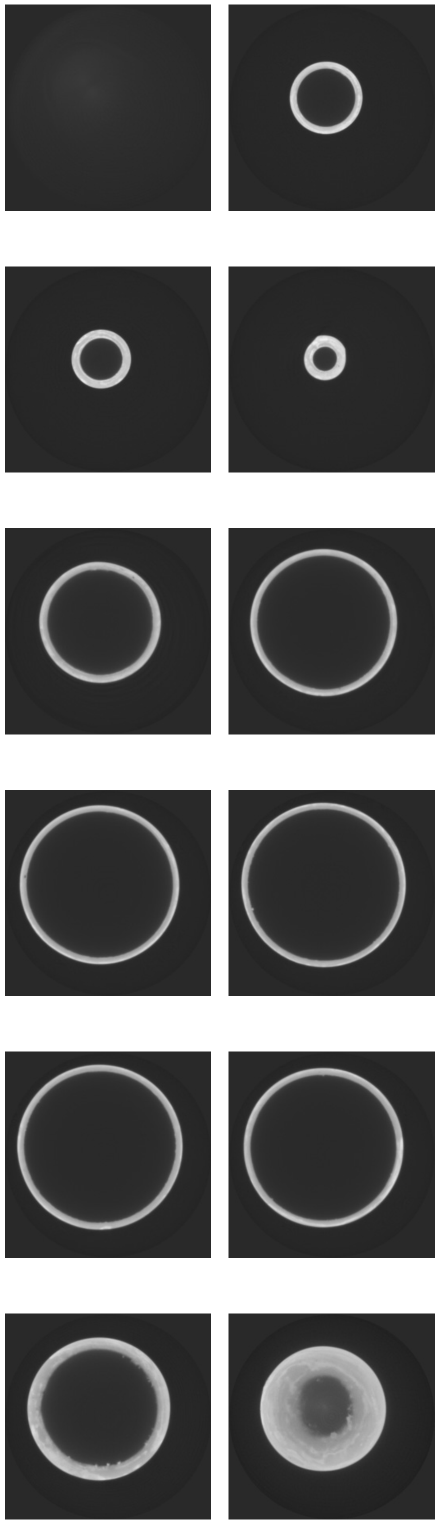


Figure 1: *Cross-sectional CT scans of a lekythos.*

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

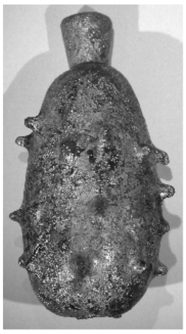
3.1. Previous Work

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.*

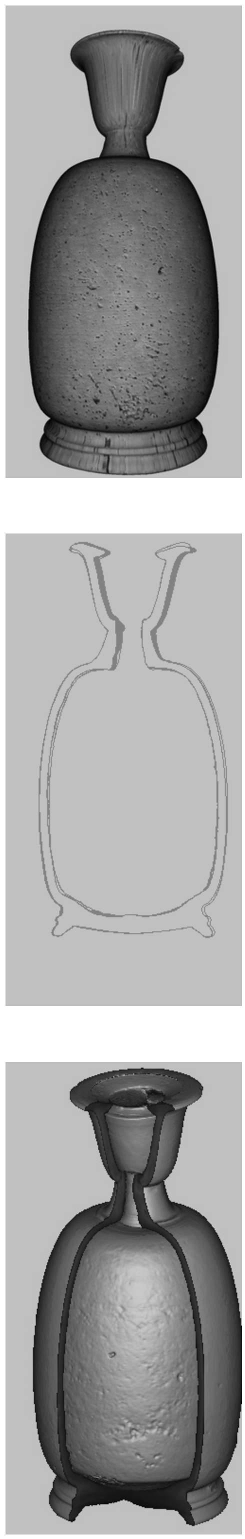
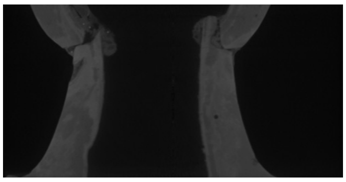
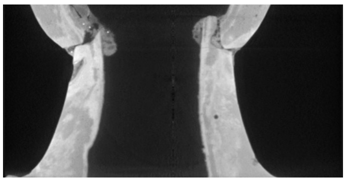


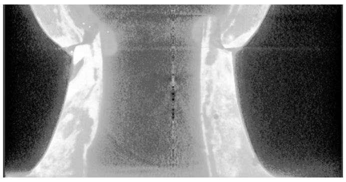
Figure 4: *Pilot study results: a) Pseudo texturing, b) Profiles extraction, c) Arbitrary cut*



(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

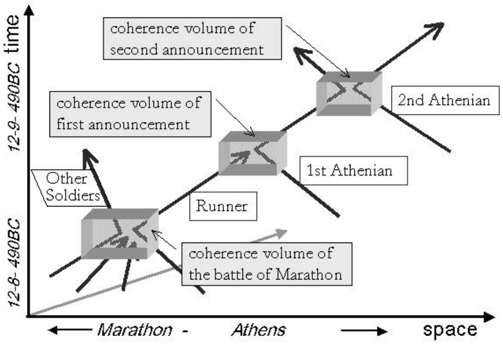

Figure 1: *Information exchange: Marathon runner "carries" a message*

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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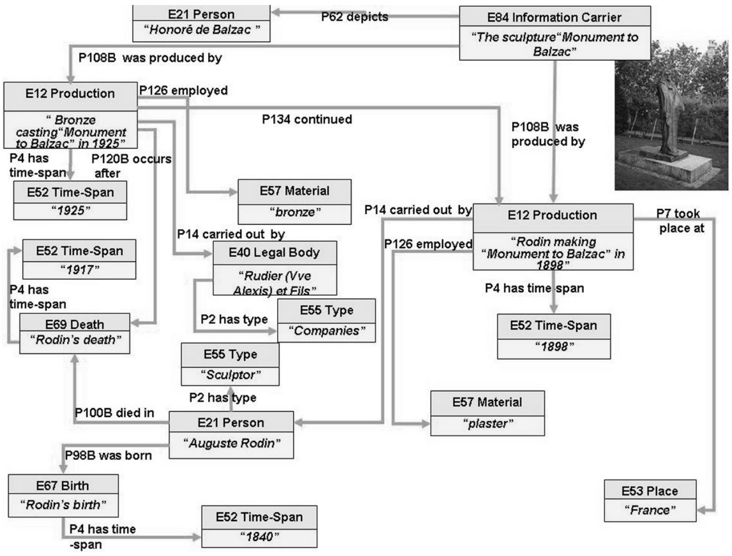

Figure 3: *A graphical representation of "Monument to Balzac" using CIDOC CRM Core*

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.

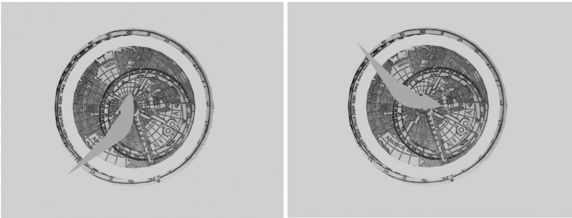

Figure 1: *The initial set of 2 pictures. The mobile part occupies two different positions*

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).

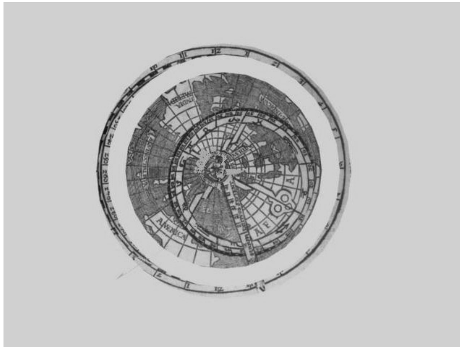

Figure 3: *The reconstructed texture for a 2 pictures initial set*

3. The Modelisation Step

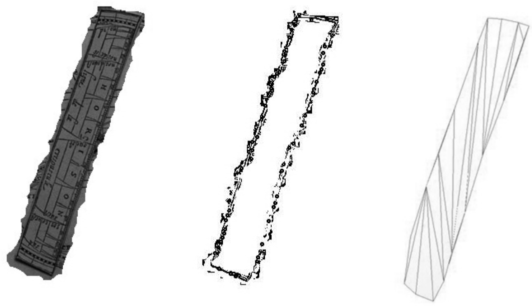

Figure 4: *The initial mobile part(a), the contour detection stage(b) and the 3D mesh(c)*

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.

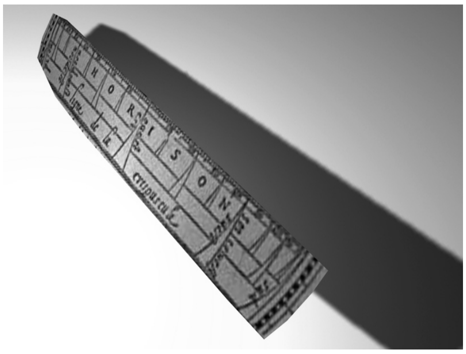

Figure 5: *The textured mesh in a 3D scene*

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)

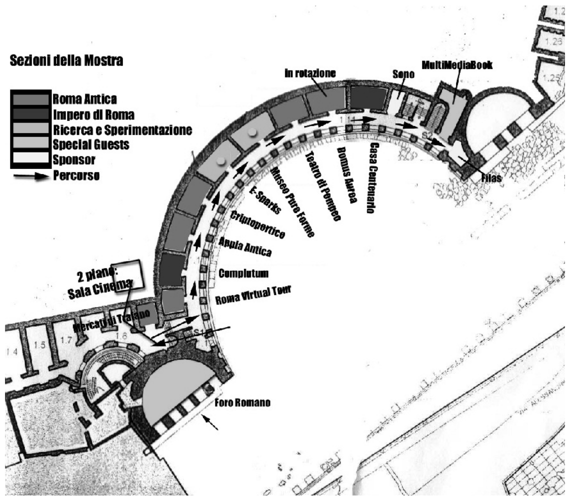

Figure 2. *The exhibition itinerary and types of tech solutions*

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.

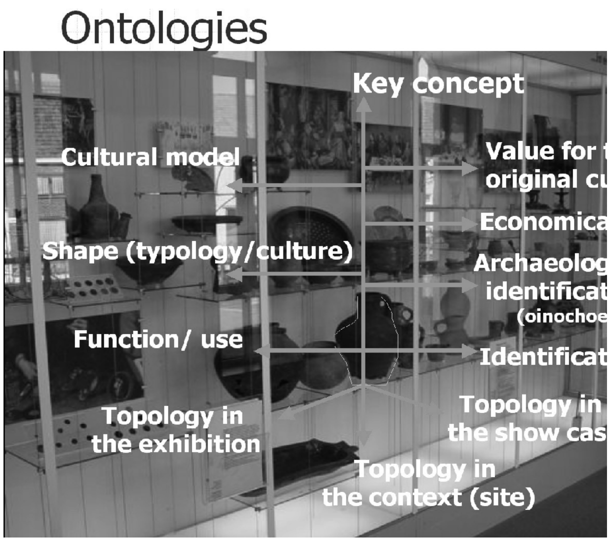

Figure 1: *a simple map showing some categories of evaluation of an exhibited object.*

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).

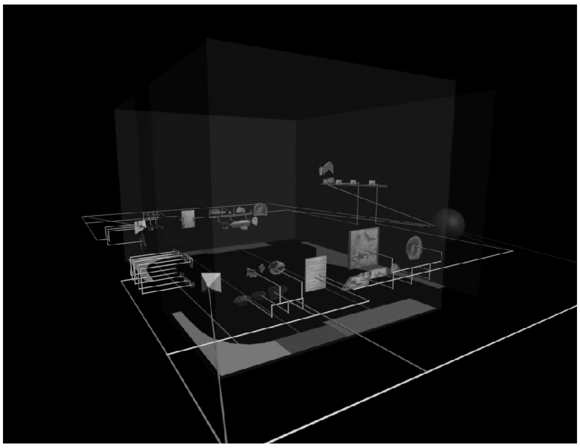

Figure 3: *An initial experiment of cybermap of the Etruscan Archaeological Museum of Castiglion Fiorentino (room of the Temple).*

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).

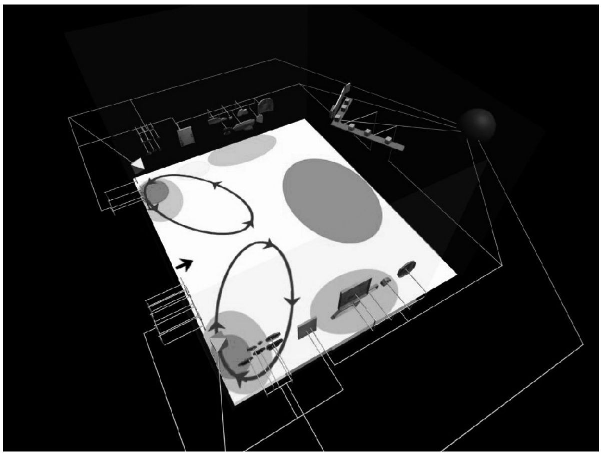

Figure 4: *Cybermap of the temple room (Archaeological museum of Castiglion Fiorentino): gradient of colours represent different levels of attraction.*
Red areas are the most attractive, in correspondence with the video installations (storytelling attractors). The relations are of circular type around 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,

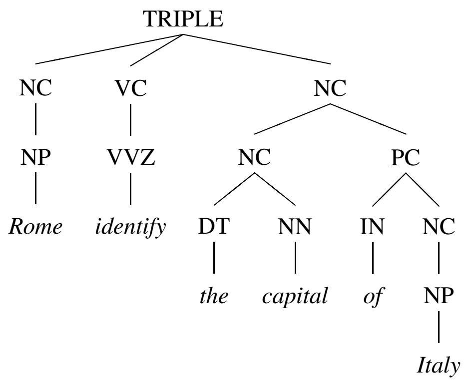


Figure 1: *Linguistic analysis of example 1.*

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:

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

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:

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

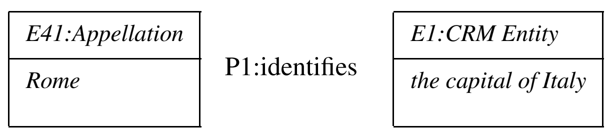
PMI is positive when two phrases tend to co-occur and negative when they tend to be in a complementary distribution. PMI-IR refers to the fact that, as in Information Retrieval (IR), multiple occurrences in the same document count as just one occurrence: according to [TL03], this seems to yield a better 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:



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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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 cultural heritage environments (landscape) scale 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 medium scale level 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 detailed scale level (decorated surfaces level) 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.

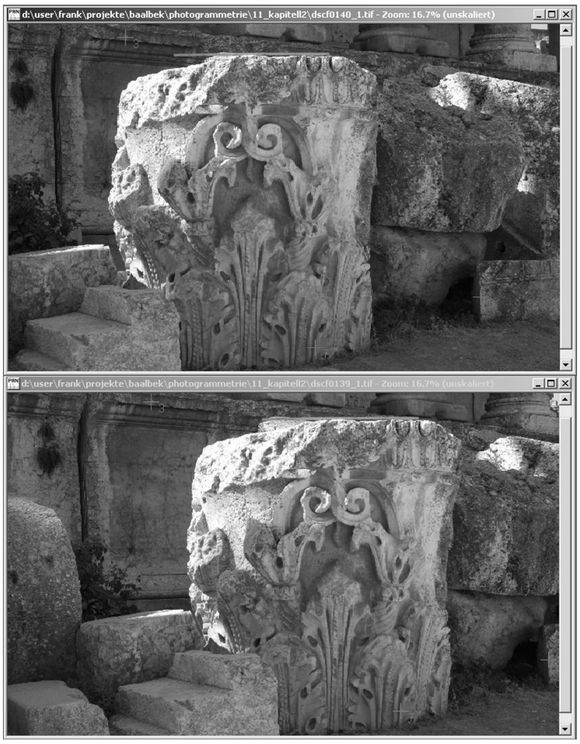

Figure 2: *Relative image orientation using correlation techniques for matching of unmarked object points, (Capitel Baalbek, hight 2 m, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)*

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

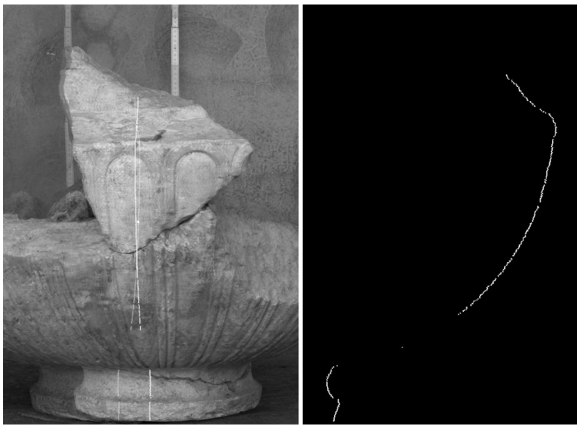

Figure 5: *Automatic measured vertical profile in stereo view (left) and profile plain (right) (Fragment of a Kratér, max. diameter 60 cm, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)*

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.

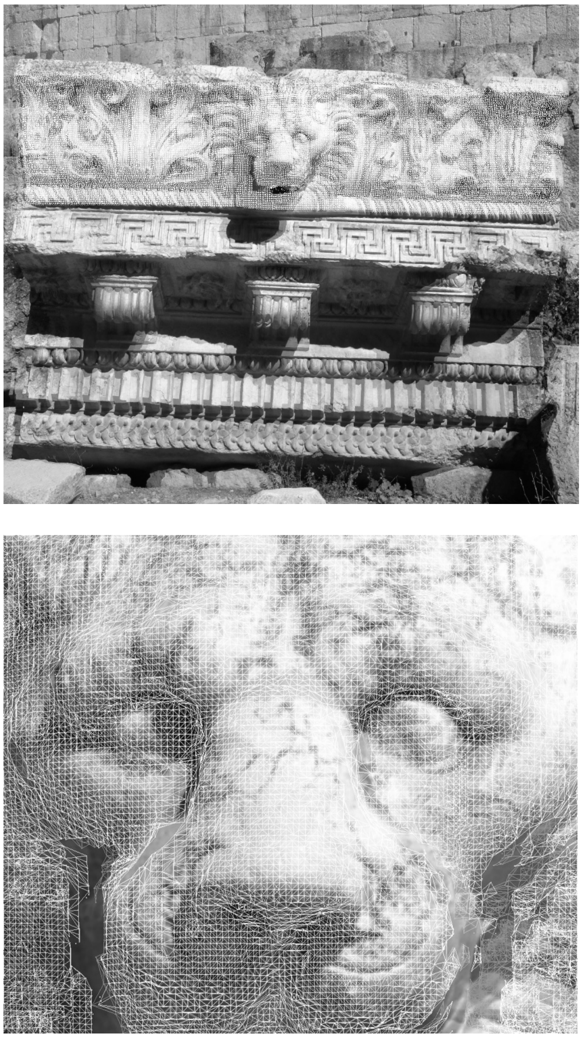

Figure 6: *Triangulated object surface of an architrav block in Baalbek (Object size 3 m x 2 m, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels)*

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.

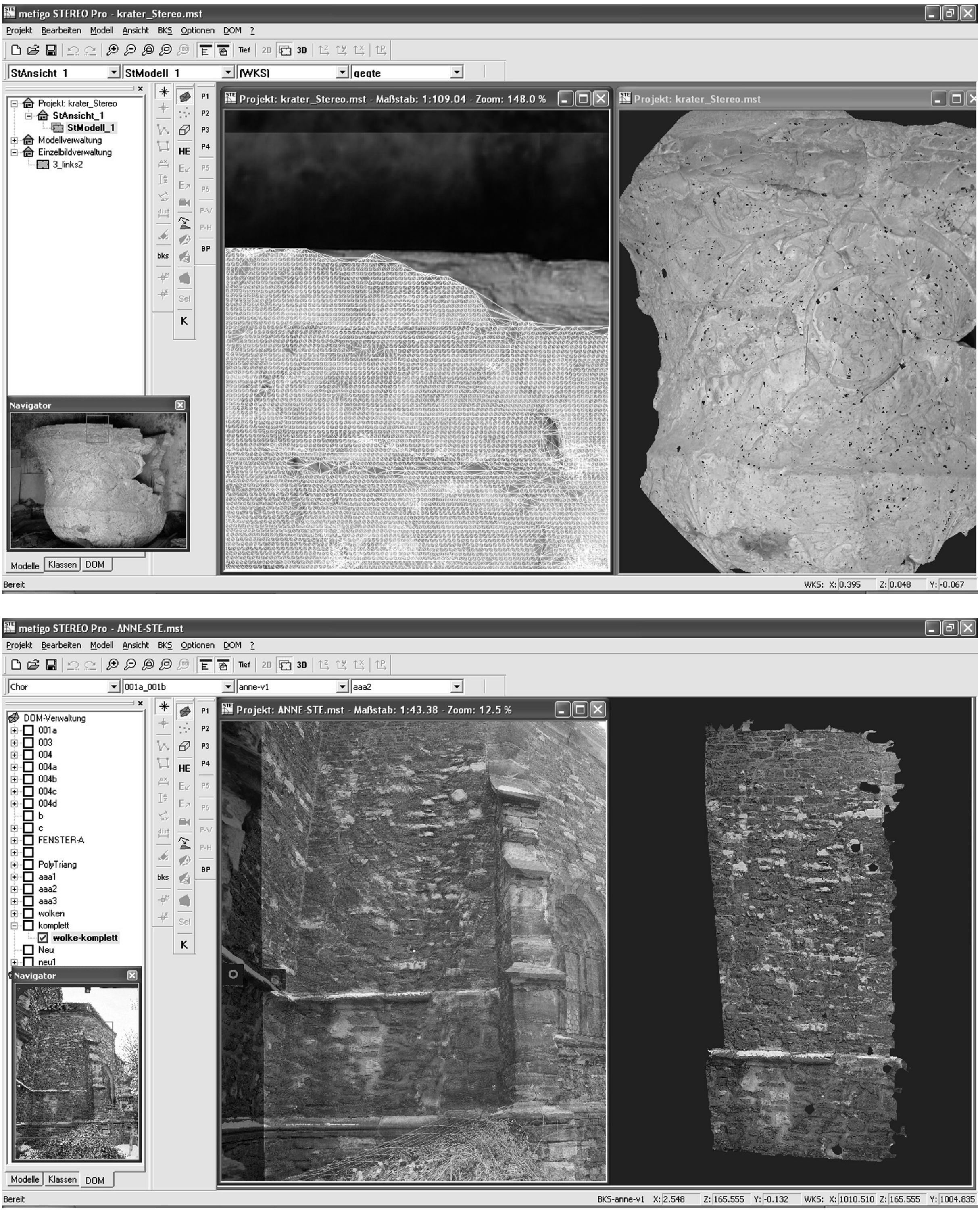

Figure 7: *Evaluation with metigo STEREO: stereoscopic view with overlaid triangulation (left) and textured 3D model (right) (upper figure: Kratér Baalbek, diameter and height 1m, Fuji FinePix S2, c_k 35 mm, CCD 4256 x 2848 pixels, lower figure: Church St. Annen, Eisleben, facade height 8 m, Zeiss UMK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

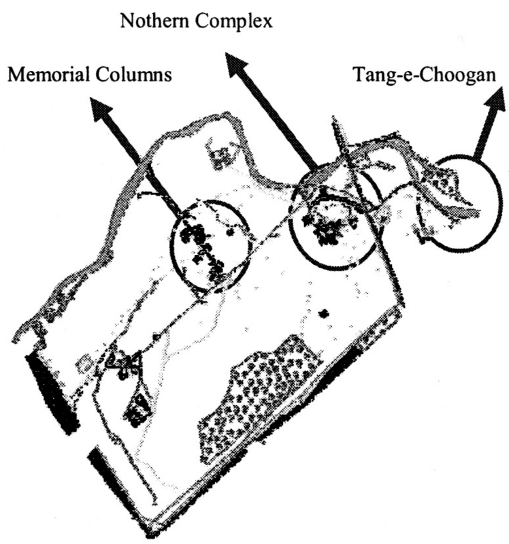

Figure ١ : *Bishapour*

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.

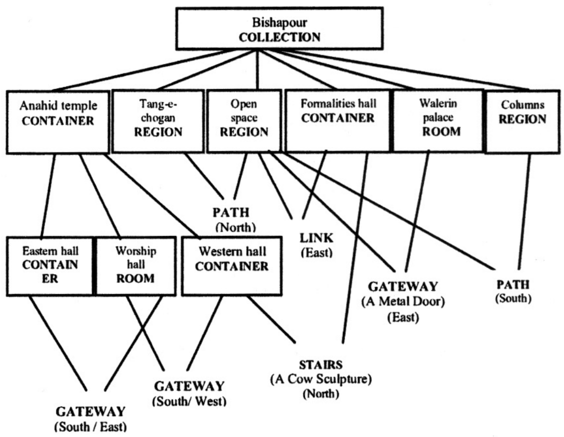

Figure 2: *Schematic geometry for Bishapour*

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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Short Papers

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.

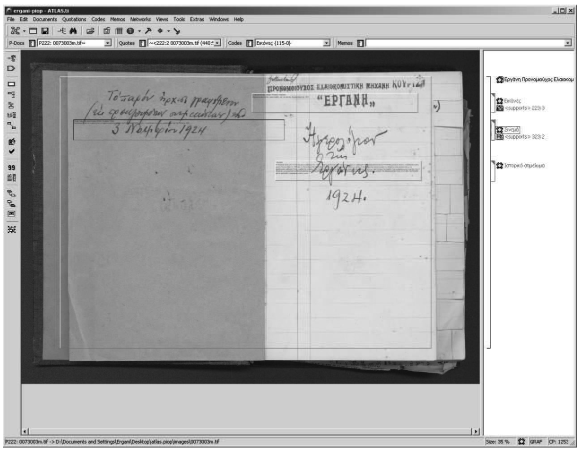

Figure 1: *Example of annotation through the use of Altas.ti software. Here, we can see the use of the code "Ergani, inspiration and creation" and the way in which the digitized archival material is annotated and interrelated semantically.*

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.

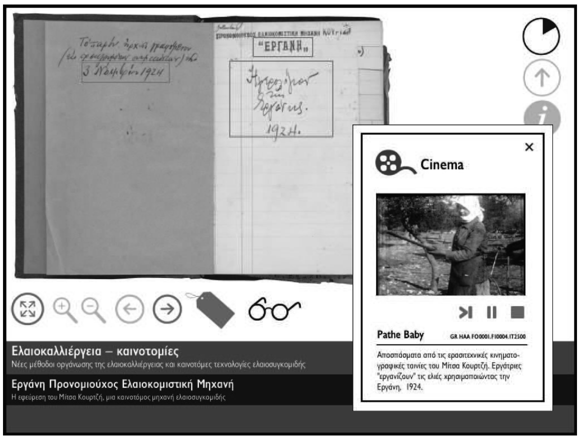

Figure 2: *Example of a Screenshot from the left screen of the application where a part of the digitized material is presented (Ergani diary, IT.0073). The user can retrieve information (text, sound, image, or video) by activating a series of hyperlinks. All information contained has been designed so 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

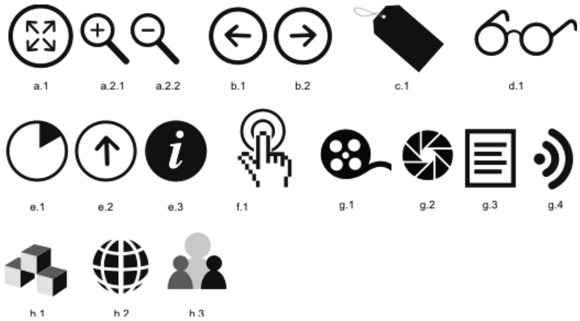

Figure 3: *Series of overviewing symbols used: group a: overview tools (full screen view - zoom in - zoom out), group b: navigating tools to-from archival items, symbol c: initializes a pop-up box which displays the archival description of each item, symbol d: initializes access hyperlinks to further 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).*

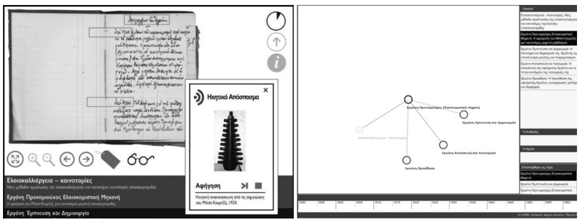

Figure 4: *Screenshot of the application (left and right screen). On the right screen, we can see the visualisation of Thinkmap software which is capable of handling cultural content by visualising it in various representational models (hypergraph, hierarchical, chronological, by name, other). On the 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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