Virtual Reality and Stereo Visualization in Artistic Heritage Reproduction

S. Livatino[1], D. Cuciti[1], A. Wojciechowski[2]

[1]Medialogy Studies, Aalborg University Copenhagen, Denmark
[2]Institute of Computer Science, Technical University of Lodz, Poland

Abstract

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

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

1. Introduction

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

a virtual museum applications: photorealistic reproduction, physical simulation, interaction with objects. A special attention is eventually paid to analyze user sense of presence and viewing experience for different VR systems, an aspect strongly related to display technology and stereo visualization. Time-spatial works-of-art are especially discussed and used as main testing application because they inherently call for user interaction, which challenges reproduction fidelity and real-time response.

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

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

Different media may be used for visual presentation of real work of art. In our analysis we consider: photography, film (motion-picture), computer animation, virtual reality. In case of photographs the 3rd dimension becomes reduced and so spatial features can be just imagined. By multiplying the number of photos connected with different viewpoints, more information can be revealed. Unfortunately such mean of presentation is incomplete due to its discontinuity and lack of thorough object observation possibility. Nevertheless, interesting efforts to overcome this limitation can be found in recent literature, [SSS06]. Another form of presentation is through motion capture and computer animations. Films and animations can more thoroughly retrieve time and spatial object features but at the same time they limit perspective and duration of the presentation. The user can not much influence presentation chronology except for stopping it, rewinding, pausing, or playing it slower. The captured images should be high-quality and entertaining. In case of virtual animation this means graphical appeal and high-quality rendering. Computer animation provides much more possibilities, but in comparison with a film it has still not acceptable image sterility. The use of virtual reality can well complement other media and it is especially important in case of time-spatial works-of-art because of the need for interaction. Even though the most advanced virtual reality simulation can not create fully photo-realistic copy of the orig-

inal, digital reproductions let the user fully experience object functionality and it could become an introductory step towards real object perception. That is why reproductions play an important role in art propagation, and it is in particular the "exploration layer", [WKP02], which provides a user with an illusion of interaction with a real object by means of its reproduction. Interactive applications usually render less accurate graphics, finding the best trade-offs between image quality and real-time performance. The user will be given the instruments to change the configuration of the object of interest at his/her will, without breaking object's physical constraints. The user should be able to interact with the object with a simple and intuitive use of common input peripherals as the mouse or the keyboard, and change the viewpoint.

3. Interactive Works-of-Art

The works of art express internal author's attitude stimulate, shake and strike the spectator's interest and creativity giving him/her satisfaction. In case of time-spatial works-of-art, the aesthetical experience is not only connected with external appearance but with internal functionalities conceptualization as well. The role of VR representation as a media for artwork functionalities presentation becomes then very relevant and demanding. In fact, virtual world presentation can be treated as object simulation rather then object reproduction. Different contemporary pieces of artistic heritage were considered (figure 1). We have then chosen the Mirror-Cube as our main testing application because it inherently calls for user interaction in order to be appreciated, which challenges reproduction fidelity and real-time response. Furthermore, the chosen object poses some challenges for what concerns photo-realistic reproduction and physical simulation, it appears suitable for VR systems comparison, and it emphasizes the VR technology added value. The Mirror-Cube is a 6-sided parallelogram, a cube, which contains six mirrors, such that each mirror fully covers the internal part of each cube side, (figure 2). This transformable installation provides a viewer with different operational and interpretational possibilities. Simple element joints assure wide spatial transformation possibilities. The usage of the mirrors for object's construction leads to a specific game between real elements of the installations (mirrors, wooden stick fixed to the mirror surface, lines painted on the external side of mirrors) and their reflections. There has been an interest in the recent time among researchers in the thematic related to time-spatial works of art [MP02], [WKP02]. P. Patyra [Pat05] investigates the J. Robakowski "Mirror's Ball". The object consists of two elements: the spherical mirror and the ball. There could be observed the distorted reflection of the ball in the mirror, together with reflected surroundings. The ball is covered by the photos. The viewer can move the ball, (which rolls on the mirror surface following an elliptic path), so changing the reflection in the mirror. Even though mentioned authors discussed problem of works-of-art presentation quite thoroughly, none of them tackle the problem of multi-level
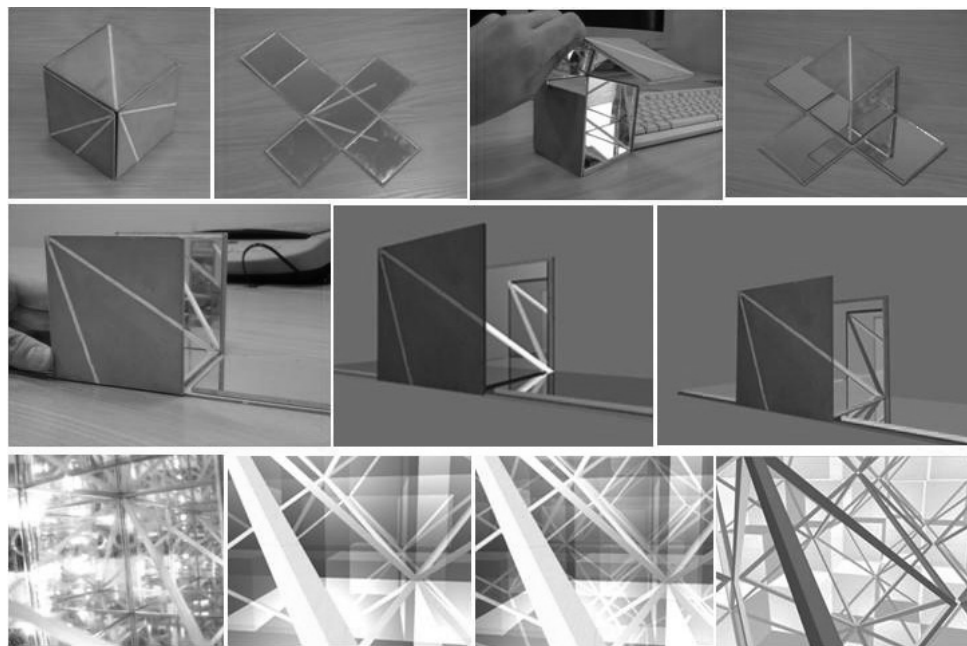
Figure 2: *The Mirror-Cube: exterior appearance and functionality (top-row), artistic nature (center row), infinite reflections (bottom-row). Center-row from left: photograph, raytraced with Mental Ray, rendered with OpenGL. Bottom-row shows multiple reflections. From left: photograph, raytraced with reflection limit 5, limit 8, rendered with OpenGL and 8 levels of reflections.*

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

4. Stereoscopic Visualization and Display Systems

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

- *Passive Stereo*. Multiplex images in space and can be subdivided in: "Anaglyph" (separation based on color filters); "Polarized" (separation based on polarized filters); "Separated Displays" (separation based on the use of different displays very close to user eye, as in HMD systems).
- *Active Stereo*. Multiplex images in time typically based on "Shutter Glasses".

- *Autostereoscopic Stereo*. Separates images based on special reflecting sheets laying on the display, or other methods. Do not require users to wear goggles.

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

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

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

5. Comparison of 3D Technologies

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

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

In order to assess support of different VR systems in time-spatial works-of-art reproduction a series of comparative user studies are proposed to be run on the above mentioned facilities. The resulting visual reproduction is also compared with a typical outcome experienced with 3D photographs and 3D movies. Figure 3 shows the stereo photo-camera

setup. A similar setup was used for 3D movies capture. With this study we assess systems capabilities for different display technologies. While performing comparative tests the users are asked to report about their experience through questionnaires. Questions are grouped into 5 judgement categories: *adequacy to application*, *realism*, *presence*, *3D impression*, *viewing comfort*.

6. Testing

6.1. Implementation, Image Quality and Speed

Over 160 pictures were taken with cameras with different resolutions. The pictures were grouped into 4 sets according to the following concepts: exterior appearance, functionality, artistic nature, infinite reflections. Figure 2 illustrates the above concepts. The animated video sequences of the object are modeled with Maya and rendered with Mental Ray. The resulting pictures are elaborated in Adobe Photoshop while animation sequences are converted with Adobe Premiere into movie files. Final presentation was based on a well defined storyboard. The interactive application is implemented in OpenGL which also simulates mirror reflections by the use of the stencil buffer. Multiple mirror reflections are added by means of recursive approach. The Mirror Cube modeled with Maya is imported into OpenGL and then interactively rendered. Object faces' physical simulation provides gravity acceleration of rotating mirror faces. The Stencil buffer which is now popular in commercial graphics cards, solves the reflection problem up to a relatively small number of nested reflections, and all mirrors ac-
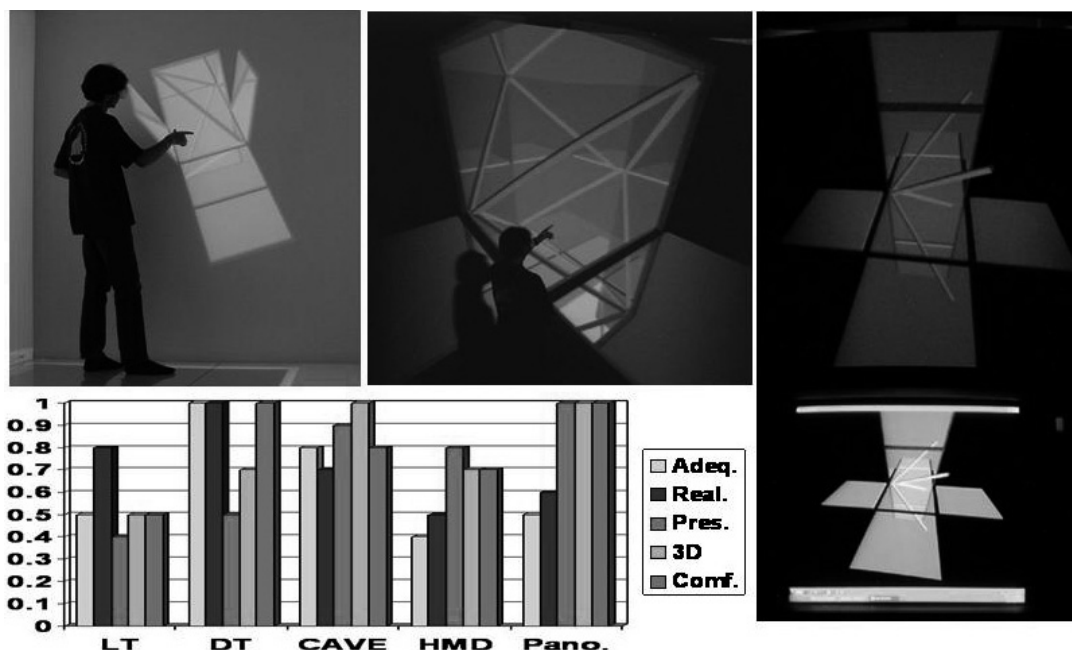
Figure 4: *The simulated Mirror-Cube in the CAVE environment (top-left) and Panorama (top-center). The left-picture shows a setup for concurrent comparison of Panorama and 3D Desktop images. The table summarizes comparative test results. The horizontal axis represents system considered: (LT) 3D Laptop with passive anaglyph, (DT) 3D Desktop with active shutters, (CAVE) CAVE system, (HMD) HMD, (Pano.) Panorama. The vertical axis summarizes users response on 5 different categories.*

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

6.2. Testing Displays Technologies

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

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

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

Presence. The larger screen VR facilities provides the best result in relation to sense of presence, (as expected). Interestingly, the user involvment decreases in the case of the passive stereo anaglyph. This seems to be mostly justified by eye-strain arising from rear-projection (screen alters colors

causing high ghosting). Passive anaglyph performs slightly better on real images, mostly due to a higher level of Realism.

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

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

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

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

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

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

A more thorough comparison is a work in progress.

References

[DJK*06] DEMIRALP C., JACKSON C., KARELITZ D., ZHANG S., LAIDLAW D.: Cave and fishtank virtual-reality displays: A qualitative and quantitative comparison. *IEEE Visualization and Graphics* (2006). 12(3).

[Dra91] DRASCIC D.: Skill acquisition and task performance in teleoperation using monoscopic and stereoscopic video remote viewing. In *Proc. 35th Human Factors Society* (1991).

[GB01] GAGGIOLI A., BREINING R.: Perception and cognition in immersive virtual reality. *Communications Through Virtual Technology: Identity Community and Technology in the Internet Age* (2001).

[JLHE00] JONES G., LEE D., HOLLIMAN N., EZRA D.: Perceived depth in stereoscopic images. In *Proc. 44th Human Factors Society* (2000). San Diego, USA.

[Kil99] KILGARD M. J.: *Improving Shadows and Reflections via the Stencil Buffer*. Tech. rep., NVIDIA Corporation, Nov. 1999.

[LP06] LIVATINO S., PRIVITERA F.: 3d visualization technologies for teleguided robots. In *Proc. Virtual Reality Software and Technologies* (2006).

[MP02] MISKIEWICZ L., PIETRUSZKA M.: Presentations of time-spatial works-of-art in virtual reality. *Visualization and Image Processing* (2002).

[NM06] NAEPLIN U., MENOZZI M.: Can movement parallax compensate lacking stereopsis in spatial explorative tasks? *Elsevier DISPLAYS* (2006). 22, 157-164.

[Pat05] PATYRA P.: *Visualization of time-spatial works-of-art whose elements can be moved by a viewer*. Master's thesis, CS Institute, Technical University of Lodz, 2005.

[SS99] SEXTON I., SURMAN P.: Stereoscopic and autostereoscopic display systems. *IEEE Signal Processing Magazine* (1999).

[SSS06] SNAVELY N., SEITZ S., SZELISKI R.: Photo tourism: Exploring photo collection in 3d. In *IEEE Trans. on Computer Graphics (SIGGRAPH)* (2006).

[WKP02] WOJCIECHOWSKI A., KRYSICKI P., PIETRUSZKA M.: Interaction with time-spatial works-of-arts and their behaviours in a virtual gallery. *Computer Vision and Graphics (ICCVG)* (2002).

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

M. Lönnqvist[1], M. Törmä[2], K. Lönnqvist[1], M. Stout Whiting[1], M. Nuñez[3], J. Okkonen[3]

[1]University of Helsinki, Finland
[2]Helsinki University of Technology, Finland
[3]University of Oulu, Finland

Abstract

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

Categories and Subject Description: Miscellaneous

1. A Long-Term Perspective from Jebel Bishri

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

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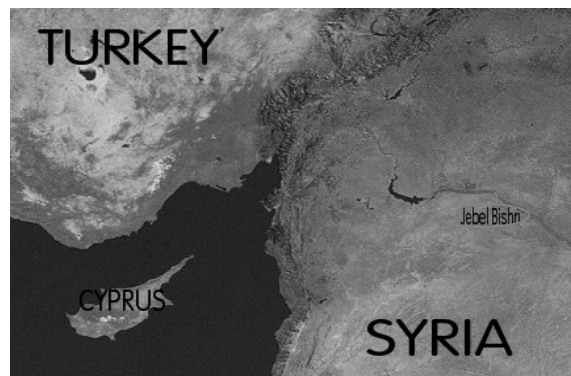

Figure 1. *The location of Jebel Bishri in Central Syria seen from a satellite.*

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

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

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

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

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

2. Towards a Regional Inventory of Archaeological Sites

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

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

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

Therefore we agree with F. Hole's statement that the surveys that aim for the basic inventory of sites are most

rational, especially in the areas where the archaeological heritage is endangered by different endeavours of humans or threats caused by nature [Hol80].

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

3. Prospecting, Surveying and Mapping with Remote-Sensing

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

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

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

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

4. A General Survey and the Depth of Cultural Time

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

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

The damage of the surveys with a sole goal in an area lacking a site inventory and mapping is in its extreme comparable to "treasure hunting" masked into a scientific research design in which individual researchers are not altruistically working for the best of the whole area and for the study of its past. Finds and sites gathered with a single period or phenomenon in mind in endangered areas may become *like museum pieces without proper information of the provenience. The state and nature of the context in the sequences of cultures of the region and the related finds/sites in the time of the discovery are ignored.* The recording of the contexts and existing neighbouring sites in the time of discovery are important. A single-period or single-type/subject survey is particularly harmful in the

areas where looting is taking place in the neighbourhood before proper general survey has been carried out. Because of the looting the contextual information can disappear very quickly without later possibility of reconstructing the situation of the original discovery.

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

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

5. Rapid Environmental Changes Affecting Cultural Remains

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

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

The climate has affected the condition of the soils. Jebel Bishri belongs to the region of aridsoils which cover 50% of the total soils of Syria. In those the Jebel Bishri region consists of gypsiorthids which constitute 20% of the soils in Syria. In the lack of proper drainage systems

the type of soils increases salination in the irrigated river valley. If some woodlands have earlier existed at Jebel Bishri, they - apart from a few trees - have completely disappeared. Erosion is caused by lack of trees, shrubs,
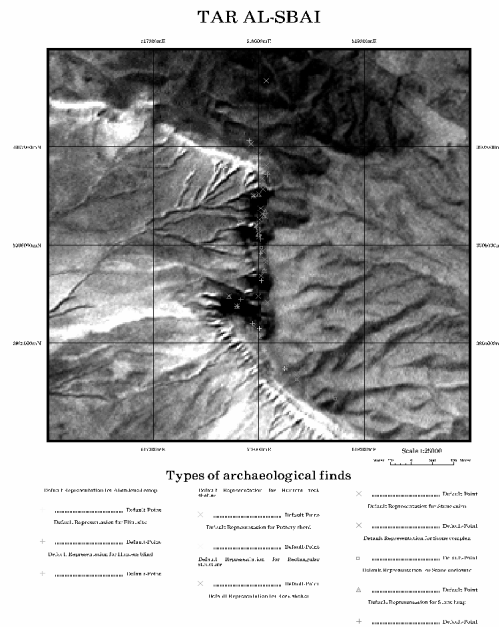

Figure 4. *Distribution of all the site types at Tar al-Sbai, the southwestern edge of Jebel Bishri, displayed on a panchromatic channel of a Landsat-7 ETM image. Mapping by Markus Törmä 2005, © Eurimage.*

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

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

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

6. An Ethnoarchaeological Approach for Understanding Past Situations

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

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

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

the mountain and on its eastern piedmont. But obviously governmental policy has played a central part through legislation as well. [LT06]

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

7. Conclusions

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

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

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

8. Acknowledgements

9. References

[AM96] ALDENDERFER, M., MASCHNER, H.D.G.: *Anthropology, Space, and Geographic Information Systems*. Oxford University Press, Oxford – New York, 1996.

[Ban02] BANNING, E.B.: *Archaeological Survey*. Kluwer Academic/Plenum Publishers. New York, 2002.

[BBBS01] BREW, G.E., BEST, J., BARAZANGI, M. , SAWAF, T.: Tectonic Evolution of the Northeast Palmyride Mountain Belt; Syria: the Bishri Block, Cornell Syria Project (2001) http://atlas.geo.cornell.edu/syria/Brew2002.html.

[BS81] BESANÇON, J., SANLAVILLE, P.: Aperçu géomorphologique sur la vallée de l'Euphrate syrien. *Paléorient* (1981), vol. 7/2, pp. 5-17.

[CT93] CAMERON, C..M., TOMKA, S.A. (ed.): *Abandonment of Settlement and Regions, Ethnoarchaeological and Archaeological Approaches*, New Directions in Archaeology., Cambridge University Press, Cambridge, 1993.

[GB91] GAMBLE, C.S., BOSMIER, W.A. (ed.): *Ethnoarchaeological Approaches to Mobile Campsites, Hunter-Gatherer and Pastoralist Case Studies*, International Monographs in Prehistory, Ehtnoarchaeological Series 1. Ann Arbor, Michigan, 1991.

[HG97] HOFFMAN VON, K., GEERKEN, R.: Degradations- und Desertifikationsprozesse in den Bishri-Bergen Syriens in *Spektrum der Wissenschaft*, 2/97 (1997), pp. 71-73.

[Hol80] HOLE, F. Archaeological Survey in Southwest Asia. *Paléorient* (1980), vol. 6, pp. 21-44.

[LT03] LÖNNQVIST, M., TÖRMÄ , M.: SYGIS – The Finnish Archaeological Project in Syria, Proceedings of the XIXth International Symposium *CIPA 2003* (The ICOMOS & ISPRS Committee for Documentation of Cultural Heritage) New Perspectives to Save Cultural Heritage, Antalya, Turkey, ed., M. O. Altan, *The ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* (2003), vol. XXXIV-5/C15, Istanbul, pp. 609-614.

[LT04] LÖNNQVIST, M., TÖRMÄ, M.: Different Implications of a Spatial Boundary, Jebel Bishri between the Desert and the Sown in Syria, The ISPRS XXth Congress Proceedings, ed. M. O. Altan, *The ISPRS International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences,* (2004) vol. XXXV. Part B. Istanbul, pp. 897-902.

[Lön06] LÖNNQVIST, M. with the contributions by Törmä, M., Nuñez, M., Lönnqvist, K., Stout Whiting, M., Okkonen, J. Riihiaho, H., Nissinen, M.: Archaeological Surveys of Jebel Bishri, the Preliminary Report of the Finnish Mission to Syria, 2000-2004, *KASKAL, Rivista di storia, ambienti e culturale del Vicino Oriente Antico,* (2006), vol.. 3, pp. 203-240.

[LT06] LÖNNQVIST, M., TÖRMÄ, M.: Observing Changes and their Effects in Nomadic Environment, Remote-sensing and Archaeology for Sustainable Development on Jebel Bishri in Syria in M. A. Reddy (ed.) *Environmental Geoinformatics and Modeling, Proceedings of ICEM '05: International Conference of Environmental Management (28-30 Oct. 2005)*, (2006) vol. IV, Hyderabad.

[Nap06] NAPC = National Agricultural Policy Center: *Working Paper No. 2 Agricultural Research and Extension in Syria: Present Situation and Policy Recommendations*, Project GCP/SYR/006/ITA – Phase II (2006).

[Wyl03] WYLIE, A.: On Ethics in Zimmerman, L.J., Vitelli, K. D., Hollowell-Zimmer, J. (ed.) *Ethical Issues in Archaeology,* Altamira Press, Wallnut Creek, CA, 2003, pp. 3-16.

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

H. Maistrou[1] and D. Psychogyios[1,2]

[1]Faculty of Architecture, NTU Athens, Greece
[2]LABoratory of Arcitecture, LABA Athens, Greece

Abstract

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

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

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

1. Introduction

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

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

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

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

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

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

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

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

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

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

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

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

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

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

2.1. The phases of the recording and documentation project.

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

Study of the historic evolution of the city and the individual city districts as they are defined by the topography of the area, the geometric characteristics of the urban web, the typology of the structures and the monumental fortifications that surround the city.

Identification of the architectural quality of historic buildings and the development of registers, which included an analysis of their typology, age, number of floors, structural condition and the degree of alteration from the original building form.

Study of the historic patterns and the geometric attributes of the city web, their function and their degree of conservation.

Identification of the city's functions through the recording of the land uses, the social and cultural equipment, the traffic and parking system and the evaluation of the city's technical infrastructure networks.

Research of the existing regulations on construction and protection and identification of the ownership status.

A second recording was performed last year with the double aim to complete the evidence that constitute the architectural characteristics of the structures –as interior elements and decoration, construction elements e.t.c– and to illustrate the changes that have occurred in the form and function of the historic buildings. There was also a recording, through a questionnaire, of the profiles of owners and tenants of the buildings in the historic center, the mobility of residents and professionals and the functional problems of the buildings.

Beyond the in-situ recordings, a major source of information were the building permit archives of the Ministry of Culture, which is responsible for the protection of the historic buildings of the city and inspects every building permit that is issued, as well as the archives of the local City Planning Office.

Historic maps, engravings, old photographs and post cards, as well as special bibliography on the city, its buildings and monuments were gathered from public libraries and archives and from private collections, for the historic documentation of the city. Further data on historic figures and intellectuals who lived in the city, as well as on literature and art that promotes the city was collected for the recording of the city's intangible cultural heritage.
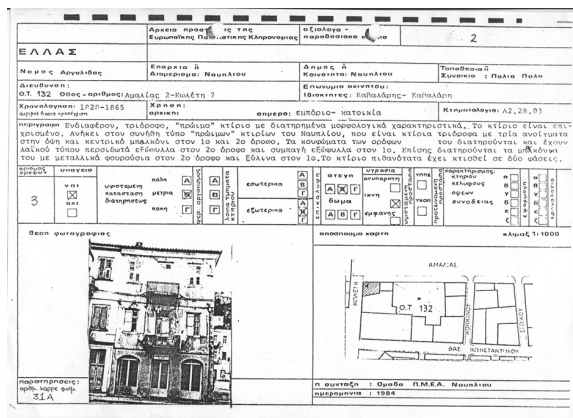

figure 2: Card of the first recording, 1985

During both recordings, there were discussion meetings held with the city residents with the aim for them to participate actively in the recording and to express their opinion on the objectives of the project. The promotion of the city's cultural importance and the organization of educational programs through the integrated recording and documentation system that is to be created have met with positive reactions from the city's residents. It should be noted, however, that there were many suggestions for the need to take advantage of the system towards the development of protection projects for the city.

2.2. Data classification, information classification and design of the database

For the design of the database has been taken into account the fact that the contents of the database are information concerning both space in the city scale as well

as the individual elements of the city (historic buildings or public spaces). Therefore, the arrangement and classification of the data was performed at two different levels:

    - General information material, which includes: General imaging of the city, general and special bibliography, literary and ethnographic texts, old maps and drawings, engravings and post cards, paintings and films.

    - Special information material, which includes maps, drawings, pictures, and writings that refers to:

    a. The characteristic elements of the city's historic center (buildings, public spaces, monuments, cultural buildings, demolished historic buildings, local social and economic data)

    b. The historic elements of the greater city area, *(buildings, public spaces, monuments, cultural buildings, demolished historic buildings)*

    c. The fortifications of the city

In particular, the information and data regarding the city's historic center was organized in the following Sections and Sub-sections.

    a. Historic – Architectural elements.

Historical information, general description of architectural characteristics, existing protection laws and regulations, time of construction, typology, roofing system, architectural alterations.

    b. Special construction and morphology characteristics

Vertical outer shell, internal bearing and non-bearing systems, floors, doors, openings, external decorative items, terraces, interior elements of special interest.

    c. Social – Economic data.

Detailed data on the owners and users of the buildings (name, age, date of purchase and/or occupation).

Use per floor, conservation conditions, time of repairs, functional problems.

    d. Imaging

Characteristic black and white picture of each building (1985)

General and special colour pictures of all sides of each building and of its special details (2006)

Building plans (layouts, elevations, sections) based on published information.

figure 3: Screen of online database

2.3. The use of the system

All historic evidence for which there will be recorded information in the system (monuments, buildings, public spaces), were identified by a unique reference number which relates to the number of the building block in which they are located and were depicted in the city map as "active elements".

The users of the system responsible for data entry are: the scientific personnel of the City, who will be responsible for entering information into the database, as weel as other special users

Users of the system with access to the information are: local public and private agencies looking for certain information, scientists and researchers from Greece and abroad, residents and professionals of the city and the student population.

2.4. Updating – monitoring

The information that is entered into the database is divided into specific time periods that may be – or will be in the future – expressly defined (i.e. 1985, 2006, 2010, etc.) or not (i.e. old photographs and drawings without exact date of production).

The above information material is today being recorded into a server located in the City of Nafplion. This information will be continuously updated and its retrieval can be performed using many different criteria. This way, it will be possible to constantly monitor the development of the activities within the city and to plan the city's evolution.

Access to the database through the Internet allows the updating of the material by special users from distant locations thus making it a "live" instrument.

2.5. Ways to retrieve and present the data - interface – access

The principles of the interface design took into account: the general objectives of the integrated recording and documentation system -as they are presented in the introduction-, the users profile, which was determined from the beginning and the content of the information which is directly correlated with the territorial standards

The retrieval of information has been designed to be performed through the city map, by selecting a random or specific building, or through thematic maps (typology and age of buildings) as well as by street names.

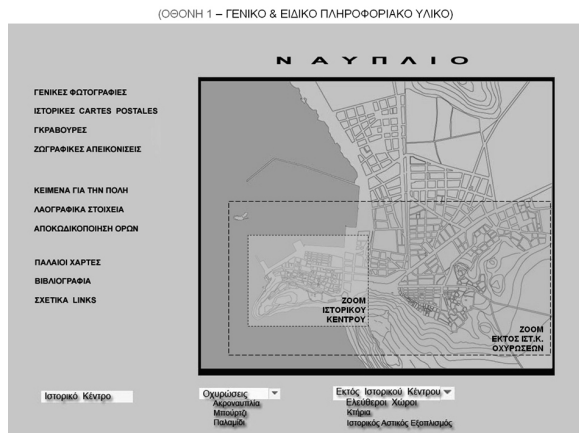Attached there is an sample presentation of the above functions.

(ΟΘΟΝΗ 1 – ΓΕΝΙΚΟ & ΕΙΔΙΚΟ ΠΛΗΡΟΦΟΡΙΑΚΟ ΥΛΙΚΟ)
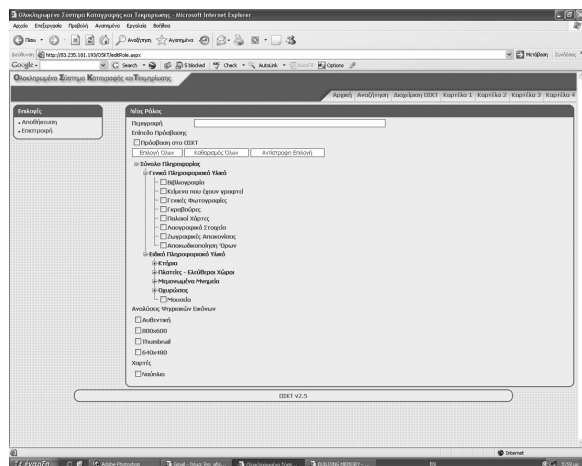
figure 4: General and special information material, A sample presentation of the data base function, version_01

(ΟΘΟΝΗ 3.2 - ΛΙΣΤΑ ΦΩΤΟΓΡΑΦΙΩΝ ΑΝΑ ΟΔΟ)

figure 5: List of buildings per road, A sample presentation of the data base function, version_01

(ΟΘΟΝΗ 3.3 - ΚΑΡΤΕΛΑ ΚΤΗΡΙΟΥ)

figure 6: Building card, A sample presentation of the data base function, version_01

(ΟΘΟΝΗ 5.1 - ΚΑΤΑΣΚΕΥΑΣΤΙΚΑ & ΜΟΡΦΟΛΟΓΙΚΑ)
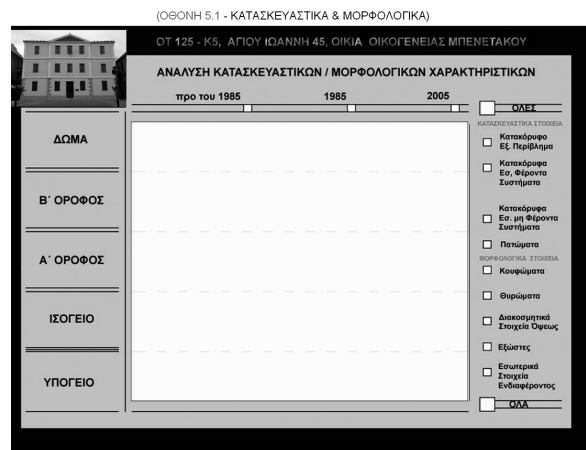
figure 7: Special construction and morphology characteristics per floor, A sample presentation of the data base function, version_01

3.   Conclusions.

The development of a digital platform which will allow the integrated recording and documentation of the cultural heritage of historic cities is a project of great significance. It contributes to the wide-spreading and learning of the special characteristics of the cultural heritage of a city, which is an important tool for all the entities involved in the preservation, protection and management of historic cities.

The above system will also prove especially helpful, in combination with the possibilities allowed by new technologies, in conservation programmes for the historic city, in the development of cultural tourism through guided visits in the city, as well as in educating the younger generations on issues concerning their local history.

The most significant problem of the above effort is to achieve the scientific and at the same time comprehensible presentation of the information, without resorting to simplifications and interpretations that may alter historic evidence and mainly to be able to present accurately the information that constitutes the general image, the aesthetic qualities and the meaning of the historic city.

4.   Contributions

Professors M. Adami and E. Maistrou were responsible for the historical and architectural documentation of the historic buildings.

A special reference must be made for the contribution of survey engineer and advisor of the City of Nafplion, Mr. X. Antoniadis, the President of DEPAN, Mr. K. Heliotis and the person in charge for the completion of the technical file cards of the project, Ms. A. Tzomaka.

The first recording of the city's historic buildings and public areas was realized within the framework of the project «City Plan Restructuring Project» 1985- 87. prof E. Maistrou was in charge of the project, prof. M. Adami was the chief advisor and S. Malikoutis and K Kiriakides architects, were special collaborators.

A specialized team comprising architects and post graduate students at NTUA worked on the second recording, with Professor E. Maistrou being in charge. The digital photographic documentation was performed by the architect and doctorat candidate at NTUA, M. Balodimou.

The architect Mr. D. Psychogyios, post graduate student at NTUA, collaborated in the design of the database

The archaeologist E. Komata has undertaken the digitation of printed material and the entering of data into file cards

The computer engineer, Mr. A. Anagnostakis has undertaken the development of the software for the integrated recording and documentation system

The architect H. Antoniadis, post graduate student at NTUA, collaborated in the design of the presentation of data.

References

[PPS*01] PAPADOPOULOU P, STAVRAKOU G, LAMBROPOULOS A, ZENTELIS P : Recording and Management of listed buildings in the historic center of Kalamata.
http://www.survey.ntua.gr/main/labs/cadast/research/Publications/MARATHON_2001-Kalamata.pdf

[Ron03] RONCHI A: Monuments Conservation and Management: ICT Tools. *Proceedings of the 7th International Symposium of World Heitage Cities, Rhodes 2003.*

PAPALEXOPOULOS D, KALAFATI E, BUILDING MEMORY
http://buildmemory.arch.ntua.gr/ui/Default.asp

ARKIS - Architecture Recovery Knowledge Information System: *CNR - Istituto per le Tecnologie Applicate ai Beni Cultural, Rome Research Area*
http://www.arkis.it

Documentation, Interpretation, Presentation and Publication of Cultural Heritage: *Proceedings of the ARCCHIP Ariadne Worksops, Volume 2.*

The 7th International Symposium on Virtual Reality, Archaeology and Cultural Heritage
VAST (2006)
M. Ioannides, D. Arnold, F. Niccolucci, K. Mania (Editors)

Short Papers

Persian Heritage Archive

Abbass Malian and Mahmoud Zolfaghari

University of Tafresh, Iran
Research Institute for Geomatics and Spatial Information (RIGSI), Iran

Abstract
Persian Heritage Archive is one the approved task groups of RecordDIM international initiative. In this task group, a unified approach is to be provided for proper documentation of Persian territories. As part of the guidelines suggested by the International Committee for Heritage Documentation (CIPA), we have established a national non-governmental documentation cell named Borde-Kootah to follow and implement the ideas proposed in the aforementioned task group. As the first step, we classified Persian Heritage remains into several major categories. Then, a case study is carried out for each category of Persian architectural types to investigate these various ancient monuments and to depict the pros and cons of the employed documentation strategies. Based on these experiments, a decision will be made on the final standards and the most appropriate methodology for a unified Persian Heritage Archive. In this paper, as a brief report, some documentation projects that have been recently conducted by authors are introduced.

Categories and Subject Descriptors: Heritage Documentation, RecorDIM, CIPA, Close-Range Photogrammetry, Persian Heritage Archive.

1. Introduction

The most important step at the beginning of the preservation work is to prepare a detailed documentation and recording of the cultural and natural heritage because without precise documentation of the historic structure and its surrounding environment, it would be very difficult to carry out a suitable restoration project.

Documentation of the cultural heritage serves as a tool to make information accessible to those who cannot investigate the site itself. Different reasons can be found for the necessity of this information transfer:

- The object is not accessible to interested people
- The object is too large or too complicated to be overlooked and it would be too time consuming to execute an own investigation
- The object is visible only for a short period of time at its location
- The object is too far for people to afford visiting it
- The object is in danger of deterioration or destruction

In general, most heritage documentation applications specify a number of requirements such as:

- High geometric accuracy
- Capturing all details
- Photo-realism
- Automation
- Low cost
- Flexibility in applications
- Efficiency in model size

2. Persian Heritage Archive

Persian Heritage Archive is one the approved task groups of RecordDIM international initiative. In this task group, a unified approach is to be provided for proper documentation of Persian territories.
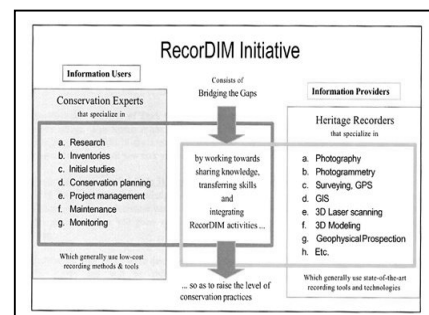

Figure 1: *RecorDIM workflow*

As part of the guidelines suggested by the International Committee for Heritage Documentation (CIPA), we have established a national non-governmental documentation cell named Borde-Kootah to follow and implement the ideas proposed in the aforementioned task group. As the first step, we classified Persian Heritage remains into several major categories. Then, a case study is carried out for each category of Persian architectural types to investigate these various ancient monuments and to depict the pros and cons of the employed documentation strategies. Based on these experiments, a decision will be made on the final standards and the most appropriate methodology for a unified Persian Heritage Archive. In this paper, as a brief report, some documentation projects that have been recently conducted by authors are introduced.

3. Case Studies

Different case studies have been carried out to study both the capabilities of available documentation methods and the documentation requirements related to the enormous number of Persian heritage monuments. Here, three recent documentation projects are introduced.

3.1. Category I: Relief and Sculpture

There exist numerous ancient inscriptions and relieves in Iran that require precise documentation for their study and maintenance. The largest inscription of world, that is the one related to Dariush, the great in Bisotun has been already performed by the first authors. As for a case study concerning Persian Heritage Archive, precise documentation of Elamite inscriptions and sculptures (6th century BC) was carried out.
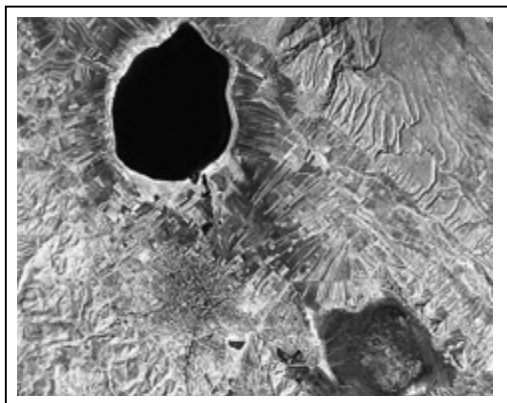

Figure 2: *Satellite image of Izeh area*

Ayapir (Izeh) is an ancient Elamite town in Iran, this ancient town has the biggest gathered collection of archaeological sites and monuments, which show special religious scenes. The oldest Iranian rock relieves and cuneiform inscriptions have been carved on the slope of Izeh mountains which are related to Early-Elamite period (20th century BC). It appears from the documents that at Neo-Elamite period, a local monarch whose name was Hani, at the same time of Shutruk-Nahunteh II reign, was the ruler of Izeh.

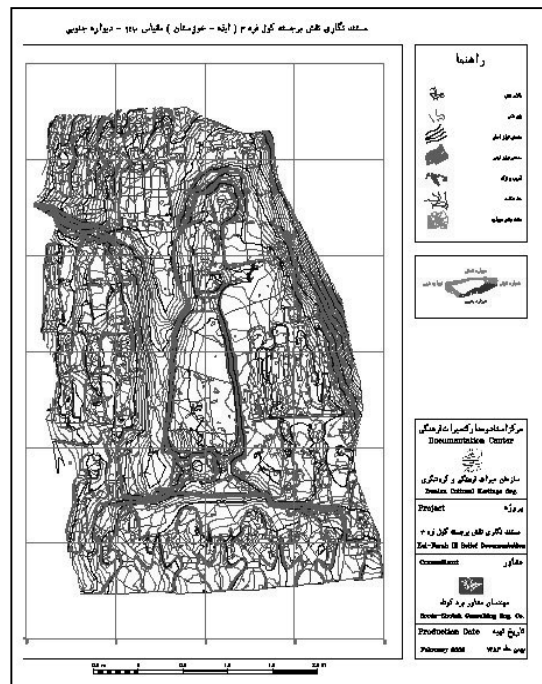

Figure 3: *Kul-Farah III documentation*

Figure 4: *Photogrammetric map of Kull-Farah relief*

3.2. Category II: Minaret and Tower

Minaret is one of the characteristic architectural types in Iran. To study the documentation of this category of Persian Heritage, the Minarets of Nezamieh in Abarkooh was selected as an appropriate case study.

Figure 5: *Aerial photo of Nezamieh site*

These huge minarets were built in 13th century AC and need urgent restoration operation in order prevent the monument from more inclination or collapse. The complexities were compounded by the problematic working space, high precision order and absolute orientation.

Figure 6: *Documenting inaccessible parts using a lift*

A solution based on digital close-range photogrammetry was employed for the documentation task.
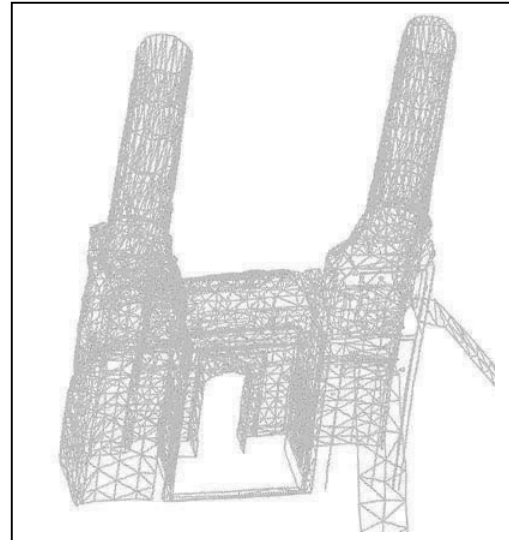

Figure 7: *Triangular Irregular Network Nezamieh*

This monument is in imminent risk of destruction and is currently in the focus of national efforts for safeguarding. The major critical issue is to study the inclination and current condition of conservation of the minarets.
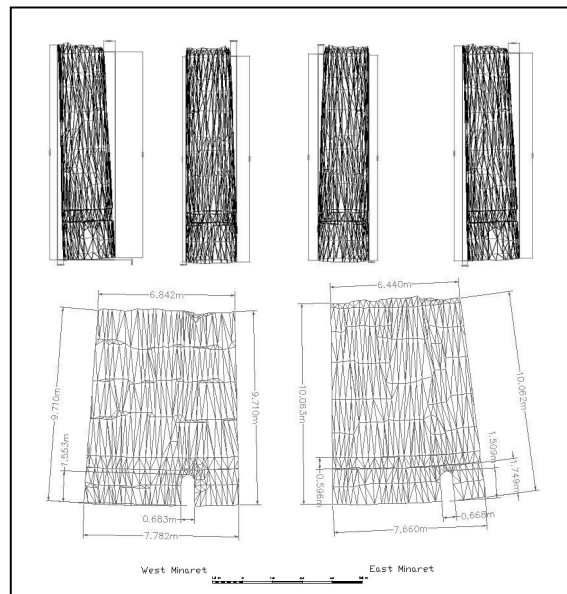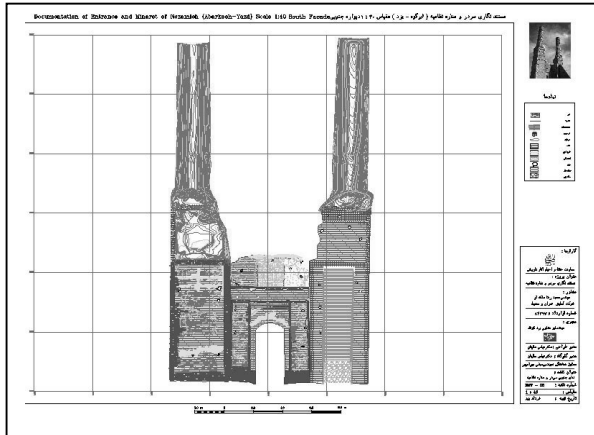

Figure 8: *Analysis of Nezamieh minarets*

Figure 9: *3D reconstruction of Nezamieh monument*

3.3. Category III: Mosque and Altar

The architecture of mosques may be regarded as the most important category in Persian Heritage. Documentation of Imam- Hassan mosque in Ardestan (10th century AC) was selected as a case study for this category.
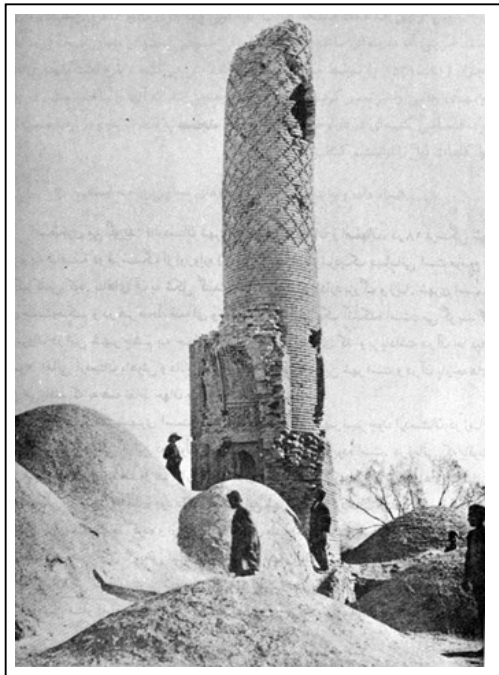

Figure 10: *Old photo of Imam-Hassan mosqu (1911)*

The dataset provided is of importance to prepare an assessment of the structural condition of the elements of the building and as reliable source of information for coming missions that will excavate further study of the monument.
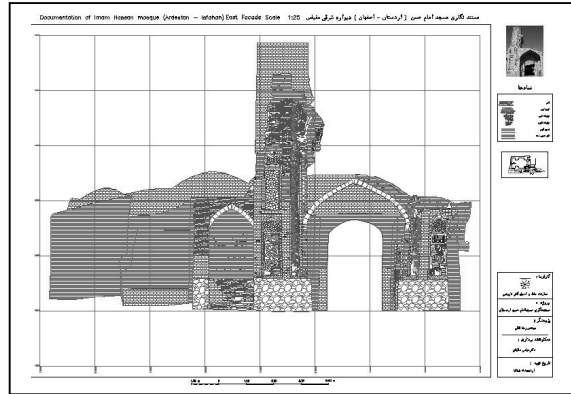

Figure 11: *Documentation Imam-Hassan mosque*

4. Conclusion

The results of different documentation projects and comparative studies on Persian cultural heritage conducted by authors by means of various surveying methods demonstrate:

- The current condition and structural stability of the monuments.
- Methodologies for evaluating the surveys carried out by previous missions, i.e. change detection.
- A solution to prepare a permanent document showing different problems and operations needed to measure the monuments.
- How to propose a model for capacity building of local experts including the development of local structure that is capable of documenting and caring the Persian Heritage. This cell should have strong links to academic and professional institutions, providing further training to experts in Persian territories.
- That, multidisciplinary teams of specialist dealing with conservation of historic buildings should take an active role in the development of *"Persian Heritage Archive"*.

Note

I) Kul-Farah relief documentation was a project of Documentation Center of the Iranian Cultural Heritage Organization (ICHO) executed by Borde-Kootah Consulting Eng. Co.,
II) Nezamieh monument documentation was a project of Mr. Mohammad Reza Malekloo carried out by Borde-Kootah Consulting Eng. Co.,
III) Imam-Hassan mosque documentation was a project of Mr. Reza Saghafi conducted by Abbass Malian.

References

[MAL2005] MALIAN, A., ZOLFAGHARI, M.: Documentation of the Ancient Village of Kharanagh for Rehabilitation Purpose: A Preliminary Report, *XX Symposium of the International Committee for Architectural Photogrammetry and Heritage Documentation (CIPA), Torino, Italy, 2005.*

[LET2006] LETELLIER, R.: Handouts of RecorDIM Partners Meeting, *Rome, Italy, 2006.*

[ZOL2004] ZOLFAGHARI, M., MALIAN, A.: Documentation of the Documentations of the King of the Kings, *XX Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Istanbul, Turkey, 2004.*

[MAL2003] MALIAN, A.,ZOLFAGHARI, M.: Gaps and Needs in the Documentation of Persian Heritage, *Roundtable of the International Initiative for Recording and Information Management of Cultural Heritage (RecorDIM), Antalya, Turkey, 2003.*

[MAL2000] MALIAN, A., ZOLFAGHARI, M.: Malian, A. and Zolfaghari, M., Non-Metric Cameras in Architectural Photogrammetry, *XIX Congress of the International Society for Photogrammetry and Remote Sensing (ISPRS), Amsterdam, The Netherlands, 2000.*

[MAL1999] MALIAN, A.: Surveying Historical Buildings by Means of Close-Range Photogrammetric Technique, *6th Conference on Geomatics, National Cartographic Center, Iran, 1999.*

[MAL2001] MALIAN, A.: Close-Range Photogrammetric Technique for Heritage Mapping, *Journal of the National Cartographic Center, No. 42, Iran, 2001.*
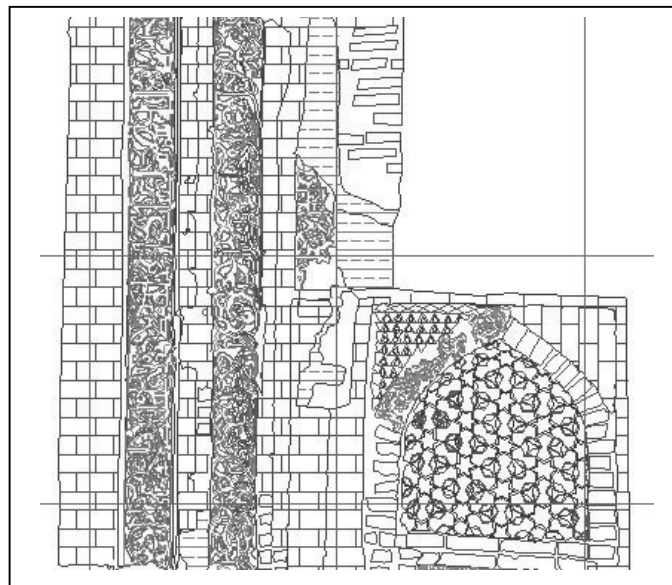

Figure 12: *Details of documentation map of the Imam-Hassan mosque altar*

MUST System - Location Based Services and Multilingual Simultaneous Transmission for Tourist Fruition

A. Cinnirella[1] S. Faralli[2] A. Labella[2] P. Maurelli[1] M. Pierro[2] and F. Rosa[1]

[1]ECOmedia s.c.r.l, Via A. Rocca, 2B - 00135 Rome Italy
[2]Dpt. Informatica, University of Rome "La Sapienza" Via Salaria, 113 - 00198 Rome Italy

Abstract

The following is a presentation of the "MUST" - Multilingual Simultaneous Transmission - system that provides radio transmitted (PMR-PLL) audio tracks up to a distance of 100-200 meters in open areas in eight different languages simultaneously. This innovative system, developed with a unique integration of technologies, provides comments, descriptions, and/or background music to groups of users in various types of situations that have been activated using LBS (Location Based System) technologies. The contents can be activated in LBS mode using GPS technologies in open areas while in indoor environments RFID technologies are necessary. The main advantages of this solution are: the low cost of the client devices (audio receivers), joined by the economic advantages of digital audio track self-production; high transportability; the possibility of extending the system's functionalities; the high number of supported system clients: more than 100 receivers can be used simultaneously and the number of simultaneous audio languages can be extended further. The next development of the sinchronized video streaming functionality gives MUST more advantages and implementation possibilities.

Categories and Subject Descriptors (according to ACM CCS): H.5.1 [Multimedia Information Systems]: Hypertext navigation and maps J.0 [Computer Applications]: General, field sciences J.5 [Arts and Humanities]: Archaeology H.3.4 [Systems and Software]: Distributed systems H.5.1 [Multimedia Information Systems]: Audio Input/Output

1. Introduction

The following is a presentation of the "MUST" - Multilingual Simultaneous Transmission - system that provides radio transmitted (PMR-PLL) or cable transmitted audio tracks in eight different languages simultaneously. Cable transmission system is the best solution for in-door or on-board applications where there are several seats with head-phones output, while the radio solution can be used in open areas where users can move up to a distance of 100-200 meters from the transmitters rack. This innovative system, developed with a unique integration of technologies, provides comments, descriptions, and/or background music to groups of users in various types of situations that have been activated using LBS (Location Band System) technologies and can be set to manual, semi-automatic or completely automated mode. The contents operated in LBS mode can be implemented using GPS technologies in open areas or RFID technologies in closed environments. The system is equipped with its own highly flexible software that can be individually compiled

to suit specific commentaries regarding the archaeological area, or theme park, being visited. It is therefore possible to use a single system to provide an audio-guided service in 8 different languages by selecting the route-monument-work of art option of the specific commentary required. The MUST system and its management software have been developed to meet the various and diversified needs of the tourist sector. MUST offers two system options: a fixed centralized option that restricts transmission of all the equipment to within the 100-meter range of the radio signal and a mobile, portable option that can be carried in a backpack or trolley. The system was developed to meet the specific needs of simultaneous transmission of audio content to groups of people of various nationalities and languages. The systems currently present on the market are for the most part conceived to provide pre-recorded or live commentaries but do not offer simultaneous commentaries in different languages. Figure 1 shows the flight-case containing the equipment, receivers, and audio transmitters.
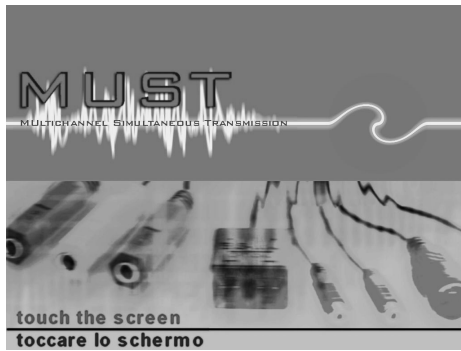
2. Description of MUST

Figure 1: MUST *system.*
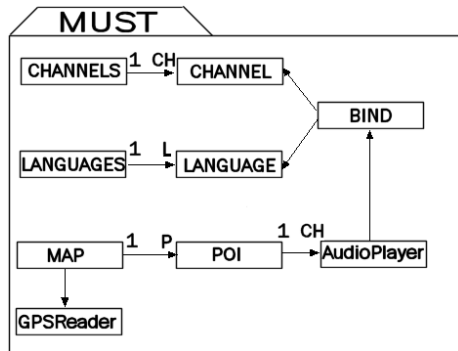

Figure 2: MUST *logo.*

Figure 3: MUST *Class Diagram.*

The MUST system was created as a device to enrich the valorisation and tourist fruition project of the UNESCO site at the Etruscan "Banditaccia" necropolis of Cerveteri (Rome). The particular characteristics of the area, a tuffaceous plateau of about 10 ha with some 400 monuments including tumulus and hypogeum tombs immersed in a unique
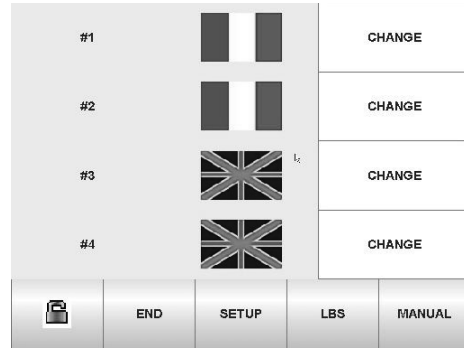

Figure 4: MUST *Binds Configuration.*

Figure 5: *The Manual selection of POI.*

landscape, made it necessary to develop an innovative audio guide system that could furnish simultaneous transmissions in up to 8 languages. The tour of the monuments runs along 3.7 km route onboard a light-electric train where the users/tourists are equipped with audio guides that describes the site in their own language. MUST offers two distinctive system options: the first system (management and control system) is made up of: a Mini PC with specific software for
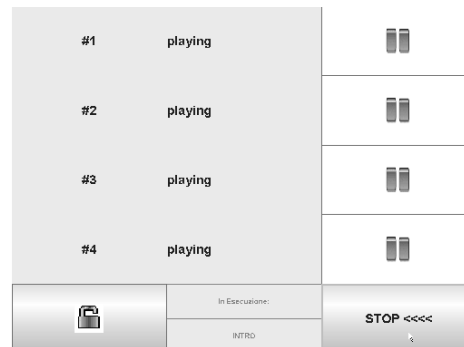

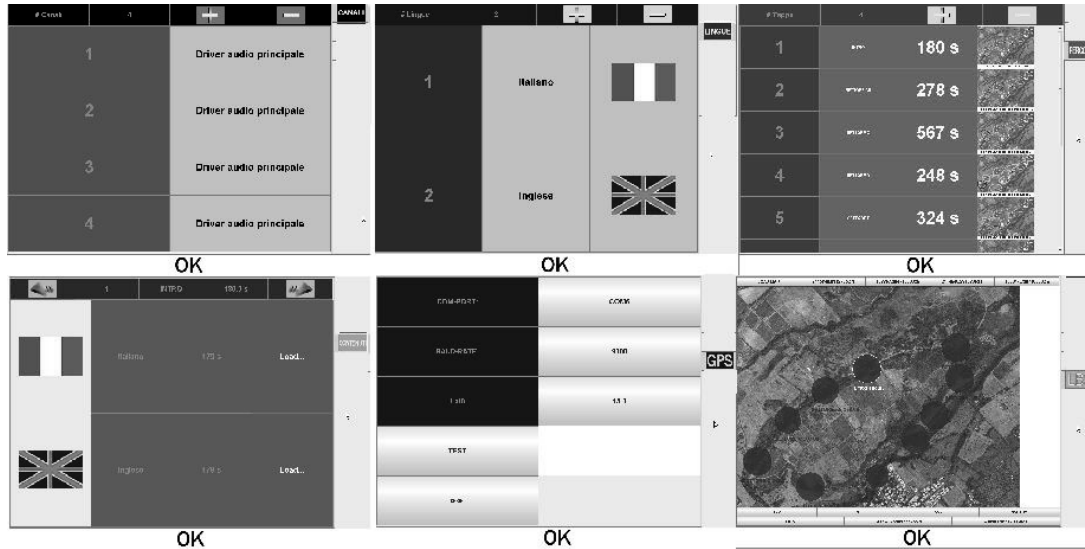**Figure 6:** *POI's contents controls.*
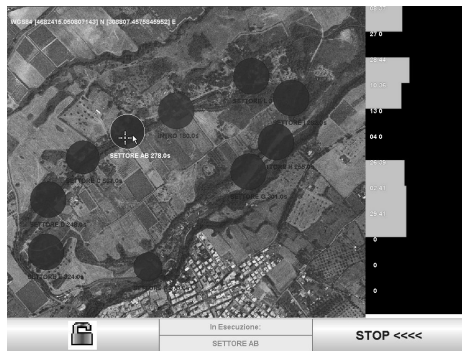
Figure 8: *MUST's Configuration GUI*

Figure 7: *The LBS execution modality.*

the management of multilingual audio sequencing of the relative area being described; a Touchscreen to facilitate use by the operator. An audio card able to distribute up to eight audio tracks simultaneously to the transmission system is connected to the Mini PC. This first system is contained in a sturdy flight case that can be transported manually for software maintenance or upgrading. Three power supply system options were applied: 220V to the network, 12V (6A), and a self-contained system with rechargeable batteries. The second system (Radio transmission and reception system) has up to a maximum number of eight transmitters (PMR or PLL) connected to the first system and the relative receivers - unlimited number - equipped with ergonomic earphones that are distributed to the users. Users can choose the transmission in their own language by selecting from the options found on each receiver. The second system is contained in a case that can hold up to 36 components (ex. 6 transmit-

ters and 30 receivers) and has a battery recharging function that can be connected to the electrical system. If the tour guides need to intervene 'live' with non pre-recorded commentaries, they can connect a microphone to the audio card or disconnect from the central control system and connect directly to the relative transmitter at any moment. For applications in large open areas with different multilingual description sequences, the system can also use a GPS system connected to the Mini PC that activates the audio commentary of the relative object/location that the users are viewing thereby reducing the need of intervention by the tour guide. This configuration, designed especially for Spatial Information Management (SIM), has made it possible to develop a completely automatic process for the integration of heterogeneous data to the system. For applications in indoor environments, MUST can be integrated with synchronized multimedia content management functions for the audio for videos or for wireless transmission towards palm receivers or smartphones.

3. LBS-GPS Application

Location Based Services (LBS) are added value services that use the knowledge of the geographical position of a mobile user to dynamically provide the necessary requirements to the user depending on their location and the characteristics of the surrounding context. In general, the Location Based Services combine information regarding the geographical location with other types of information regarding the surrounding context and environment. These services are usually based on the use of a communication network and one or more localization technologies combined with Geographic Information Systems (GIS) that manage data collection and

how it is presented to the final user. Furthermore, in some cases added value application solutions integrated with the technological infrastructure and GIS systems are also used. Their complexity depends on the type of service provided. In this specific case, the MUST system includes very simple GIS functionalities, being a tool dedicated non expert users to manage LBS cvonfiguration and monitoring and to link audio contents to the active areas and positions. Once it was coded in audio format, the information was transferred to the MUST system that, using the position given by the GPS, selects the available information in audio format from the WebGIS application called SITAC (Sistema Informativo Territoriale e Archeologico Ceretano [CMR06]) and transmits this information to the user who asked for it through his position. The system used is based on open source software. The data bank developed foresees the use of a common geographic database (Postgress and PostGIS) that can be accessed through a WAN or the Web. Finally, given the necessity to develop a satisfactory and above all low cost system, an economical and compact entry level GPS was used. The geographic position of the user can be obtained by a reference system integrated within the environment (ex. RFID), or by a total reference system (GPS). The services provided are usually personalized to meet functional and content supply requirements as well as fruition modality requirements in response to the user's profile and position at that moment.

4. MUST Architecture

The MUST system has been developed using JAVA. The MUST class diagram (see Figure 3) defines five main components: Channels, Languages, Map, GPSReader and MUSTAudioPlayer. A Channels instance holds a set of references of size CH to instances of the class Channel. Each Channel object defines a target_audio_device_ID (e.g.. an identifier for a hardware audio output channel) and a channelSEQN from 1 to CH. The Languages class holds a set of size L of instances of Language. Each instance defines the triple (languageSeqN, languageID, languageIcon), where a languageSeqN is a sequential number from 1 to L, a languageID is a string (e.g. "Italian") and a languageIcon is a javax.swing.ImageIcon instance (e.g. an image of the Italian flag). The role of the class Bind is to determine the selected language for a Channel. A Map class defines: a set of size P of points of interest (POI),a georeferenced bound and a bitmap representing the interested area. Each POI instance holds: a POI_ID: a unique integer number from 1 to P, identifying the POI, a pair ((Lon,Lat), Radius) where the pair (Lon,Lat) defines the geographical position of the POI, and Radius (the distance in meters from (Lon,Lat)) is the parameter used by the LBS in determining the active boundary of the POI, a set of CH MUSTAudioPlayer instances and a POI_DURATION defining an upper bound for the time duration of the audio files related to the POI. The MUSTAudioPlayer class defines the methods to play(), stop() or pause() an audio content on a Channel in a particular lan-

guage defined by an instance of the class Bind. The audio files are stored in a folder named "contents". Each audio file name is formatted as "cilj.wav"; where i and j define respectively the corresponding POI_ID and languageSeqN. Finally, the GPSReader class defines a thread for the MUST's LBS execution modality. This thread continuously reads data from a GPS receiver, converts the coordinates in the corresponding reference system, and triggers the activation of a POIp if the distance between the GPS location point and the POIp.(Lat,Lon) is less than the POIp.Radius. When a POI is active, a sequence of calls to play() is made - one for each of the CH Channel instances - and the corresponding audio contents are streamed to the MUST transmission subsystem via the audio players.

The MUST interface allows a user access to the setup screen, and to the manual or LBS execution modalities. Figure 4 show the first main window where a user can: modify the binds between channel and language; choose between LBS and Manual execution; run the setup phase; exit from the application and lock the touchscreen. Figure 5 shows a POI's choice panel and transmission control for a manual session. Figure 6 shows the "Map" with ten preconfigured POIs. In the same Figure, a particular POI is interested by the presence of the MUST GPS device inside the area of activation. The tourists will listen to the commentary in their preferred language until the audio content will be fully played and/or a new, unvisited POI is reached. If the user selects the SETUP button (shown in Figure 4) a new Window with a tabbed pane of 6 panels appears on the screen. Figure 8 shows an explosion of the configuration GUI, divided in: Channels configuration panel, Languages configuration panel, Tour configuration panel, Contents configuration panel, GPS receiver configuration panel and LBS configuration panel. In the Channels configuration panel, the user can set the number of channels (CH) and their target audio device ID. In the Languages configuration panel, the user can set the number of languages (L), their languageIDs and their languageIcons. The Tour configuration panel allows to define the set of POIs, while the Contents configuration panel allows the user to select the audio files for each POI. Finally, the GPS configuration panel and the LBS configuration panel help the user in configuring the GPS device and in correctly placing the set of POIs on a specific georeferenced map.

MUST uses the JavaSound API [SUN] to handle the different audio streams needed for multichannel broadcasting. JavaSound is a standard Java library (J2SE version 1.3.x and higher) which abstracts the underlying audio hardware and streams, thereby allowing low-level device control and reproduction/recording of different audio file formats, maintaining at the same time the multi-platform capabilities of the Java language. In MUST, each audio stream related to one of the available languages is handled by a custom MUSTAudioPlayer class. Each instance of the class uses the Observer/Observable pattern to report its activity to the rest of

the MUST system. Other components of the system, such as the user interface, can register themselves as observers so that they are notified when specific events occur in the audio stream - as an example, when the end of an audio file is reached. Internally, each MUSTAudioPlayer instance employs a local JavaSound audio stream to play the assigned file, plus a local thread to control the audio stream activity at regular intervals, fetching new data from the audio file in the drive and writing that data to the audio hardware. There is thus no need to load the whole audio file in memory, since only a small buffer is used by each player. Audio file length is therefore only constrained by the available disk space. When created, each MUSTAudioPlayer class instance accepts a local audio file name, an audio hardware device name, and a reference to an observer object as the parameters of its constructor, and encapsulates the use of the JavaSound API, so that it is possible to port MUST to a different audio platform by specializing the MUSTAudioPlayer class. Multichannel audio hardware, such as the M-Audio sound card, usually maps its physical outputs to a set of separate audio devices available to the OS. Since each MUSTAudioPlayer class instance handles its own audio stream independently, multichannel audio reproduction is realized by instantiating several MUSTAudioPlayer classes, each assigned to a different audio device representing one of the soundcard's physical outputs. Therefore, MUST is easily scalable to employ as many audio channels as its CPU and audio hardware can handle. Moreover, it is possible to use different formats to encode the audio, as long as JavaSound provides native, platform-specific codecs for them - MP3 format is a typical example. Compressed formats, though, need far more CPU resources to be decoded, therefore uncompressed WAV format is currently employed in MUST to represent audio guides, so that more audio channels can be achieved. This is acceptable, given that there is more than enough space to accommodate uncompressed files in the system's hard drive and that employing a more powerful CPU would pose serious problems to the system's autonomy, heat dissipation and price.

5. Related works

In [GDVG] existing audio guide systems are categorized according to their properties. They are mainly divided in two categories: manual activation and automatic activation systems. Manually-activated audio guides are widely used but they require some learning time. Among groups tour systems, solutions offered by Antenna Audio [Ant] are widespread but require the presence of an operator for each language, while the Actia-Datavox system is GPS-equipped but delivers audio tracks through cables inside a tourist vehicle. Automatically-activated audio guides are easier to use, and in many tourist offices (such as in Venice [APT]) it is already possible to rent a GPS audio guide. To the best of our knowledge, the multilingual radio transmission of audio contents is an emerging technology [Orp]. The combination of GPS and radio transmission technology is yet to be fully explored.

6. Conclusions

Simultaneous radio transmission of commentaries in different languages represents an innovative solution in the field of Multilingual applications, tools and systems for CH. Location Based System (GPS or RFID) integrated in the MUST system allows commentaries to be automatically activated along tourist fruition paths. Another factor characterizing the MUST system is the implementation of low-cost solutions using Location Based and Wireless services to improve the multilingual fruition of cultural resources. The system proposed can be adapted in archaeological sites, museums, theme parks, town and city tours, with or without operator. After the project and applicative stages of this first release, the work group is now elaborating the next phase. The second step foresees transmission not only of audio content but also of multimedia (video, images, 3D reconstruction) content for terminals using the latest developments in technology such as palm pilots and Tablet PCs.

7. ACKNOWLEDGEMENTS

References

[Ant] ANTENNA AUDIO: the world is listening. http://www.antennaaudio.com.

[APT] APT: Azienda di promozione turistica di venezia. http://www.turismovenezia.it.

[CMR06] CINNIRELLA A., MAURELLI P., ROSA F.: GIS to Improve Knowledge, Management and Promotion of an Archaelogical Park: the Project for UNESCO Etruscan Site in Cerveteri, Italy. In *ASIAGIS 2006* (2006).

[GDVG] GEBBENSLEBEN S., DITTMANN J., VIELHAUER C., GUERICKE O.: Multimodal audio guide for museums and exhibitions. http://wwwiti.cs.uni-magdeburg.de/ gebbensl/Multimodal Audio Guide for Museums and Exhibitions.pdf.

[Orp] ORPHEO: Orpheo tgs. http://www.ophrys.net.

[SUN] SUN: Javasound api reference. http://java.sun.com/products/java-media/sound/.

Intra-site Level Cultural Heritage Documentation: Combination of Survey, Modeling and Imagery Data in a Web Information System

Élise Meyer [1], Pierre Grussenmeyer [2], Jean-Pierre Perrin [1], Anne Durand [3], Pierre Drap [3]

[1] MAP-CRAI UMR CNRS-MCC 694, Nancy School of Architecture, Nancy, France
(meyer, perrin)@crai.map.archi.fr

[2] MAP-PAGE UMR CNRS-MCC 694, INSA Strasbourg Graduate School of Science and Technology, Strasbourg, France
pierre.grussenmeyer@insa-strasbourg.fr

[3] MAP-GAMSAU UMR CNRS-MCC 694, Marseille School of Architecture, Marseille, France
(anne.durand, pierre.drap)@gamsau.map.archi.fr

Abstract
Cultural heritage documentation induces the use of computerized techniques to manage and preserve the information produced. Geographical information systems have proved their potentialities in this scope, but they are not always adapted for the management of features at the scale of a particular archaeological site. Moreover, computer applications in archaeology are often technology driven and software constrained. Thus, we propose a tool that tries to avoid these difficulties. We are developing an information system that works over the Internet and that is joined with a web site. Aims are to assist the work of archaeological sites managers and to be a documentation tool about these sites, dedicated to everyone. We devote therefore our system both to the professionals who are in charge of the site, and to the general public who visits it or who wants to have information on it. The system permits to do exploratory analyses of the data, especially at spatial and temporal levels. We propose to record metadata about the archaeological features in XML and to access these features through interactive 2D and 3D representations, and through queries systems (keywords and images). The 2D images, photos, or vectors are generated in SVG, while 3D models are generated in X3D. Archaeological features are also automatically integrated in a MySQL database. The web site is an exchange platform with the information system and is written in PHP. Our first application case is the medieval castle of Vianden, Luxembourg.

H.2.8 [Database Management]: Database Applications ; H.5.1 [Information Interfaces et Presentation]: Multimedia Information Systems ; J.2 [Physical Sciences and Engineering]: Archaeology

1. Introduction

Cultural heritage documentation induces the use of computerized techniques to manage and preserve the information produced. In the archaeological domain particularly, data computerization gives solutions to specific problems in allowing inventory actions to save, present or interpret the features. Archaeology is an erudition discipline where the knowledge grows up in necessarily referencing the precious documents already gathered. Computer science has fast appeared as a very convenient way to manage this information, which the development of the field is enriching at great speed in an inflation quite difficult to master. It is required to develop systems allowing to create relationships between the different types of information generated by the working of an archeological site. We have chosen to work at the scale of a site, because there are more completed projects at

regional or national levels. In addition, these projects are mostly Geographic Information Systems, whereas we are creating an Information System permitting to manage very different types of data (not only geographical) what is more uncommon. We dedicate besides our system both to the professionals who are in charge of the site and to the general public who visits it or who wants to have information on it. Hence, we are using web techniques and languages to develop our web information system, in order to be independent of any software and to allow maximum accessibility and adaptability to the needs of the diverse actors using the tool. Our first application case is the medieval castle of Vianden, located in Luxembourg.

The system notably combines survey, modeling and imagery data, and our purpose is to highlight up to what point can such a system offer new possibilities for the management and the documentation of the data of an archaeological site. First of all, we will present the

objectives of the project and the methods chosen to reach our aims, according to the state of the art in the domain. Afterwards, the tool that we are developing will be presented. We will describe how the different data types are recorded in the system. Then, we will show the access possibilities to this data: through queries and through 2D and 3D interfaces. Finally, we will explain on the prototype of the Vianden castle site the way to create original 3D models and synthesis plans, and the means to update and revise the data for the experts working on the site.

2.   Objectives of the project

To introduce the aims of the project presented in this paper, we will give the principal conclusions of the bibliographical study that has been made in the beginning of our work. So, we will correlate the fixed objectives with the lacks and needs identified during this study.
A good overview on computer applications in archaeology has been given by J. D. Richards [Ric98]. This paper reflects that "although archaeologists have been quick to apply the latest technology, in most cases the technological driving force has been outside the discipline" [Ric98]. What means that the use of computer science in the archaeological domain is often driven by software offers rather than by archaeological questions. This is a problem to which we will try to propose solutions.

Concerning databases, Richards write that the description of a document that is recorded in a database is at least as rich as the report from traditional publications. The recording of metadata (data about data) is something common nowadays, notably with the format XML (Extensible Markup Language, standard language of the W3C) which is dedicated to the formalization of such information and which allows polymorphism. This is the format that we have adopted to record metadata about the archaeological features that our system permits to manage. The idea is that an excavation archive can be viewed as a hyper document with texts and images bounded by internal links and allowing readers to follow different paths to retrieve information through the report [Rya95]. And "if such documents can be made publicly accessible, over the Internet, for example, then they begin to blur the distinction between archive and publication". So we have chosen to develop a free Information System that works over the Internet. An example of integrated computerized field projects linking basic finds, plans and context data recording in the field and operated using GIS mapping tools is related in [Pow91], and examples of Internet databases applications are given in [CFR03] and [Ric04].
A drawback of projects carried out currently, according to Richards and as already said in introduction, is the fact that a large proportion of the literature until now has been concerned with the establishment of databases of archaeological sites and monuments at regional and national levels for cultural resource management purposes. They are few projects concerning data management at a site level, the data recorded being obligatory dissimilar at this scale than at a bigger. Consequently, our project is

devoted to the management of data generated by the working of a particular site (and not of a group of sites).

Regarding Geographical Information Systems, they have been developed to create relationships between data and to analyze spatial information recorded in databases. In archaeology, the principal applications of GIS are either heritage management (monitoring of known sites or identification of new ones) or explanatory framework (site catchments or view shed analysis). A great quantity of examples are cited in Richards' paper and his conclusion is the following: "There has been a lack of projects that have made effective use of GIS at the intra-site level; the projects on an Iberian cemetery [QBB95], Roman Iron Age sites in the Assendelvers Polders [Mef95], and the Romano-British settlement at Shepton Mallet [BCE*95] are rare exceptions." [Ric98]. For that reason, the project that we are developing concentrates on this lack. We generalize the notion of Geographical Information System in saying only Information System to describe our work. In fact, the types of data that are managed are not only geographical data (maps, vectors) but also archaeological, historical, topographical, architectural, geological, environmental… An information system must permit to carry out a real multidisciplinary synthesis of all resources of the database. For archaeological data especially, the creation of an information system can lead to achieve:

- to treat graphically several information derived from very different kinds of surveys, because a selective superposition could be a precious help for the interpretation;
- to combine elements selected in diverse graphs for the carrying out of visualizations in a synthesis plan;
- to present images and their connections with the concerned texts from the database, to lead to a complex system in which the examination of texts and images would be possible simultaneously.

Especially for our project, the aim is to create a tool permitting to manage data generated by the working of an archaeological site. The term management comprises the gathering and description (metadata) of all the documents (photographs, plans, drawings, models…) already created or that will be done during the further exploitation of the site, and the construction of relationships and links between them.

To continue, visualization of archaeological information is one of the most exciting ways in which computer technology can be employed in archaeology. This word is taken for any exploration and reproduction of data by graphical means. The use of this technique allows visual interpretation of data through representation, modeling, display of solids, surfaces, properties or animation, what is rarely amenable to traditional paper publication [Ric98]. Until now, the most 3D models are intended for heritage center and museums displays, rarely are some available on-line over the Internet. An impressive and popular publication of visualizations of international important sites has been edited by [FS97]. Also virtual reality with fully immersion has a great potential as a medium for

interpretation and communication to the general public [GE04]. An example of web-based visualization in VRML that allow to explore an archaeological landscape (large scale) is given in [GG96], and explanations about the use of the SVG format are to read in [Wri06]. One of the principal inconvenience of the types of 3D models used in archaeology until now is that these models are blank. In fact, they only serve for visualization needs and they don't give any other information. Nowadays, 3D models can serve as research interface to access different kinds of information, notably in coupling them with web procedures (scripts). Our project is carrying out this way: we are producing interactive plans in SVG and models in X3D that work like web interfaces to access the database data.

Finally, when spoken about communication in the domain that interests us here, it is often heard as publication. More precisely, significant developments regarding communication currently have appeared with new forms of electronic publications. Electronic publication allows the distinction between traditional archive and hard copy report to blurred, with supporting data made accessible for the first time [Rya95]. From another source, there are advantages through multimedia and accessibility of new forms of data, particularly drawings, plans, video, and photographs [RS94][Smi92]. [McA95] note that doubts have been expressed about the speed of adoption because of resistance from traditional publishers. We can say now that these doubts were well-founded because there are not yet a great quantity of electronic publications in archaeology, especially available over the Internet. However, one of the best examples of on-line publication (peer-reviewed journal of record) is *Internet Archaeology*, an international electronic journal project set up with funding from the United Kingdom's Higher Education and Further Funding Council (HEFCE) as part of their eLib (Electronic Libraries) program [HRR95]. This publication doesn't contain any other material than textual documents. According to Richards, "undoubtedly the major growth area of the second half of the 1990s has been that of archaeology on the Internet, particularly on the World Wide Web" [Ric98]. This is even more true today, the web provides a tremendous opportunity to link distributed resources and to make unpublished material widely available (remarkably uncommon material like detailed fieldwork data, quantities of photos and archive drawings, vectorial plans or 3D models). The traditional division between publication and archive could thus be removed, even if there is still a big challenge to control the way in which the Internet is used (for the discoveries, quality controls or copyrights). From our side, the way we perceive the term communication is more complete than just the publication. Aim of the web site including the information system, is to assist the digital archiving of the documents, their inquiry and their processing by everyone, both the professionals (archaeologists, surveyor, architects, etc.) and the general public. Different types of access to the data are available depending on the user of the system. Representations adapted to museum displays (public attractive) have been done as well as interfaces permitting

to update the data directly from the 3D models (for instance) for the needs of the site managers. This system works over the Internet to allow accessibility and simplicity for all the users, and above all to be free from any software. As a conclusion, Richards said that "in all areas of computer applications in archaeology, the discipline has been technology driven and software constrained. Rarely has the use of computers in archaeology been led by archaeological theory, although in specific fields, such as GIS, it can be demonstrated that computers have advanced archaeological knowledge." [Ric98]. Thus we hope the information system we are developing will also serve archaeological knowledge in proposing an other type of communication and sharing of the information generated by an archaeological site.

3. Implementation of a web information system dedicated to archaeological intra-site features documentation

According to the objectives explained before, we will now present the way the project has been developed to reach these aims in the best possible way.

To begin with, it is relevant to point out the fact that the computational base of the information system carried out comes from projects done to integrate photogrammetric data and archaeological knowledge on the web (ISA-PX "Information System for Archaeology using Photogrammetry and XML"). These projects are parts of research of P. Drap and his team [DG00] [DDS*05].

In fact, a certain number of the computer formats (XML, VRML) used in the ISA-PX system were adapted to our needs. The laboratory of P. Drap being partner with us, it has been possible to base our project on the computer developments already done. We have adapted the existing system afterwards to our particular case, notably to allow the management of different types of data (not only data coming from photogrammetric surveys), and coupled with a web site to permit simple data access by everyone. Our system has been named SIA (Archaeological Information System).

3.1. Database management system

The types of data that the system allows to manage are:
- temporal data (description of historical periods)
- spatial data (description of places of the archaeological site)
- different sorts of plans that have been digitized (axonometries, maps, sections, plans, elevations, excavation profiles and plans)
- digital photos or ancient photos digitized
- scanned drawings
- scanned texts
- vectorial plans (generated in SVG)
- 3D models (generated in X3D)

These data are recorded both as XML files and in tables of a MySQL database. These two record possibilities were already available in the ISA-PX system, to obtain standardized data formulized in XML (for simple

information exchanges) and a classic form of data searchable through SQL queries in MySQL. More precisely, it is metadata about the before quoted data that is recorded (for instance the provenance, author, subject, coordinates… of a photo). Figure 1 sums up the process to fill the XML and MySQL databases (both are filled simultaneously).
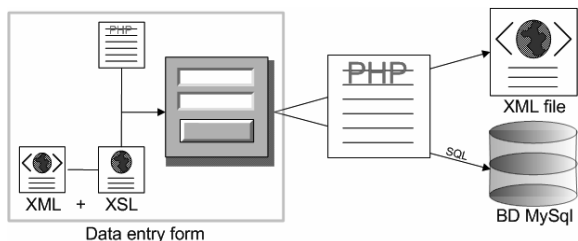

Figure 1: *Filling of the databases (computer behavior).*

After having integrated a first time the corpus of each data type in the form of an XML file generated by the system (data entry form to give the metadata structure), all the metadata is recorded through data entry forms like in Figure 1. The data itself is attached thanks to URL links.

Figure 2 gives an example of the HTML representation of an XML photo file (data and metadata) thanks to an external XSL document. When the user clicks on the miniature of the photo, he have access to the original photo.
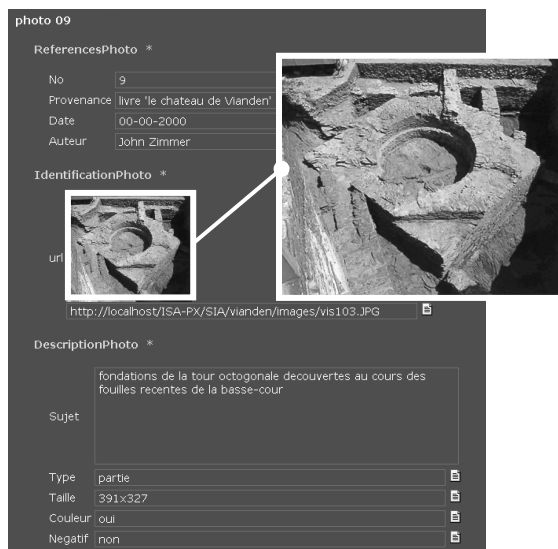

Figure 2: *HTML representation of the XML data and metadata of a photo thanks to an external XSL document.*

3.2. Accesses to the data in the system SIA

Figure 3 illustrates the computer behavior of the platform that has been developed. The initial information system ISA-PX has been totally included and adapted to the web interface that has been created to form the SIA system, which permits a user friendly and insightful access to the archaeological data recorded.
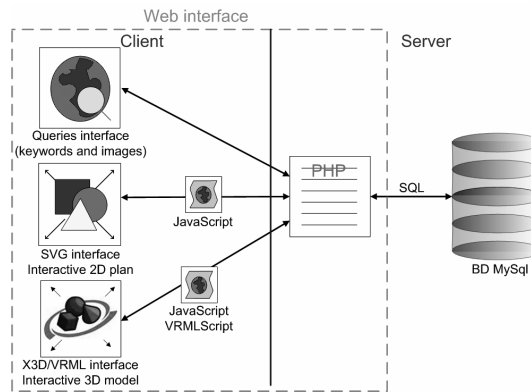
Figure 3: *Types of data accesses in the SIA Information System (computer behavior).*

In parallel to these accesses, two menus are available in the web site to retrieve documents in covering the history of the site and in visiting its places. To sum up, the documents inquiry in the system SIA is schematized in Figure 4.

Figure 4: *User's path for the documents inquiry (UML).*

Each use case (presented as a folder here) is also detailed in an other UML schema showing precisely the different operations to do for an efficient exploitation of the SIA information system. For instance, Figure 5 shows the detailed use case "Interacting with plans".

Figure 5: *SIA use case "Interacting with plans" (UML).*

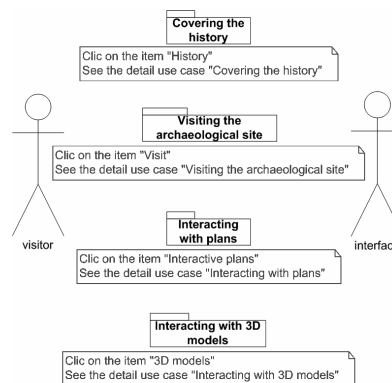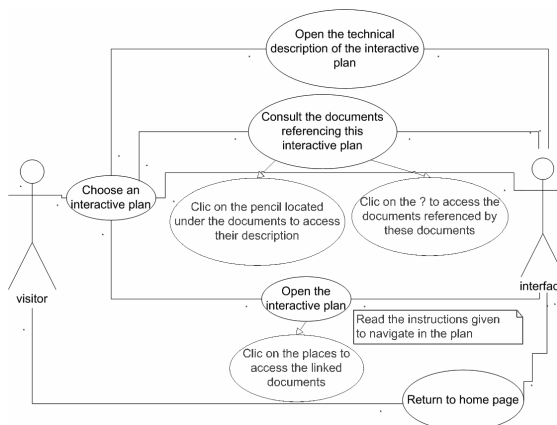All the UML schemas done to help the users of the system (visitors and expert users) are available in the web site in an item entitled "help and users' paths". Likewise, the queries interfaces (by keywords and images) are explained thanks to UML schemas, to allow the user to find a document as fast as possible if he has particular criteria. The keywords search engine is multi-criteria, what means that the user has choice between different words, he doesn't give the words himself.

3.3. Example of the Vianden castle site

The place of interest on which we have done our first experimentations is the medieval castle of Vianden located in North-East Luxembourg. This archaeological site has a very long and interesting history, during which a lot of documents have been created and hold. Then, this site was very interesting for us to test our system on a real case, notably because we have had access to historical models of the castle made by the MAP-CRAI laboratory of Nancy. So we have collected in the SIA system a lot of data produced by the conservators of the castle (plans, photos, excavations profiles…), along with the MAP-CRAI 3D models (converted from the Maya® format into VRML) and with interactive plans that we have created in SVG thanks to the software Adobe Illustrator®.

All these documents gathered and created have been registered in the database (themselves and the metadata attached) in using the procedure explained in Figure 1.

The principles of accesses to the data are explained in Figure 3. In a more detailed way, Figure 6 shows the example of Vianden site.
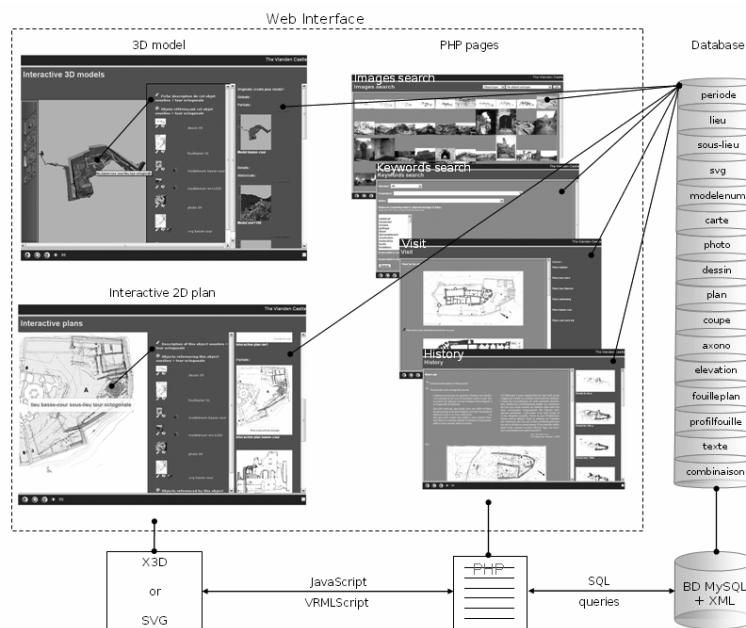

Figure 6: *SIA information system in the case of the Vianden castle.*

Creating models and plans. In addition to the data working possibilities explained before, the user of the SIA system can create his own models and composition plans thanks to multi-criteria data entry forms. In the web pages, he has the choice to select for example one or several places and one or several historical phases for which he wants to create "on the fly" the 3D model to see the evolutions in time of the castle. The procedure is to see in Figure 7. The resulting model presents different parts of the castle (yard, chapel, hall) in two different periods (year 1100 in yellow and 1150 in pink). We can see here the architectural changes that have been done during the 50 years considered. The same process is available to create synthesis plans or photo-montage allowing for instance to superimpose the physionomy of the castle today with its former aspects.
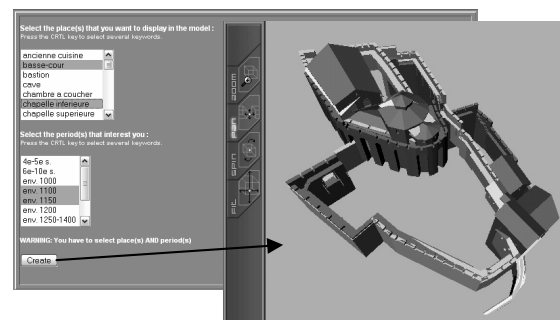

Figure 7: *Process to create on the fly 3D models.*

Updating the data. To look at the data is the first step in the analysis of a dataset. To go further on, the archaeologist (or any expert that is logged on) needs to entry/edit them.

To update the metadata:
- the metadata corpus can be used to correct some basic errors (misspelling, simple inconsistencies, etc.),
- through the graphic interfaces in SVG or VRML, the expert user can directly modify the selected object,
- through different types of research modes (by object type, by location, by epoch, …), the user can straight access to the data and can edit it for modifications.

For the revising, the conceptual model used to describe the objects can change during the time of the study, according for example to new archaeological knowledge. The expert user can modify accordingly the tree structure of the dataset describing the object model.

4. Conclusion and future work

After having set our work objectives in the state of the art of computer applications in archaeology, we have introduced the Information System that we have developed. The web site and the underlying information system allow to record, make use and represent the data of any archaeological site. The SIA system has been made to search solutions to help archaeologists in their tasks at an intra-site level and to avoid that they are software-driven. The full XML choice for textual and graphical representations permits relevant interactions. The use of 2D vectorial graphics and 3D models as user-interfaces to the data link purely documentary data and metadata to geometric representations. We connect very different types of data to emphasize new research possibilities and new information exchanges between many sites to be able to draw conclusions by crosschecking. Moreover, the data are available through the Internet what allows us to work in the direction of communicating them in an innovative and interactive way. Experiments will be carried out soon on a gallo-roman site to highlight the subsisting problems (integration of new data types…) and to test the clarity of the help files created (UML schemas) in order to know if the system is usable by everybody.

Final aim is to create a simple and everywhere accessible tool for all the archaeological sites managers, who wish to be able both to exploit the quantity of data produced and to represent them, in order to make use of this archaeological information system as a virtual storefront for the communication and the e-publication of their findings.

References

[BCE*95] BISWELL S., CROPPER L., EVANS J., GAFFNEY V., and LEACH P.: GIS and excavation: A cautionary tale from Shepton Mallet, Somerset, England. In, *Archaeology and Geographical Information Systems: A European Perspective*, Lock, G., and Stani, Z., eds., pp. 269-285. London: Taylor and Francis, 1995.

[CFR03] CLARKE A., FULFORD M. and RAINS M.: Nothing to hide - online database publication and the Silchester Town Life Project. In, The Digital Heritage of Archaeology, *Computer Applications and Quantitative Methods in Archaeology 2002*, Doerr, M., and Sarris, A., eds., pp. 401-404. Hellenic Ministry of Culture, Greece, 2003.

[DG00] DRAP P. and GRUSSENMEYER P.: A digital photogrammetric workstation on the web. *Journal of Photogrammetry and Remote Sensing* 55(1): 48-58, 2000.

Official publication of the International Society of Photogrammetry and Remote Sensing (ISPRS). ISSN 0924-2716.

[DDS*05] DRAP P., DURAND A., SEINTURIER J., VANNINI G., and NUCCIOTTI M.: Full XML documentation from Photogrammetric survey to 3D visualization. The case study of shawbak castle in Jordan. In, *The ISPRS International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXVI-5/C34, pp. 771-777, 2005. ISSN 1682-1750.

[FS97] FORTE M. and SILIOTTI A.: *Virtual Archaeology. Great Discoveries Brought to Life Through Virtual Reality. Foreword by Colin Renfrew,* Thames and Hudson, London, and Harry N.Abrams, New York, 1997.

[GG96] GILLINGS M. and GOODRICK G. T.: Sensuous and reflexive GIS: Exploring visualization and VRML. Internet Archaeology, Issue 1. Published Autumn 1996. `http://intarch.ac.uk/journal/issue1/gillings_index.html`

[GE04] GOODRICK G. and EARL G.: 2004 A manufactured past: virtual reality in archaeology. Internet Archaeology, Issue 15. Published in 2004. `http://intarch.ac.uk/journal/issue15/earl_index.html`

[HRR95] HEYWORTH M. P., ROSS S. and RICHARDS J. D.: Internet Archaeology: An international electronic journal for archaeology. *The Field Archaeologist* 24: 12-13, 1995.

[McA95] MCADAM E.: CD-ROM—The publishers' view. *The Field Archaeologist* 24: 17-18, 1995.

[Mef95] MEFFERT M.: Spatial relations in Roman Iron Age settlements in the Assendelver Polders, The Netherlands. In, *Archaeology and Geographical Information Systems: A European Perspective*. Lock, G., and Stani, Z., eds., pp. 287-299. London: Taylor and Francis, 1995.

[Pow91] POWLESLAND D. J.: From the trench to the bookshelf: Computer use at the Heslerton Parish Project. In, *Computing for Archaeologists*, Ross, S., Moffett, J., and Henderson, J., eds., pp. 155-169. Oxford: Oxford University Committee for Archaeology Monograph, No. 18, 1991.

[QBB95] QUESADA P., BAENA J. and BLASCO C.: An application of GIS to intra-site spatial analysis: The Iberian Iron Age cemetery at El Cigarralejo (Murcia, Spain). In, *Computer Applications and Quantitative Methods in Archaeology 1994*, Huggett, J., and Ryan, N., eds., pp. 137-146. Oxford: BAR International Series, No. 600, 1995.

[RS94] RAHTZ S. P. Q. and SINCLAIR P.: Multimedia information systems for East African archaeology. *Archeologia e Calcolatori* 5: 219-236, 1994.

[Ric98] RICHARDS J. D.: Recent Trends in Computer Applications in Archaeology. *Journal of Archaeological Research* 6:331-382, 1998. DOI 10.1023/A:1022879819064, URL `http://dx.doi.org/10.1023/A:1022879819064`

[Ric04] RICHARDS J. D.: Online Archives. Internet Archaeology, Issue 15. Published in 2004. `http://intarch.ac.uk/journal/issue15/richards_index.html`

[Rya95] RYAN N. S.: The excavation archive as hypertext document? In, *Computer Applications and Quantitative Methods in Archaeology 1994*, Huggett, J., and Ryan, N., eds., pp. 211-219. Oxford: BAR International Series, No. 600, 1995.

[Smi92] SMITH N.: An experiment in electronic exchange and publication of archaeological field data. In, *Computer Applications and Quantitative Methods in Archaeology 1991*, Lock, G., and Moffett, J., eds., pp. 49-57. Oxford: BAR International Series, No. 577, 1992.

[Wri06] WRIGHT H.: Archaeological Vector Graphics and SVG: A case study from Cricklade. Internet Archaeology, Issue 20. Published in 2006. `http://intarch.ac.uk/journal/issue20/wright_index.html`

The Processing of Laser Scan Data for the Analysis of Historic Structures in Ireland

M Murphy [1], E McGovern [1] and S Pavia [2]

[1] Dublin Institute of Technology

[2] Trinity College Dublin

Abstract

While laser scanners take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information. The testing and application of software platforms, which will manipulate the laser and image data, is necessary in order to identify the most efficient process for analysis of the laser survey data. The main aim of this paper is to present the findings to date of the processing of scan data of 17th and 18th century historic structures in Dublin. The process of reverse engineering is illustrated which generate orthographic plans, elevations and projections of the buildings to facilitate the analysis of the historic geometry, detail of building techniques and materials used.

Categories and Subject Descriptors J.6 COMPUTER-AIDED ENGINEERING Computer-aided design (CAD)

1. Introduction

Current research into automated recording and surveying techniques has been promoted by CIPA which is the International Scientific Committee for Documentation and Architectural Photogrammetry (CIPA) and is a joint committee set up by the International Council on Monuments and Sites (ICOMOS) and the International Society for Photogrammetry and Remote Sensing (ISPRS). The current research within CIPA promotes the development and application of laser scanning and digital photo-modelling for recording architectural heritage, which is emerging as an innovative and novel solution for automating the process of surveying and recording large amounts of architectural data.

2. Processing Survey Data – Further Research Requirements

A laser scan collects a large range of data representing three-dimensional co-ordinates, called "point cloud data"; (see figure 1a) proprietary software is then required to manipulate massive amounts of 3D data. While laser scanners take a few minutes to scan millions of accurate 3D points, there is enormous work in transporting this data into a 3D model containing useable information. Dedicated software programmes such as polyworks, Leica cloud-works for AutoCAD and RiScanpro have greatly improved the processing, manipulation and analysis of vector and image data from the point cloud. All of these software platforms have combined algorithms for triangulation and surfacing of the point cloud [REM 2003]. Recent research for improving point cloud data processing has been concerned with reducing the point cloud density without affecting the quality of geometric data and providing data management. High-resolution orto- photographs when combined with the point cloud geometry comprise of more detailed image and geometric information than the conventional data sets of solely the point cloud. The recent developments of plug-ins for existing point cloud-processing software by SANDIG3D and CITY-GRID result in the creation of 3D models from the point cloud and associated image data in addition to the ability to create planes and sections for exporting to other programmes. This data is imported or exported across platforms in the following file formats: ASCII, XML, AutoCAD, 3D Studio or VRML. Recently the research work of English Heritage Metric Survey team and the University of Newcastle upon Tyne have produced a set of guidelines for the use of laser scanning in cultural heritage [BB 2005]. These guidelines establish the best practice for scanning cultural heritage objects for the production of an accurate record. Further research is required in the area of processing of scan and image data across a range of software platforms, to facilitate the identification and analysis of the historic techniques and materials used in the creation of the historic structures.
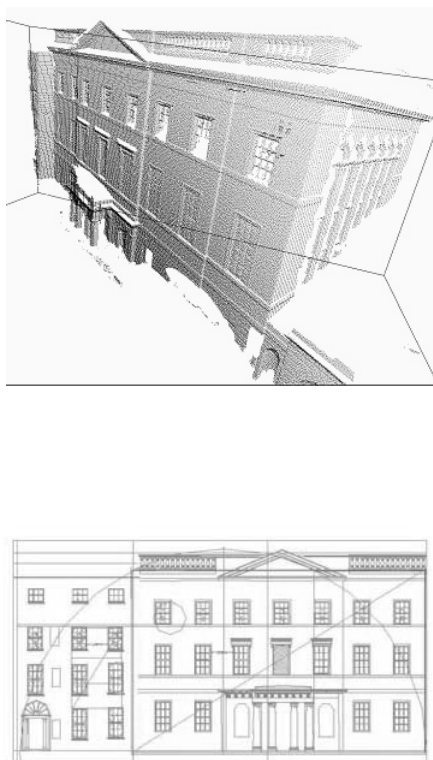
Figure 1:

- a. *Top -Example of Laser scan – point cloud of 18th Century Structure – Henrietta Street Dublin*

- b. *Bottom - Vector plot from Scan illustrating historic techniques used to establish façade.*

2.1 Data Collection

The following laser scan surveys were carried out in May and October 2006 using a Terrestrial Laser Scanner (*RIEGL* LMS-Z420i,) and were confined to the **front elevation façade and street fabric** of Henrietta Street and Capel Street 17th and 18th century Georgian streets in Dublin City. Data was collected using a terrestrial laser scanner combined with digital photo modelling. The terrestrial laser scanner consists of a laser ranger that is directed towards an object of interest by a dual-mirror system. The laser ranger measures distance, using the time-of-flight principle, based on diffuse reflection of a laser pulse from the surface of the object. The laser scanner is combined with a digital camera, which captures corresponding images to the scan, appropriate software is later used to combine the image and scan data. Digital photo modelling is used alongside the laser scanning, but can also be used for independent data collection where laser scanning is not appropriate. Digital photo modelling is the process of obtaining three-dimensional geometry

from a single or series of images. The recorded image of an object can be accompanied with measurements, which define a plane on this object [BHM 99]. Camera calibration is introduced to correct for the distortion of lenses, this image can then be correctly scaled to represent the geometry of the recorded object. Information concerning colour and texture of the object can also be provided.

**Figure 2:** *Point Cloud of Capel Street 18th century Façade*

2.2 Processing

The initial data obtained from the laser scan surveys is described as a point cloud (see figure 2.). Thousands of points are recorded per second, at centimetric grid intervals, across a scanned object to build up a dense 3D-point cloud representation of the object containing, typically, millions of points and requiring specialist software to process. The three dimensional points are in a common co-ordinated system that represents the spatial distribution of an object or site. It can contain also the RGB values for each point. The point cloud density depends on the relative distance between co-ordinates. The point cloud can represent a single or a number of small or large objects or these objects can form a part or whole of a building or site.

The large amount of data, which represents three-dimensional coordinates of an object, must be processed in order to abstract geometry, shape, measurements, and texture. RISCAN PRO the companion software to *RIEGL* 3D Scanners (LMS-Z210i, LMS-Z360i, and LMS-Z420) is used as the platform to process the point cloud survey data. The point cloud can be used as a visualisation tool before processing. The scan can be coloured from the images taken from the same position as the laser scanner. A three-dimensional model used for visualisation is the initial product of the laser scan survey, which allows for full orientation and the creation of walkthroughs of the coloured point cloud.

2.3 Data Cleaning and Sorting

The first stage involves cleaning the data to remove artefacts such as reflections of the scan through objects. As stated previously the point cloud is made up of millions of points and is not suitable for plotting vector orthographical projections or for material analysis. It is not usually possible to export the point cloud into AutoCAD or similar programmes because of the size of the data set. If the density of the point cloud is reduced and the data is cleaned of unnecessary points the data can be imported into Auto CAD for plotting. RiCube is available as an additional software platform for RiScan Pro to process point cloud data, to improve the accuracy and to reduce the amount of data. The point density on the object surface varies significantly due to the varying range to the surface during acquisition. Processing using RiCube is based on sorting all data in an octree structure followed by cleaning and sorting of the data. The processed point cloud can be exported in various formats including 3PF, ASCII, Autodesk DXF, VTK, and WRL as reduced data sets for processing in programmes such as AutoCAD.
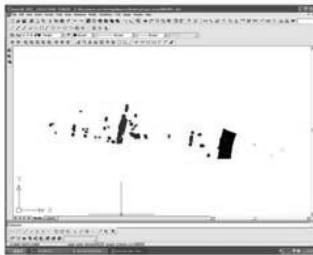

Clean scan in CAD

**Figure3:** *Cleaning Data Artefacts*

2.4 Meshing

The point cloud data does not carry the image data when exported; therefore, edges and texture are missing when the data appears in AutoCAD or similar programmes. The creation of a three dimensional ortho-image allows for all of the image and geometric data to be exported for further processing. This involves processing the point cloud through the following stages triangulation, meshing and texturing with the corresponding position image data and combining the colour textured scan with the corresponding geometric plane of the associated scan image [NDS 2005].

Triangulation is the initial process (see figure 4), which creates a surface on a point cloud; the created surface is made up by triangles connecting the data points. A 2D-Delaunay triangulation algorithm is used to triangulate the data. The Delaunay triangulation is computed from the 2D coordinates of the points mapped onto the computer screen. Triangulated data (also called "mesh") improves definition of the scanned object, (de-

fining objects, edges etc.). The function of smoothing modifies the surface structure of the polydata object by optimising the point data; decimation is a process to reduce the amount of polygons and points in the mesh (see figure 5).
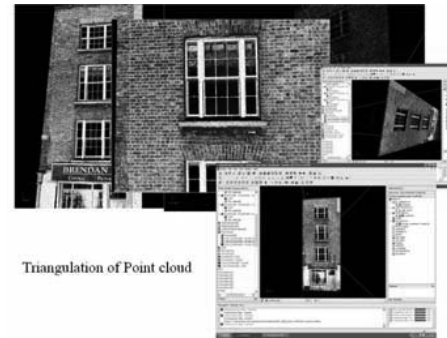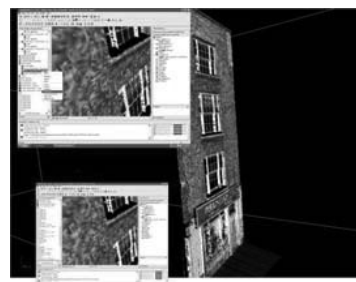

Triangulation of Point cloud
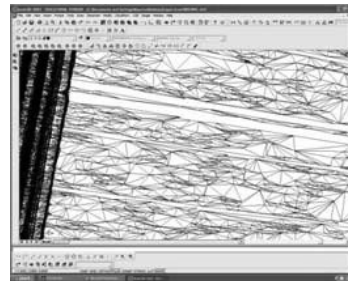
Triangulated point cloud in CAD

Figure 4: *Triangulation of Point Cloud*

Smoothing and Decimation

Figure 5: *Smoothing and Decimation*

2.5 Texturing

Additionally triangulated data can be textured (see figure 6) with the high-resolution images taken by the digital camera which leads to a nearly photo realistic model.

The texturing procedure takes every triangle and tries to find the optimal image to texture it. The image has to meet several criteria such as smallest distance between camera position and centre of a triangle, visibility of the triangle in the image (no other objects between camera position and triangle) and smallest angle of view. Different parts of the point cloud are triangulated until the desired result is reached.
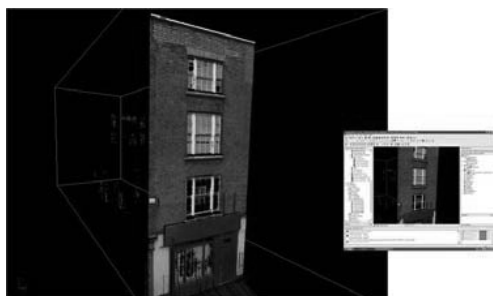
Texturing from image

Figure 6: *Texturing of point cloud from image*

2.6 Ortho-Image

The generation of the ortho-photo is based on the geometry information (scan data) and image data. Images taken by the camera can be distorted by the lens and must be rectified during the processing stage. The ortho-photo represents the data for a particular plane on the x, y, and z-axis; this can therefore represent elevation, plan, or section of an object [RIS 2006]. The planes can be created on the x-y, x-z and y-z axis.

Un-distorting image

Create plane for ortho image
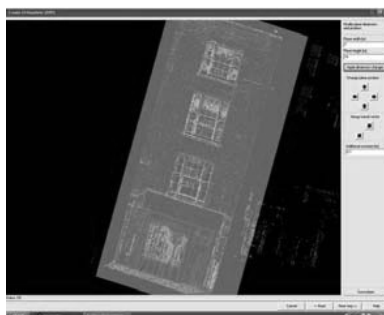
Position plane for ortho image

Figure 7: *Processing of image and textured point cloud data to create orto-image*

Near and far planes are established parallel to the projection plane (distances along the normal vector of the projection plane) between the projection plane and the near plane and the projection plane and the far plane.

Plot from point cloud and ortho image
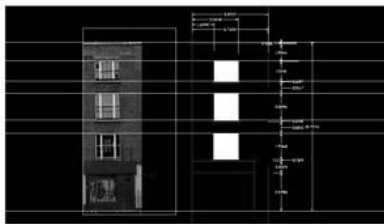
Plot from point cloud and ortho image

Plot from point cloud and ortho image

Figure 8: *Plotting of vectors from exported point cloud and ortho-image in AutoCAD*

2.7 Reverse Engineering

The final process of reverse engineering is illustrated in figure 8 above, the production of orthographic plans, elevations and projections of the buildings to facilitate the analysis of the historic geometry, detail of building techniques and materials used.

2.8 Conclusion

The following is a summary of the main process stages; initially the point cloud is triangulated and meshed, texturing the triangulated data with colour information from the high-resolution images then follows this. Defining vertical and horizontal planes on the textured scan to match image geometry is then

followed by the creation of the orthographic-image; this is a combination of the geometry of the point cloud and the colour and texture from the image. The elevation of the street facades can then be plotted using the point cloud and ortho-image in AutoCAD. The vector plot in figure 9 below was constructed using the above processPDF Generation.

References

[REM 2003] REMONDINO FABIO, *From point cloud to surface: The modeling and visualization problem*, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXIV-5/w10. International Workshop on Visualization and Animation of Reality-based 3d models, 24-28 February 2003, Tarasp-Vulpera, Switzerland.

[BMB 2005] BARBER D, MILLS J, BRYAN P

*Towards a standard specification for terrestrial laser scanning of cultural heritage ,*School of Civil Engineering and Geosciences, University of Newcastle upon Tyne, Newcastle upon Tyne and English Heritage Metric Survey Team, English Heritage, , 2005, York.

[BHM 99] Boehler, W., HEINZ, G., MARBS, A., 1999, Documentation - Surveying - Photogrammetry, W. Boehler, G. Heinz CIPA International Symposium, October 3-6, 1999, Recife/Olinda - PE - Brazil

[NDS 2005]W. NEUBAUER, M. DONEUSB , N. STUDNICKA, J. RIEGL, Combined high resolution laser scanning and photogrammetrical documentation of the pyramids at Giza, CIPA 2005 XX International Symposium, 26 September – 01 October, 2005, Torino, Italy.

[RIS 2006] RiScan Pro, 2006, Operating and Processing Software, Riegl, Austria, http://www.riegl.com/index.htm

Low Cost Integrated Spatial Information System For Polish Cultural Heritage Promotion And Preservation

J. Nowak[1] and M. Happach[2]

[1]Faculty of Geodesy and Cartography, Warsaw University of Technology, Poland
[2]Faculty of Architecture, Warsaw University of Technology, Poland

Abstract

This paper (and associated poster) summarizes the findings of our on-going research project on a planned Polish Cultural Heritage Promotion and Preservation Spatial Information System. The authors proposed to utilize the advantages of a GIS together with the power of a geo-browser and visual information in order to support the promotion and preservation of Polish cultural heritage properties. These properties specifically include unique architectural, engineering and natural heritage elements. As part of the project, legal, organizational, technical, and social issues have already been analysed and although the results are presented in a Polish context, most of the remarks can be applied to other countries or regions. The authors approach foresees the use of the publicly available geo-browsers and community-based participatory data collection in order to enrich the public knowledge and understanding of the basic matters concerning their cultural heritage.

Categories and Subject Descriptors (according to ACM CCS): J.5 [Computer Applications]: Arts And Humanities H.5.1 [Information Interfaces And Presentation]: Multimedia Information Systems H.3.5 [Information Storage And Retrieval]: Online Information Services

1. Rationale

Cultural heritage preservation is one of the strategic aims listed in the Environment and Sustainable Development European Policy Programme. The recording and documentation of cultural heritage provides the world with a historical record of mankind's past achievements. It permits research on the development of mankind and its historical and cultural roots and the possibility to restore, reconstruct or archive the data for future reference.

Obtaining the full professional documentation of a historical building, satisfying official technical specifications, requires groups of qualified people, sophisticated instruments, money and time. The result is a collection of data of different types: geodetic measurements, sketches, cross-sections, drawings, pictures, maps, text, etc. Such complex and precise documentation is definitely useful for many applications including the conservation or restoration of the item (if needed). However, due to the increasing damages to monuments (vandalism, armed and political conflicts, natural disasters or atmospheric pollution) it is essential to record existing items for future generations as quickly as possi-

ble. In such circumstances the classical documentation techniques are not the best solution due to time and resource constraints.And yet, even if the number of architectural heritage sites is recorded, the access to the data is complicated because , taking into consideration the Polish context, the documentation mainly exists in the analogue form (i.e. paper) and the search or browse services are not available even offline.

Following the professional and enthusiasts interests in cultural heritage and visual information, and realizing the ability of computer technology to provide effective, cost-efficient data processing and management capabilities, we began the research project on 'The Usage Of Satellite, Aerial And Amateur Images And Geographic Information Systems To Preserve And Promote The Polish Cultural Heritage with an emphasison architectural, engineering and natural heritage sites.

The main challenges of this research are twofold. With regard to images, the study encompasses their photogrammetric elaboration focusing on amateur photographs taken by means of a non-metric camera with unknown sets of

parameters (some research have been already shown in [HNN03, NN05, NN01]). In parallel, the study follows the currently expanding techniques to envisage the data, and the methods of creating VR and AR models are examined. Whereas with regard to spatial information systems, our aim is to design such an effective tool that is able to manage and disseminate huge volumes of heterogeneous information (alpha-numerical data, geometrical data, images, VR and AR models), and ideally serves as the Polish Cultural Heritage Information System. The foreseen system is going to be a freely accessed system that the public can refer to in the context of promotion and preservation of architectural, engineering and natural heritage sites. Thus the survey on the requirements of its potential users is foreseen as a part of the research.

2. State-of-the-art

In the scope of protecting cultural heritage, Polish law focuses on the regulation of legal aspects concerning monuments, museums and archives. Acts and regulations provide for a legal framework for their protection, functioning, organization and public access. The basic act of law regulating the issue of protection of cultural heritage in Poland is the Act from the 23 July, 2003 (Polish Journal of Law 03.162.1568) on the protection and care of monuments (hereinafter referred to as the 'Act'). The Act provides compliance of Polish law with the law of the European Union.

Based on this Act, a monument must have the following characteristics: (a) be an immovable estate or a movable thing, their part or collection, (b) be the creation of a person or be connected with human activities, (c) attest to a past era or past events, (d) its preservation must be in the public interest because of its historic, artistic or scientific value. The status of a monument and therefore protection granted by law (by virtue of the law) possess all movables and immovables which fulfil the above mentioned requirements [Gol04, Pru04].

The Act provides the methods for the protection of monuments as follows: entrance into the register of monuments, awarding historic monument status, creation of a cultural park, and conferring protection in the local master plan. Registers of monuments are kept by Voivodeship Conservators of Monuments that are, together with the General Conservator of Monuments, the authorities specifically created for the protection of cultural heritage properties (a voivodeship has been a second-level administrative unit in Poland since the 14th century, in the EU Nomenclature of Territorial Units for Statistics it is referred as NUTS2). Monuments are entered into the register on the basis of a decision of the Voivodeship Conservator of Monuments issued ex officio or on the motion of the owner.

It should be noted, that all monuments regardless whether they were entered into the register of monuments or not, should be entered in the so-called records of monuments but such entrance does not guarantee protection. Records of monuments are only a database of monuments and a basis on which local self-government bodies create programs for the protection of monuments.

The above described registers and records of monuments are open for public access. For natural persons and institutions access is free of charge. In Voivodeship Offices for Monuments Protection each interested person may find out which of the monuments situated on the territory of a voivodeship has been entered into the register of monuments and obtain a certificate of such an entrance. The main problem is the access to such information. The Voivodeships Conservators of Monuments are unlikely to create electronic versions of registers of monuments and publish them through the Internet.

3. Remember to take a picture

How can we increase the access to data? How can we manage complex data effectively? How can we speed up data collection? The authors of this paper were asking themselves such questions in the context of Polish cultural heritage promotion and preservation and specifically those with unique architectural, engineering and natural heritage elements.

Cultural heritage information has important geographic aspects, and therefore the authors chose to use Geographical Information Systems (GIS) to provide effective, cost-efficient heterogeneous data processing and management capabilities. Cultural mapping has also been recognized by UNESCO as a crucial tool and technique in preserving the world's cultural assets.

The question about data capture was still pending when the improvements in technology and the slump in prices of amateur digital photographic cameras provided the best reasons to use this technology. The advantage of imaging techniques is that they are permanent records, which can be the subject to further modelling and/or processing, providing detailed maps (facades included), or cross-sections, and 3D models or animations of the represented objects. The photographs that provide the historical record of mankind's achievements enable individuals to experience the beauty and wonder of the monuments and sites of the past without actually visiting them. As a result of computer visualizations, sightseeing of historical sites is possible even when they are in poor condition and in danger of further damage, or no longer exist.

Realizing that some works of art and historical monuments cannot wait for a professional heritage recorder, authors think that amateur pictures are able to serve as the rough data archive, and propose seizing the advantage of the growing popularity of taking pictures (another good cultural behaviour).

4. Public cultural heritage awareness

Poland is characterized with rich culture and natural and cultural heritage. Interesting occurrences of the culture and the natural and cultural heritage increase the potential of the development of the country, e.g.: heritage tourism, agricultural tourism or eco-tourism, to name only a few. However, it is necessary that the society in general is aware of the cultural heritage. This refers both to the nation, and the local or regional communities. The inquiries effected among students and inhabitants of Warsaw and its suburbs showed that the average inhabitant does not know about the monuments in their area or region (excluding very famous ones), although most of them declare an emotional identification with the region. The care of monuments in Poland today seems to be focused on the protection of large prestigious monuments such as cathedrals, castles, palaces, etc. even though the law does not specify this directly. The majority of people are not aware of the fact that many ordinary buildings like crosses and wayside chapels, houses, bridges, mills, cemeteries, etc are also being preserved. The public awareness with regards to the legal commitments of the owners of buildings with historic and cultural value is also very low. The sad conclusion is that our great cultural potential and the modern policies that are in line with European Union policies with respect to cultural heritage protection, as well as the laws, are partially spoiled.

Public cultural heritage awareness is a fundamental contribution to heritage preservation. The authors approach (namely SIS for Polish CH Promotion and Preservation) is driven by this issue. We are looking for a successful formula for awareness raising. The knowledge of the neighbourhood (on the regional scale) and the country (on the national scale) in the context of monuments helps the citizens better understand the basic matters concerning cultural heritage. Our idea is to bring the public into closer contact with historic buildings and consequently,enrich their understanding of the basic matters concerning cultural heritage.

5. Neogeography

Last year Google opened its mapping service to the public so that hobbyists could use the maps on their own Web pages. The recent appearance of such geo-browsers, i.e. Google Maps and subsequently Google Earth, NASA World Wind, Virtual Earth by ESRI, etc. stimulate a revolution in electronic cartography. The world is so astonished of the second life mash-ups [Paf06] that even they are referred to as 'neogeography' [Jac06]. It is a complementary approach compared to the traditional, geodetic based, Geographic Information Systems, and subsequent Spatial Data Infrastructures (more details can be found in [Gou06]). The indispensable advantages of open source applications,and the unbelievable great success of Google Earth, are currently evoking some changes in our project. Making use of an application based on the Google engine will make our system cheaper (no need to buy reference/geodetic data). Moreover the application based on the Google Map/Local/Earth, encompasses the community-based participatory data collection and thus helps us reach our project goal, that is cultural heritage awareness raising.

6. Conclusions

This paper and the associated poster, present the up-to-date findings of our on-going project on the planned Polish Cultural Heritage Information System specifically focused on the unique architectural, engineering and natural heritage elements. Our preliminary analysis of some legal, organizational, and technical issues, as well as the programmes of the protection of cultural heritage objects and some interviews, showed the great need for greater public cultural heritage awareness. Being driven by this issue, which is said to be a fundamental contribution to heritage preservation, the authors are looking for a successful formula for awareness raising. Thus the foreseen system is to be an effective tool to manage, visualise and disseminate heterogeneous data provided mainly through community-based participatory data collection.The latest idea is to use open source applications i.e. one of the widely known geo-browsers.

References

[Gol04] GOLAT R.: *Ustawa o ochronie zabytkow i opiece nad zabytkami. Komentarz.* Zakamycze, 2004. 2

[Gou06] GOULD M.: The high and low road. spatial data infrastructure is evolving as a convergence: Different approaches to reach the same goal. *Geo-connexion magazine 4* (2006). 3

[HNN03] HAPPACH M., NOWAK E., NOWAK J.: Amateur photographic recording used to rescue works of cultural heritage. In *Geographical Information Systems - Interdisciplinary Aspects. Abstract book of International Conference and Exhibition GIS Silesia 2003* (2003), Gajos M., (Ed.). 2

[Jac06] JACKSON J.: ′neogeography′ blends blogs with online maps. *National Geographic 4* (2006). 3

[NN01] NOWAK E., NOWAK J.: Building shape reconstruction on the basis of amateur photographs. In *International Conference GIS Polonia 2001* (2001), Nowak J., (Ed.). 2

[NN05] NOWAK E., NOWAK J.: Parametric modelling of amateur digital photographic cameras and their images. In *Research reports of Wroclaw University of Technology, no 114/45, XIX JSG* (2005). 2

[Paf06] PAFFENDORF J.: Google earth and second life mashups: Virtual worlds meet geospace. In *The 2006 Where 2.0 Conference, San Jose, California* (2006). 3

[Pru04] PRUSZYNSKI J.: *Dziedzictwo kultury Polski. Jego straty i ochrona prawna.* Zakamycze, 2004. 2

Computer-Assisted Estimation of the Original Shape of a Japanese Ancient Tomb Mound Based on Its Present Contour Map

Kazumasa Ozawa

Department of Engineering Informatics,
Osaka Electro-Communication University, Neyagawa, Osaka, Japan

Abstract

This paper presents a support system for estimation of the original shape of a Japanese ancient tomb mound, termed Keyhole-shaped tomb mound, based on its present contour map. Using the system, we can make two-dimensional matching of a template and a contour map of the tomb mound. Between 4th and 6th century, Keyhole tomb mounds were built all over the country, of which shapes have been playing a key role in studying the Japanese ancient regime. More than 5000 mounds still remain across the country, most of which are, more or less, deformed for many centuries. The template is keyhole-shaped and superposed on a contour map, which can be controlled by referring to contour lines so as to be a reasonable shape that is likely to be the original shape. This paper also presents some applications of our system and related discussions.

1. Introduction

Most of ancient monuments are deformed from their original shapes for a long time. Generally stone-made monuments are scarcely deformed excepting violent artificial destruction. In contrast, soil-made monuments such as Japanese ancient tomb mounds are often heavily damaged even by natural and slight artificial destruction. The peculiar shapes characterize the Japanese ancient tomb mounds; they have been called *Keyhole shaped tomb mounds* (See Fig.1). Between 4th and 6th century, Keyhole tomb mounds were built all over the country, of which shapes have been classified into several types that play a key role in studying the Japanese ancient regime.

More than 5000 mounds still remain across the country, most of which are more or less deformed for about fifteen centuries. A number of Keyhole tomb mounds have been surveyed and their present shapes have been published as contour maps (See Fig.2). A type of archaeological studies has been focused on estimating the original shape based on a given contour map. It can be regarded as a pattern recognition problem that we estimate the original keyhole shape from a contour map that represents the present deformed shape of a tomb mound. In fact, such an estimating task mostly is going on in the process of trials and errors; such iteration as once drawing a circle and lines on the contour map and next eliminating them is going on until a drawn shape can be recognized as a proper one representing the original shape of the mound.

A support system probably helps improve such inefficient estimating task. The support system presented in this paper provides a keyhole shaped template that can be superposed on a contour map. The shape of the template can be controlled using a mouse and keyboard, while it is always keeping the keyhole shape.

Figure 1: *The biggest Keyhole tomb mound built in the Early 5th century; the Mausoleum of the Emperor Nintoku. The mound in the moat is about 500 meters long.*

(a)   (b)

(c)   (d)
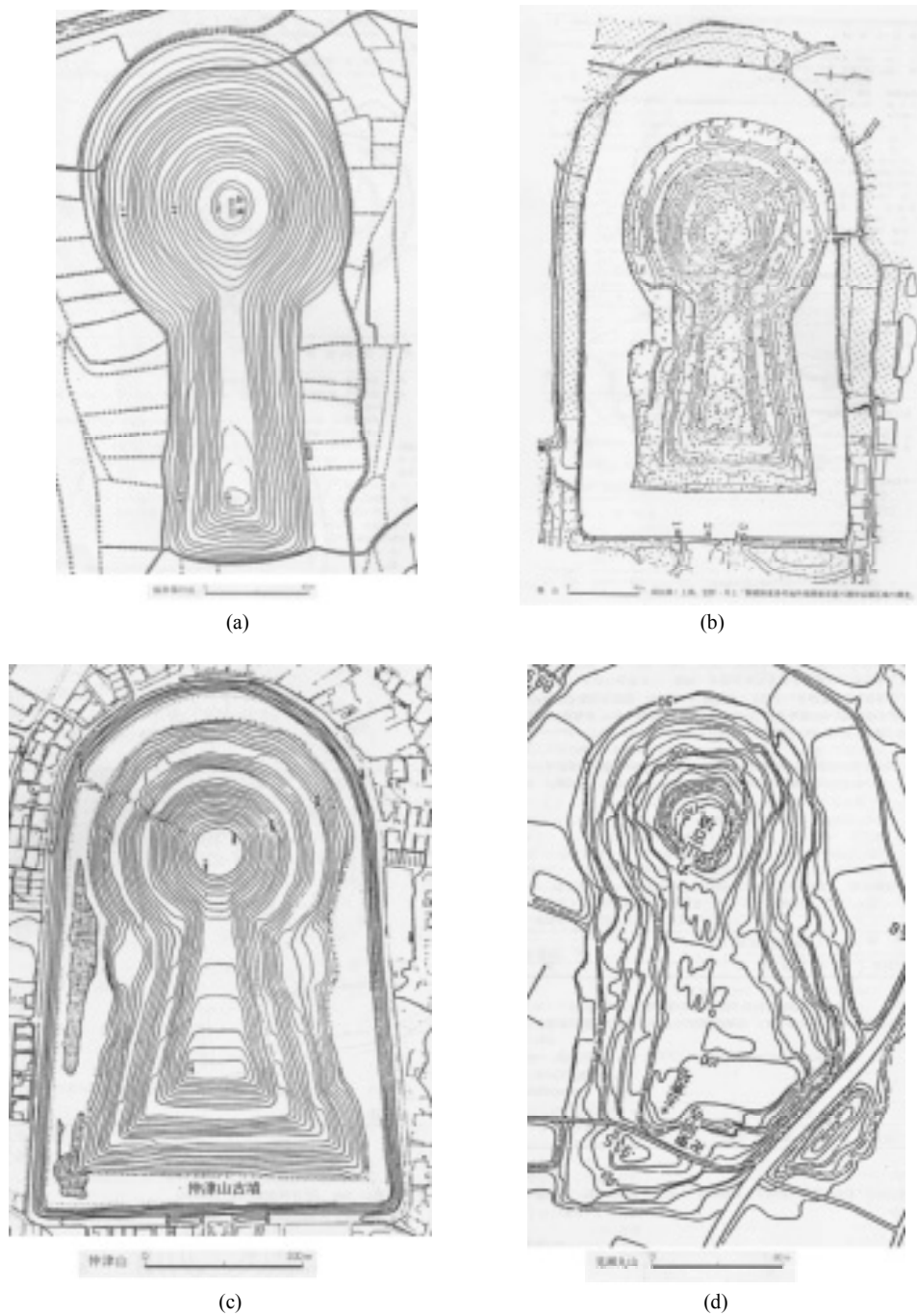
Figure 2: *Examples of contour maps of Keyhole tomb mounds.* (a) *Early 4c.*   (b) *Late 4c.*   (c) *Middle 5c.*   (d) *Early 6c.*

2.   System [O05]

Our aim has been placed on developing a system to support pattern recognition for estimating the original shape of a tomb mound from its contour map. The central idea for developing our system is introduction of the keyhole shaped template (See Fig, 3), which comes from a supposition that every original shape of the tomb mound should geometrically be keyhole shaped; i.e. it is formed with a circle and straight lines.

the tomb mound: From this, it can be computed how long each dimension of the mound is. The four dimensions referred in (5) mean the length of the mound *a*, diameter of the round part *b*, width of the neck *c*, and width of the square part *d* as shown in Fig.4. Our system provides real values for {*a*, *b*, *c*, *d*} and also the three ratios {*a*/*b*, *c*/*b*, *d*/*b*} based on the finally fixed template.

Figure 4: *The four dimensions*

3. Similarity relation [O00]

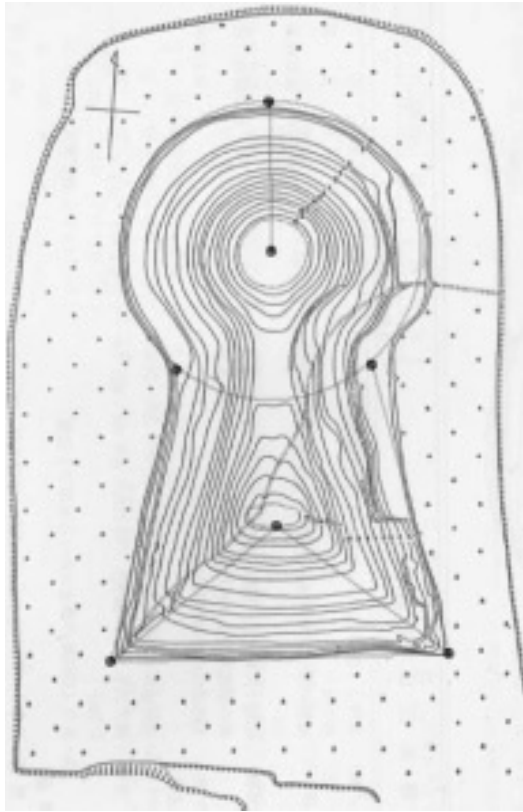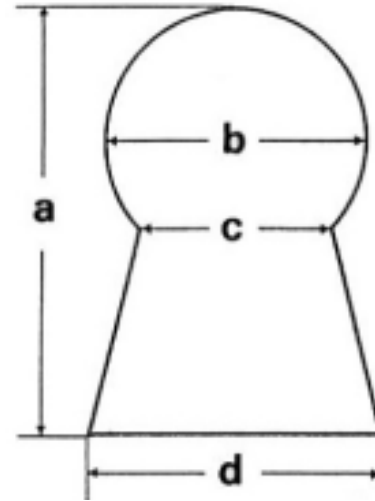The Keyhole tomb mounds have so far been classified into several types in different ways[U96]. A well-known approach to classification has been based on similarities between shapes of the mounds. An archaeological supposition is that if plans of two tomb mounds are similar, they might be built in the same age and buried persons might also politically be intimate. Our system would be useful for such shape-oriented classification problem: The three ratios {*a*/*b*, *c*/*b*, *d*/*b*} form a metric space where we can analyze similarity relation between the tomb mounds. In fact, some interesting results have been obtained from our analysis in the metric space:

Fig.5 shows distribution of 28 tomb mounds in the metric space. Where the figure presents projection of their three dimensional distribution in the space into two planes; i.e. (*c*/*b*, *d*/*b*) and (*c*/*b*, *a*/*b*) planes. It should be noted that distribution of the mounds in the first plane clearly shows a temporal sequence of the tomb mounds from the Early to the Late Ancient Tomb Period. Where the Middle and Late tombs situate in the two striped zones, respectively.

4. Computer graphic restoration

A number of the Keyhole tomb mounds were destroyed due to rapid urbanization during the latest hundred years. Among them, there existed some fortunate mounds that were archaeologically surveyed prior to their destruction, of which contour maps and related knowledge were published. In this case, we can estimate the original shape of a mound using our system as well as existing Keyhole tomb mounds.

Figure 3: *A green-colored keyhole shaped template superposed on a contour map. Each of red points can be dragged by a mouse for changing the keyhole shape; moving, magnifying or reducing, or rotating the whole shape, or partially changing the shape.*

As far as well-preserved mounds such as Fig.2 (c) are concerned, it is not so difficult to estimate their original shapes. By contrast, we have so many contour maps such as (d), which need much more effort to estimate their original shapes. In such cases, the template has been very helpful for our pattern recognition works. A typical template matching procedure using our system is as follows:

Procedure
(1) Display a contour map taken by a scanner.
(2) Input the scale information written in the map.
(3) Superpose the template.
(4) Control the template using a mouse and keyboard, seeking good fit to the whole of contour lines. Fix the template when it is recognized to be best for description of the original shape of the mound.
(5) Store the estimated values of the *four dimensions* and the displaying image.

Where (2) is needed for conversion of a pixel size on the display into its corresponding real size in the area including
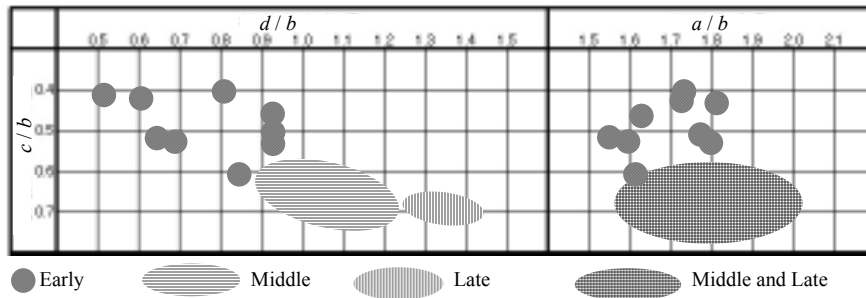
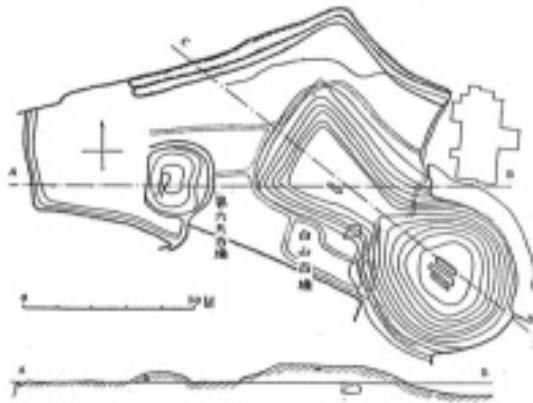Figure 5: *Distribution of the tomb mounds in the metric space.*

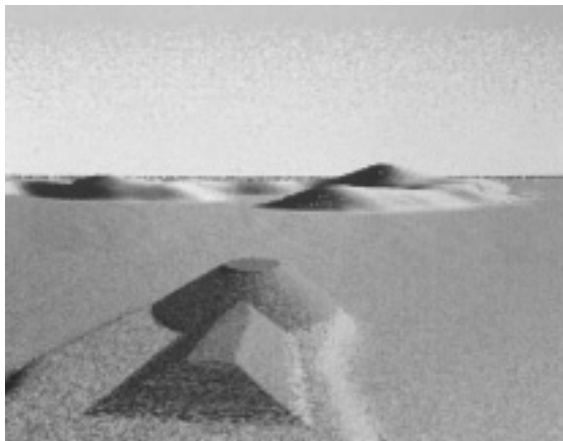Figure 6: *Contour map of Hakusan tomb.*

Figure 7: *Computer graphic image of Hakusan tomb*

Fig.6 shows the contour map of a destroyed and vanished big Keyhole tomb mound, named *Hakusan tomb*, located in Kanagawa Prefecture near Tokyo, which has archaeologically been dated to be in the Early Ancient Tomb Period (around early 4th century). It was destroyed in 1940s for construction of a building. Using the system, we obtain the three ratios of Hakusan tomb; i.e. $a/b = 1.81$, $c/b = 0.49$ and $d/b = 0.81$. This shows that the tomb situates within a zone where the nine early tombs distribute in the metric space (See Fig.5).

Fig.7 shows a computer graphic restoration of Hakusan tomb. To generate this image, we employed the estimated original shape as the floor plan of the mound. In addition, we also employed much archaeological knowledge for modeling its three dimensional shape; i.e. description of findings in the survey report, empirical or statistical knowledge about existing Keyhole tomb mounds and terrain data around the tomb.

5.   Conclusion

This paper describes a view of our support system for estimating the original shape of a Keyhole tomb mound. As previously described, our system helps *excavate* the original shape of a mound buried in contour lines. This paper also mentions two applications based on the estimated four dimensions of the tomb mound: First, similarity relation between shapes of the mounds is discussed in terms of the metric space formed by the three ratios. Next, an example of computer graphic restoration of a destroyed tomb mound is presented. Since we have treated a small number of the tomb mounds using the system, then our future task will be concerned with analyses on the other many Keyhole tomb mounds all over the country.

References

[U96] Ueda H.: *The Keyhole Tombs*, Gakuseisha 1996 (in Japanese).

[O05] Ozawa K.: Estimation of the Original Plan of a Japanese Ancient Tomb Mound from Its Present Dimensions, IPSJ SIG Technical Reports, 2005-CH-65 (Jan. 2005), pp.41-48 (in Japanese).

[O00] Ozawa K.: A Dating Chart for Quantitative Chronology of Japanese Ancient Tombs – A Consideration on a Tentative Draft -, IPSJ SIG Technical Reports, 2000-CH-45 (Jan. 2000), pp.17-24 (in Japanese).

Combining GIS and 3D Graphics to form a tool to empower digital visualizations on Cultural Heritage

A.Papakonstantinou[1], V. Christodoulou[2,3] and N.Soulakellis[1]

[1]Univesity of the Aegean Dept of Geography
[2]Foundation of the Hellenic World, Athens, Greece
[3]Department of Cultural Technology & Communication, Aegean University, Mytilene, Greece

Abstract

The main aim of this paper is to provide a methodology for the integration of Geographical Information Systems (GIS) and 3D Graphic Software (3DGS) in order to form a useful tool for the construction of 3D Landscape models. More specifically the combination of spatial information that can be recovered in great detail for landscape from GIS and its adaptation to 3DGS has the objective of the construction of 3D Landscape models. These models can reproduce in a very precise and detailed manner the topography of the landscape. Using digital geographical data via GIS, three Digital Elevation Models (DEMs) have been created which after necessary adaptations have been transferred into 3DGS. We will study the recovery of geographical data and the construction of 3D landscapes of small, medium and large scales. The processes and methodology of integrating the two technologies will be presented and analyzed reaching conclusions for sizes, formats but also the level of detail of the used files which aims at the optimization of the final result. Emphasis is given to their suitability according to the objective of their visualization but also the sources, demands and limitations that apply in each case. Finally, comments are made on the abilities that researchers obtain from the use of this integrated methodology for the documentation and description of sites of archaeological interest.

Categories and Subject Descriptors (according to ACM CCS): I.6.5 [Model Development]: Modeling methodologies

1. Introduction

The term digital representations of landscapes as used in this paper, is reported in the best and most precise representation of earth surface via DEMs. These models are "mathematically determined, 3D visual representation structures of ground surface, elements and phenomena of nature and society" [Ban01].

Subject in this work is the use of data that emanate from Geographical Information Systems (GIS) and its adaptation in 3D Graphic Software (3DGS), aiming at the most reliable study and digital representation of landscapes and areas with archaeological importance.

This paper treats the creation of DEM of landscapes with archaeological importance. More precisely computers and suitable software are used for the research and the organisation of geographic and spatial information, aiming to attribute to a 3D model and to be presented as picture or a concatenation of pictures developing into an animation. Below all the aspects of manufactured DEM will be given using the more modern cartographic procedures and will stressing their appropriateness depending on the aim that will serve their visualisation but also the resources that are required and the restrictions that are placed in every case.

2. Study Areas

It becomes explicit through the definitions of UNESCO that the surface of earth it constitutes a very important piece of cultural heritage when it does have on it or under it archaeological interest [BSS*001]. We observe therefore the direct relation of cultural heritage with the archaeological landscapes as well as the cross-correlation of each archaeological research with the space that these occupy. Thus the study areas have each their own individual importance as this derives from the role in the history that each one of them presents.

The choice of the most appropriate study areas was based on two criteria:

1. To constitute important cultural "monument" according to the definition of UNESCO (Roe00) and simultaneously

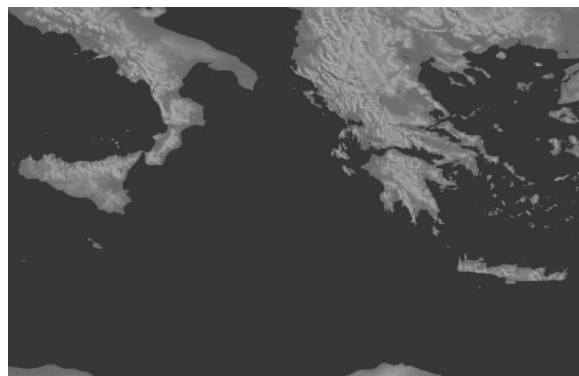2. The availability of digital cartographic data.

Figure 1: *Study Areas.*

Based on the above criteria the following three geographical areas were selected (see Figure 1):

1. The regions which crossed the Athenians at the Sicily expedition witch covers

a. South East Mediterranean sea and

b. The island of Sicily.

2. As well as the region of Petrified Forest of Sigri located in Lesvos island.

3. Data and Methodology

The challenge that is faced by the present work is the finding of the most optimal way for the unification of two technologies for GIS and 3DGS in order to serve the culture with 3D landscape representations.

An effort was made in order to find a common axis in which the two categories of programs would collaborate with the most efficient manner. Thus our methodological approach was separated in two stages. The first one has as aim the unification of commercial parcels of GIS with the 3DGS while the second one has as aim the exploitation of the capabilities offered by open source software for the management of geographic information.

3.1. Available data

The three areas selected for the implementation of the methodology and were separated into three scales small, medium and large.

After the search and selection of the cartographic datasets

that would attribute with the required precision for each of the three study areas the following are available and selected:

For the area of Southern Greece and southern Italy and also for the island of Sicily:

- Contour lines (primary contour interval was 1,000 feet (305 meters), and supplemental contours at an interval of 250 feet (76 meters) are shown in areas below 1,000 feet in elevation) from ESRIs DCW (Digital Chart of the World) and

- Gtopo30 DEM (USGS Global 30 Arc Second Elevation Data Set)

- Raster with pixel analysis 100 x 100 m from the Cartography laboratory, Department of Geography of the University Aegean.

For the area of the Petrified Forest in Sigri of Mytilini:

- Contour lines (4 meters) witch created from digitation of map with scale 1:5000.
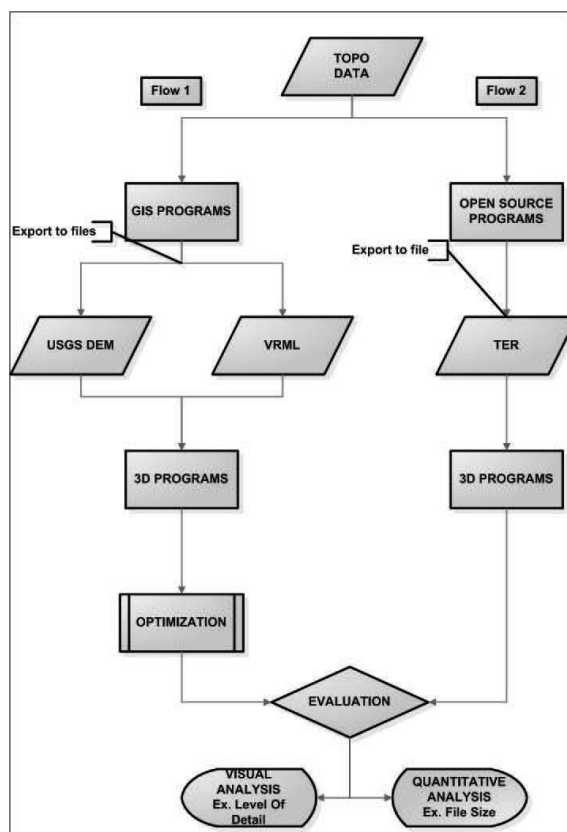
3.2. Methodology

Figure 2: *Methodology Flow.*

The creation of DEM existed having as basic condition

that these would have to have suitable format aiming at their import in the 3DGS, knowing that we would use the following software:

- 3d Studio MAX (Discreet)

- Cinema 4D (MAXON)

Much effort was given to find the common axis in which the two categories of 3DGS and GIS would collaborate more easily. Thus the main restriction witch was the compatibility of files between the software's became the initial object of study for the convergence of the two technologies.

Thus our methodological approach was separated in two key routes.

Stage-1: It had as aim the unification of commercial parcels of GIS with the 3DGPS see in Figure-2 Flow-1).

Stage-2: The unification open source software for the management of geographic-spatial information with the 3DGS (see Figure-2, Flow-2)

3.3. Methodology (Stage-1)

In the first case the methodology had as aim the use of GIS and more specifically the commercial parcel of ESRI ArcGis 8.1 that has to create the possibility with the help of extensions using data of spatial information for 3D-representations of landscapes.

After study of file formats with which ArcGis 8.1 attributed the geographic-spatial data in form of files that were recognized by the 3DGS we led to conclusion "That only the files with extensions wrl and dem (USGS) are what can constitute common base and for the two computations". Therefore our efforts had as aim the final file where the result from ArcGis 8.1 should have extensions dem or wrl.

The DEM files as these are produced by GIS in both ways (wrl and USGS dem) contain the spatial information which describes the landscape, but the number of polygons that constitute them was extremely necessary and essential to give the desirable scale form of surface for the study areas. The results of representation in the areas of southern Greece and southern Italy and also for the island of Sicily were not the appropriate (Figure 3)

Thus we tried to optimize the 3D models in order to take the desirable level of detail in the 3D representations.

In the theory of 3D graphics there are a number of procedures for changing the topology of a model in order to create smother surfaces. These are Optimization, Subdivision, Triangulation and Untriangulation. But there is a question of "Which one is the most appropriate?"

For each study the desirable result differs so there is a need of making different combinations in each case. In our study at first combination of "Subdivision" and "Triangulation" was made to take the desirable level of detail in the 3D
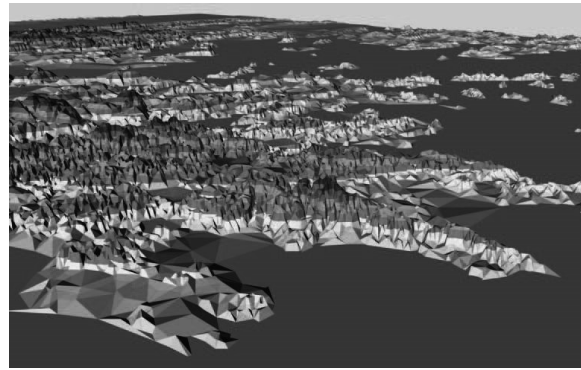
Figure 3: *DEM file produced from GIS.*

models. Final the procedure of "Optimization" was made in order to create the better possible representation and to avoid the creation of non smooth surfaces.

3.4. Methodology (Stage-2)

In the second case the followed methodology had as an aim the use of open source software for the management of geographic-spatial on creation of DEM and their import in the 3DGS.

Therefore by study of available programs and placing as a restriction the solution and confrontation of common spatial data, but also his direct collaboration with the 3DGS. From all these open source programs "Terragen" was selected. This program has the possibility of combining spatial data in order to create high precision DEMs which have the appropriate format to import them directly in 3DGS.

The choice and the use of "Terragen" were also combined and with the use of three plugins as well as for the Cinema4D and 3D-Max. It should be reported that all this are open source programs and are free of charge on the internet.

It should be explicit that with the combined use of these programs we achieve with a big precision the creation of 3D landscape representations of the surface of the earth.

3.5. Evaluation

After the end of each methodology and having manufactures DEM under each study of regions took place evaluation of the results. Their import in the 3DGS had restrictions that they had as main axes:

- The optimisation of DEM (Levels of detail of representation)

- The "economy" in the manufacture of models (Number of polygons in connection with size of files)

- The use and the forms of representation.

The evaluation took place taking into consideration quantitative and by qualitative characteristics produced DEM.

Thus they would have to fill the specifications that had been placed by

- Having the right geographic scale.

- Find itself in the desirable suitable level of detail.

- Have the right relation of detail and size for files.

4. Results and discussion

In the previous sections were given the methodology of creation of DEM from the GIS and the storage of their information in forms of data that are direct recognisable from the 3DGS. Knowing the format the files that are common between the two categories of programs and through the prism of two different approaches should the process be evaluated according to the restrictions had been placed.

4.1. Stage-1

The DEM files as these are produced by GIS contain the geographic information, but the number of polygons that constitute is extremely necessary and essential so that they give the most desirable scale form of surface for the study areas. The result can be desirable in order to cover the needs of representation in the GIS, while in the 3DGS usually corresponds in one simply acceptable DEM (Figure 4).
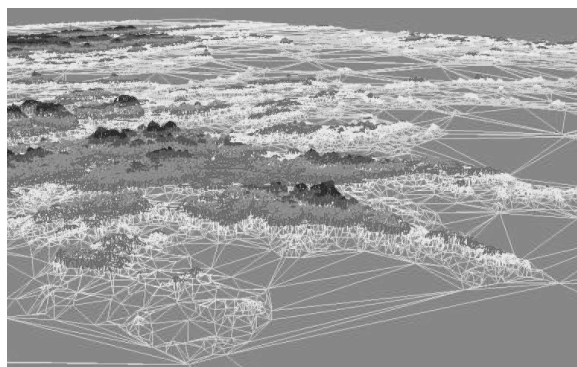

Figure 4: *Part of Greece without optimization.*

As way should be found therefore to increased the number of polygons of DEM in order for the morphology of surfaces that represent to attributed with smoother fluctuations. According to theory of 3D graphics in which the functionality of 3DGS is based on, exist a lot of techniques to optimise the DEM by changing their topology. With their use is possible the increase the number of polygons in a 3D model but also the elaboration of his structure. These have as result the DEM and every 3D model to acquiring the desirable for each case level of detail.

DEM of Mediterranean	Before optimize	After optimize	percent
No of Polygons	517.073	1.035.933	200,3
No of Points	1.646.082	11.224.127	681,87
File size	27.373 kb	293.401 kb	1.071,9
DEM Sicily	Before optimize	After optimize	percent
No of Polygons	220.492	3.012.683	1.366
No of Points	692.050	3.144.617	454
File size	11.559 kb	83.928 kb	726

Table 1: *Comparison of DEM polygons, points and file size, before and afterward the optimization*

Combination of the above processes was followed for all DEMs that were made from the GIS while at their modification and their trials of presentation, the initial results were not expected.

It should be reported that at the optimisation of DEM aiming at the better possible approach the study areas was observed a dramatic increase in storage space but also in the time that they needed for their data processing. This was owed in the information size that they had the DEMs because had been increased dramatically the number of polygons that they are constituted (Figure 5).
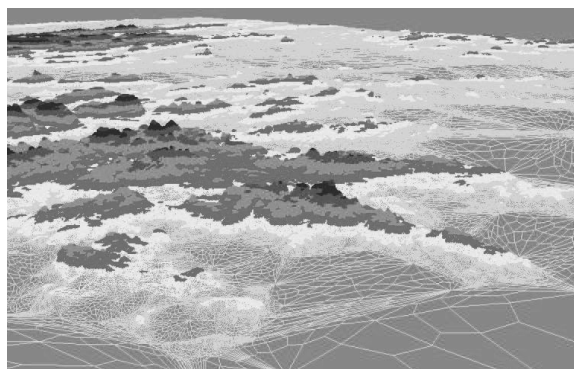
Figure 5: *Part of Greece with optimization.*

Characteristically are the results and the comparison of DEM polygons, points and file size, of South East Mediterranean sea and Sicily before and afterward the process (Table-1).

4.2. Stage-2

With the second approach that had as a base the use of Terragen and his plugins, exceeded all the above obstacles. This became feasible initially from the make that problems of incompatibility did not exist in the produced files. Finally easy and with no problems, import of files in 3D programs had as

File format VRML	file size
South Greece Italy	95.955 kb
Sicily	35.586 kb
Sigri-Petrified forest	6.280 kb
File formatUSGS DEM	file size
South Greece Italy	22.612 kb
Sicily	860 kb
Sigri-Petrified forest	498 kb
File format TER	file size
South Greece Italy	8.201 kb
Sicily	515 kb
Sigri-Petrified forest	130 kb

Table 2: *Comparison of files size*

a result the most efficient visualisation of spatial information according to the restrictions that had been placed.

In this particular methodology the total files size in each scale of representation was very small. Thus has as a result very easy treatment and configuration of DEM files.

Characteristically are the results and the comparison of DEM polygons, points and file size, of South East Mediterranean sea and Sicily before and afterward the process (Table-1).

Evaluation it quantitatively became with base and Qualitative characteristics it showed that the use of second methodology had results filled the initial restrictions.

5. Conclusions

This paper is presenting the process of unification GIS and 3DGS for the most faithful representation of landscapes with cultural content. The aim of this work is to indicate the common way with which these two technologies can blend with the best possible way to constitute a useful representational methodology of archaeological landscapes.

In most cases making 3D representations requires different kinds of visualisation to aim a more realistic effect. As a result this has the need of different levels of detail and the exact determination of them.

The initial step in both of the methodological approaches constituted the finding of suitable spatial data for the regions of study. It should be reported that their choice became with the criterion of requirements and restrictions that emanated from the size of area that they will represent. In this way we accomplish the study of three different cases of areas with different scales (small, medium and big). With this choice it was covered completely the level of detail which is possible to be recovered from the GIS using by all of their precision.

The first methodological approach (Step-1) with the storage of geographic information from the GIS in VRML and

USGS.DEM file formats and their direct import in 3D programs, presented important disadvantages in visual representations and more specific in level of details.

Disadvantage of the use of VRML file format was the creation of big file sizes for small levels of detail. This as a result has an optimisation to approach the correct level of detail. The optimisation caused a dramatic increase of elements that describes the topology of DEM. Also we figured an increase in the file size that the topology is stored, without the final result approaches the levels of detail that had been placed for each scale. Respectively the use of USGS.DEM data had important disadvantages contrary to the small size that they had. This data at their import in 3D programs did not keep the geographic information of ground elevation. This as a result is the DEMs that was produced by this file and is presented in a deformed manner. Thus they constituted a non preferable methodology of unification of both technologies.

Through the effort of unification of GIS and 3DGS we discovered problems and difficulties in the first methodological approach. The problems we encountered had a relation with:

1. The file sizes of DEM (were very big).

2. The required limits of detail for realistic visualisations (were poor).

The second methodological approach according to which it became the use of Terragen software and some freeware Terragen plugins attributed the desirable results for each level of detail. We had very precise DEM with important smaller file sizes (Figure 6).

Figure 6: *Photorealistic representation of Sigri's Petrified Forest.*

Comparatively with the first methodology it constituted easier (easy in use programs), cheaper (use of freeware programs) and also "economically" (creation of small file size files). We conclude therefore that it is possible to integrate

GIS and 3DGS technologies in order to create a new category of archaeological landscape visualisations. Visualisations based on precise spatial and geographic data.

6. Future Directions

The study of integrated computational simulations platform for archaeological landscapes, which belongs in the area of Geoinformation applications that is connected with the documentation, management, protection and promotion of archaeological landscapes. This constitutes the next step of integration of these two technologies. 3DGIS will constitute one of the basic tools in this sector of applications which compared to other techniques as the topographic research, offer most advantages for the determination, comprehension, interpretation and presentation of archaeological landscapes. The advantages for the use of 3dGIS are:

- Simultaneous acquisition and production of quantitative and thematic elements

- Exceptionally precise 3D data

- Possibility of producing a precise 3Dmodel of an archaeological landscape.

Developing a thematic cartography that would combine the scientific results of archaeology, with a 3Dgraphic representation adapted in spatial analysis,perhaps confirms that the 3D representations using spatial data becomes an inevitable tool for the archaeologists. A tool to produce new information and conclusions in the research of Cultural Heritage.

References

[Ban01]   BANDROVA T.: Designing of Symbol System for 3DCity Maps. *Icc2001* Beijing. 2001

[BSS*001]   BOEHLER W. SCHERER Y., SIEBOLD M., MAINZ: Topographic information in cultural and natural heritage visualization and animation.2001 http: //gisdevelopment.net/application/ archaeology/general/archg0006.htm   .

[BKL*01]   BECKER O., KOENIGSMARCK A., LINK D., MARRIOTT S., O'NEILL M., O'REILLY D.,PAUKE J.,STACY P,WALKER J.: 3D for real world CINEMA 4D release 8 Tutorials. Maxon.1996.

[BPP96]   BELL G.,PARISI A.,PESCE M.: The Virtual Reality Modeling Language Version 2.0 Specification. 1996. http: //vag.vrml.org/vrml110.html   .

[RHD95]   ROW L.W., HASTINGS D.A., AND DUNBAR P.K.:   Terrain Base Worldwide Digital Terrain Data - Documentation Manual, CD-ROM Release 1.0. *National Geophysical Data Center, Boulder, Colorado* 1995

[RM03]   ROSSI S., MAGGI R.: Managing different scales

in intra site and micro regional analyses using GIS. *Proceedings of the 30th CAA conference held in Vienna Austria* .2003

[Roe00]   ROESSLER S.:   Wold Heritage Cultural landscapes. Indetification, Conservation, Monitoring.   *ISPRS Proceedings, UNESCO-ICOMOS-CIPA-ISPRS.Wold Heritage Session, Amsterdam. 2000*

Function-based Shape Modeling for Cultural Heritage Applications

G. Pasko [1] and A. Pasko [2]

[1] University of New York / Tirana, Albania, galinapasko@unyt.edu.al
[2] Hosei University, Tokyo, Japan, pasko@k.hosei.ac.jp

Abstract
We present a function-based shape modeling paradigm for cultural heritage applications, briefly survey several related modeling problems and their original solutions: bounded blending and controlled metamorphosis, modeling of two-dimensional cells in the form of trimmed implicit surfaces; and describe corresponding cultural heritage case studies.

1. Introduction

Current practice in shape modeling for cultural heritage applications is to use polygonal meshes and other boundary representations for the purposes of interactive visualization. There are other applications for the shape models in the area of cultural heritage: long term archiving of models, recreation of lost or damaged cultural heritage objects, reproduction of existing objects, and interactive inspection of models with arbitrary level of detail. These emerging applications require creating shape models of more high abstraction level than polygonal meshes and other boundary models. Such a model should provide high accuracy of description of not only external appearance but also of internal structure of the real object, including volumetric distribution of its material and other physical properties. Recently several alternative shape models have been applied in the area of cultural heritage: voxels [N97], implicit surfaces (radial-basis functions) [SFS*02], constructive models [VPP*04], and procedural models [HF04].

One of relatively new constructive shape models of higher abstraction level is the function representation (FRep) [PAS*95]. It is a generalization of traditional implicit surfaces, constrictive solid geometry (CSG), voxel, sweeping, and other shape models. This representation supports a wide class of primitive objects and operations on them. The generality of this model comes from the main principle postulating that the modeled object at every step of the modeling process is described in a uniform manner by a single procedurally defined real continuous function of point coordinates.

In this paper, we present our research and development results in the FRep based shape modeling for cultural heritage preservation. We analyze some of open modeling problems related to shape modeling of cultural heritage objects: bounded blending and controlled metamorphosis, and propose original solutions to the formulated problems. From the heterogeneous (mixed dimensional) modeling point of view, we choose implicit complexes [AKK*02] as the basic model and concentrate on modeling of two-dimensional cells in the form of trimmed implicit surfaces. We implement the proposed solutions and illustrate them by several cultural heritage related case studies such as the Virtual Shikki project on modeling and Web presentation of Japanese lacquer ware craft, the Dancing Buddhas project, and 3D modeling of the Escher's drawings.

2. Shape modeling for cultural heritage

The digital preservation of cultural heritage has recently attracted considerable attention in computer graphics, geometric modeling, and virtual reality communities. The *digital preservation* includes the capture and archiving of the form and contents of the existing cultural heritage objects through the use of computer modeling techniques, the reproduction of those objects that have already been lost, and usage of introduced models for active experience in the form of Web sites, multimedia presentations, games, and virtual environments.

One of the important characteristics of the object in digital preservation is its shape, especially for three-dimensional physical artifacts such as pottery, sculpture, and architecture. As it was mentioned in [VPP*04], loss of information is one of the biggest problems of shape modeling in cultural heritage because of using non-standardized (often proprietary) and frequently changing formats for archiving of data and models. Other problems are difficulties of data exchange between different systems and across platforms, lack of understanding of modeling processes and data structures by users, and therefore limited possibilities to verify the application's operations independently.

Current shape modeling systems and cultural heritage preservation systems are traditionally based on polygonal meshes and other boundary representation (BRep) models. These models have such disadvantages as lack of construction history and of the constructive object structure, accumulation of numerical errors resulting in surface cracks, and high complexity of processing algorithms, allow only for simple time dependences and limited parameterization with fixed topology. Traditionally for digital preservation, models of external surfaces and textures of objects are obtained using different 3D scanning and mesh reconstruction techniques [BR02]. Constructive geometric modeling procedures and the

fundamental mathematical base for 3D shape modeling, volume rendering, and multidimensional modeling are not well known in the digital preservation community.

From our point of view, internal structures (revealing the logic of construction and material distribution) of objects, as well as their time, and other parametric dependencies also can be added to the consideration. On this basis, we choose the function representation as the most powerful constructive geometric model (see the next section), discuss and illustrate the development of a new paradigm for cultural heritage preservation that includes constructive modeling reflecting the logical structure of objects and cellular modeling of dimensionally heterogeneous objects.

3. Function representation and its extensions

The function representation was introduced in [PAS*95] as a generalization of traditional implicit surfaces, CSG, sweeping, and other shape models. In FRep, a 3D object is represented by a continuous function of point coordinates as $F(x,y,z) \geq 0$. A point belongs to the object if the function is non-negative at the point. The function is zero on the entire surface (called usually an *implicit surface*) of the object and is negative at any point outside the object. The function can be easily parameterized to support modeling of a parametric family of objects. In a FRep system, an object is represented by a tree data structure reflecting the logical structure of the object construction, where leaves are arbitrary "black box" primitives and nodes are arbitrary operations. Function evaluation procedures traverse the tree and evaluate the function value at any given point.

The following types of geometric objects can be used as primitives (leaves of the construction tree): algebraic surfaces and skeleton-based implicit surfaces, convolution surfaces, objects reconstructed from surface points and contours, polygonal shapes converted to real functions, procedural objects (such as solid noise), volumetric (voxel) and other objects. Many modeling operations have been formulated, which are closed on the representation, i.e., generate another continuous function defining the transformed object as a result. These modeling operations include: set-theoretic operations based on R-functions, blending set-theoretic operations, offsetting, sweeping by a contour and by a moving solid, projection to a lower dimensional space, non-linear deformations and metamorphosis, and others [PPS*95, PA04].

A new operation can be included in the modeling system without changing its integrity by providing a corresponding function evaluation or space mapping procedure. In FRep, there is no principal difference in processing skeleton-based objects, CSG solids, or volumetric objects (with an appropriate samples interpolation). FRep also naturally supports 4D (space-time) and multidimensional modeling using functions of several variables. The main idea of visualization is to provide a mapping of such objects to a multimedia space with such coordinates as 2D/3D world space coordinates, time, color, textures and other photometric coordinates, and sounds.

The HyperFun language [ACF*99] is a minimalist programming language supporting all notions of FRep.

HyperFun was also designed to serve as a lightweight protocol for exchanging FRep models among people, software systems, and networked computers.

In many application areas, it is quite useful to construct a heterogeneous object model. Heterogeneous objects have internal structures with non-uniform distribution of material and other attributes of an arbitrary nature (photometric, physical, statistical, etc.) along with elements of different dimensions (k-dimensional point sets in n-dimensional space with k ≤ n). Such objects can be represented as *constructive hypervolumes* [PAS*01] and *implicit complexes* [AKK*02].

4. Shape modeling problems and case studies

The applications of the function representation and its extensions in digital preservation of cultural heritage formulate the following new requirements:

- intuitive and interactive user's control over the modeled shape;
- precise predictability of the result of modeling operations;
- generality of modeling methods independent of specific restrictions and preprocessing steps;
- support of dimensionally heterogeneous and multi-material models;
- models formulation allowing for further conversion into other auxiliary models suitable for different applications.

The following subsections present several related modeling problems and proposed original solutions, and illustrate them by corresponding case studies.

4.1. Bounded blending and Virtual Shikki

The localization of blending is an example of the operation satisfying the above requirements of intuitive and precise control over the modeled shape. Blending operations generate smooth transitions between two or several surfaces. These operations are usually smooth versions of set-theoretic operations on solids (intersection, union, and difference), which approximate exact results of these operations by rounding sharp edges and vertices. The major requirements to blending operations are tangency of the blend surface with the initial surfaces, automatic clipping of unwanted parts of the blending surface, C^1 continuity of the blending function everywhere in the domain, support of added and subtracted material blends, support of blend on blend, and blending of a single selected edge. Special attention is paid to the intuitive control of the blend shape and position.

To satisfy most of the above requirements for FRep solids, we introduced original bounded blending operations defined using R-functions and displacement functions with the localized area of influence: bounding by control points and bounding by an additional solid [PPK05]. The shape and location of the blend is defined by an additional bounding solid thus making the ternary blending operation (having three solids as arguments). It is provided that the blending surface

exists only inside the bounding solid, and only initial surfaces exist outside the bounding solid. The proposed bounded blending operations can replace pure set-theoretic operations in the construction of a FRep solid with replacing binary nodes by ternary ones and with additional sub-trees for bounding solids. The bounded blending operations were actively used for modeling traditional Japanese lacquer ware items in the Virtual Shikki project (see Fig. 2). We provide in Fig. 1 an example of the sake pot construction from the Virtual Shikki project. More examples can be seen at our Virtual Shikki project Web site:
http://cis.k.hosei.ac.jp/~F-rep/App/shi/Shikki.html

Initially, the model is constructed using set-theoretic operations with two unwanted sharp edges in the area of the spout and at the top of the pot body. For the spout, a cylindrical bounding solid is used for the blending union operation. At the top of the body, a cylinder with a hole is used for bounding the blending intersection operation.
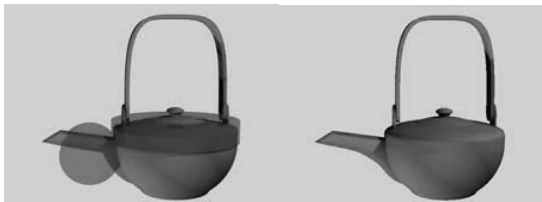

Figure 1: *Two bounded blending operations are applied in the construction of a Japanese sake pot: union of the spout elements and intersection for the top part of the pot body.*
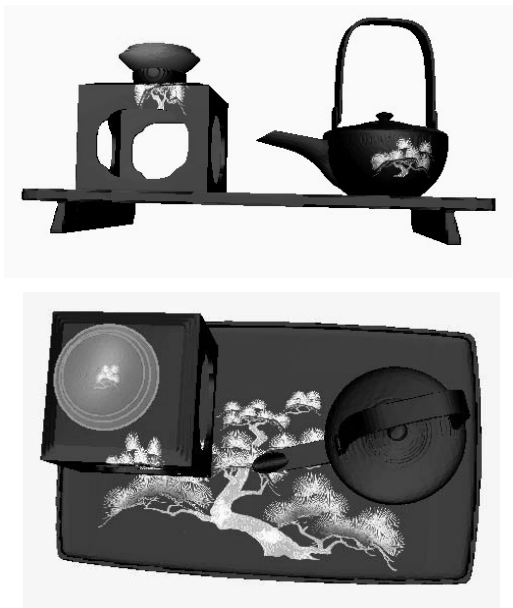

Figure 2: *Front and top views of a Virtual Shikki object VRML model.*

4.2. Space-time blending and Dancing Buddhas

The bounding blending operation is also applied to formulate an original approach to shape metamorphosis through the dimension increase and objects blending in space-time, which allows us to eliminate most of existing constrains in shape transformations. The time-dependent shape transformation between given objects (metamorphosis) is one of typical space-time modeling operations. In general, the initial and final shapes for metamorphosis can be topologically different. The existing approaches to metamorphosis are based on one or several of the following assumptions: equivalent topology (mainly topological disks or balls are considered), polygonal shape representation, shape alignment (shapes have common coordinate origin and significantly overlap), possibility of shape matching (establishing of shape vertex-vertex, control points or other features correspondence), the resulting transformation should be close to the motion of an articulated figure.

Linear interpolation between functionally defined shapes has proven to solve some of the above problems for computer animation and artistic applications. The problem which remains open is a transformation between non-overlapping shapes, which combines metamorphosis and non-linear motion. We have developed a new approach to shape metamorphosis using blending operations in space-time. The key steps of the metamorphosis algorithm are: dimension increase by converting two input k-D shapes into half-cylinders in (k+1)-D space-time, applying bounded blending union to the half-cylinders, and making cross-sections for getting intermediate shapes [PPK04].

The bounded space-time blending procedure for 2D shapes consists of the following steps:

- two initial 2D shapes are given on a 2D plane;
- each shape is considered as a 2D cross-section of a half-cylinder (a semi-infinite cylinder bounded by a plane from one side along the time axis) defined in 3D space-time;
- two half-cylinders are placed at some distance along time axis to provide a time interval for making the blend;
- the bounded blending union operation with added material is applied to the 3D half-cylinders with two planar half-spaces orthogonal to the time axis forming a bounding 3D object (a slab between two planes);
- consecutive cross-sections of the blend along the time axis are combined into a 2D animation.

In the case of 3D objects, each shape is considered as a 3D cross-section of a half-cylinder defined in 4D space-time.

The proposed space-time blending was used in the case study of 2D metamorphosis in the Dancing Buddhas project. The idea of this case study came from a concept that each Chinese character (*kanji*) of the text of the Lotus sutra is in fact a Buddha, which can be illustrated by 2D transformation of a Buddha shape into a Chinese character. Two polygonal shapes were obtained from the images: the Buddha shape (see

the image in Fig. 3) consists of the main concave polygon (49 segments) and two simple polygonal holes, the Chinese character (see the image in Fig. 3) consists of two disjoint components, one of which is a simple concave polygon (left part of the character) and another (right part of the character) is a concave polygonal shape (12 segments) with five holes. We applied the proposed algorithm using bounded blending in 3D space and obtained an animation, where all topological changes are handled automatically. Several frames of the animation are shown in Fig. 4 and the full animation is available at
http://cis.k.hosei.ac.jp/~F-rep/STBB/FSTBB.html

Figure 3: *Initial Buddha shape and a Chinese character.*

4.3. Trimmed implicit surfaces and Escher's rinds

We mentioned in section 3 the problem of modeling objects of mixed dimensions and the approach based on combination of cellular and functional representations. The geometric domain of FRep in 3D space includes 3D solids with so-called "non-manifold" boundaries and lower dimensional entities (surfaces, curves, points) defined by zero value of the function. For example, an implicit surface patch can be defined as an implicit surface trimmed by an intersecting solid. A specific problem of modeling two-dimensional cells as trimmed implicit surfaces was considered in [PP04]. Some applications such as visualization or physical simulation based on finite-element meshes require the conversion of an implicit complex to the pure cellular representation. Such a conversion of a trimmed implicit surface to a polygonal mesh was a subject of our research.

This work was also inspired by art works of M. C. Escher namely "Sphere Spirals" (1958), "Bond of Union" (1956), and "Rind" (1955), showing spiral shaped surface sheets cut of a sphere and human head surfaces. The proposed approach is to represent the trimmed surface by a kind of constructive tree, where the initial surface and the trimming solid are represented separately as two primitives defined by equations or as two FRep sub-trees – arguments of the set-theoretic operation.

The initial surface can be polygonized using one of conventional algorithms and the resulting mesh can be trimmed using vertices classification against the trimming solid. The polygon subdivision (mesh adaptation) has to be applied near the surface-surface intersection curves to remove trimmed parts of the initial implicit surface and to more precisely approximate the trimmed surface boundary.

Fig. 5 presents two experiments with the implemented implicit surface trimming algorithm related to modeling some art works of M.C. Escher. The initial implicit surface for the "Rind" model was constructed using set operations with R-functions on algebraic primitives, soft objects, and convolution solids. Note that Escher's works are 2-dimensional drawings of 3D objects. Modeling and rendering them directly in 3D as we did in the above examples can be considered as a step to live heritage applications such as multimedia, virtual reality, or gaming interfaces to artistic and historical cultural environments.

5. Discussion and conclusion

In this section, we discuss advantages and known problems of the function representation in cultural heritage applications, its conversions and combinations with existing shape models, and different levels of utilization of FRep models in virtual environments.

5.1. Advantages and problems of FRep in cultural heritage

Let us summarize advantages of using FRep in cultural heritage applications. First of all, it provides a precise mathematical definition of modeled objects. The use of other existing models is supported by conversion of them to and from FRep. Thus, several other types of shape models can be included in FRep as modeling primitives. For the efficiency of visualization and interactive manipulation, FRep models can be converted to BRep or voxel models. The combination of FRep and cellular models provides necessary framework for modeling dimensionally heterogeneous objects.

The combination of geometry and attributes in the constructive hypervolume model [PAS*01] allows for modeling not only the shapes, but material and other object properties. Support of multidimensional and particularly time-dependent models in FRep is useful for the modeling aging objects with the help of finite element analysis. The recovered structure and constructive elements of the object can be employed for rebuilding lost objects and for the implementation of "live heritage" applications such as animation or interactive multimedia.

The clearly defined open text format of FRep models in the HyperFun language obviously increases the survival period of the archived models, especially in comparing with not openly specified proprietary formats.

The major problems of FRep are time consuming function evaluation at each given point, which currently retards interactive applications; capturing sharp and thin object features during rendering; interactive manipulation and editing. Parallel and distributed processing and special hardware can help resolve most of these problems in near future. Another difficulty is that constructive modeling usually requires high levels of 3D modeling skill and is labor-intensive. One of the possibilities of automation is fitting of a parameterized FRep model to a cloud of surface points [VPP*04].
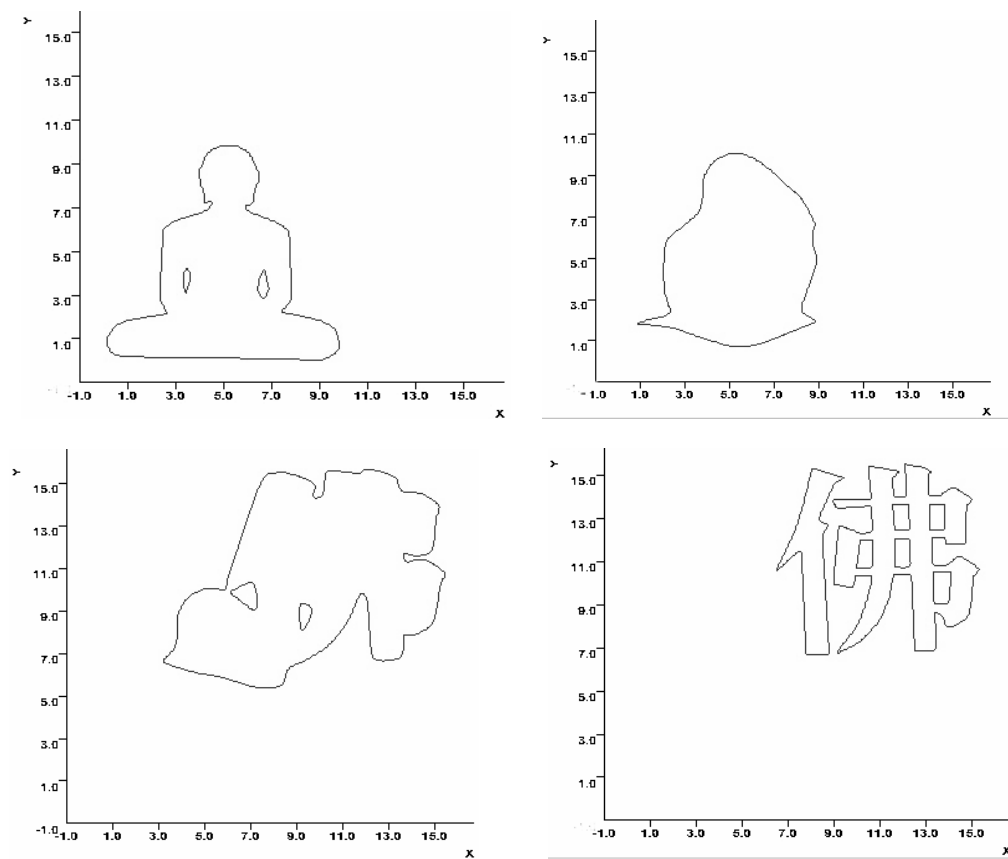
Figure 4: *Frames of the animation: transformation of a Buddha shape into a Chinese character.*
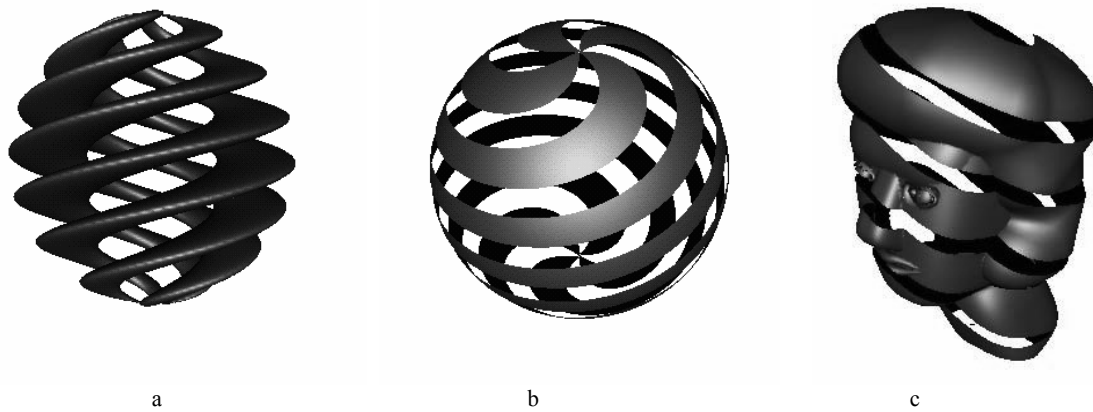

a b c

Figure 5: *Models of "Sphere Spirals" and "Rind" by Escher: (a) trimming solid as a union of three spirals; (b) trimmed sphere surface; (c) trimmed head surface.*

5.2. FRep in virtual cultural environments

There are different levels of utilization of FRep models in virtual environments. The simplest way is to polygonize object surfaces and to export them in one of available Web 3D formats, for example, in the Virtual Reality Modeling Language (VRML). Examples can be seen in our Virtual Shikki project. The next level is embedding of FRep models into existing protocols such as a special VRML node proposed in [MSL02]. In the case of small local object modifications such as carving, embossing, or engraving, a FRep model can be directly updated in the virtual environment and its image can be locally modified by ray-casting or polygonization [S01]. If the overall shape of the object is changing in the interactive process, then a voxel model or another auxiliary model is needed to support the visual feedback. An example of such global shape modification is the group metamorphosis with immersive interactive control in the Augmented Sculpture project [ACK*05].

6. Conclusion

This paper describes an approach to some actual shape modeling issues related to the digital preservation of cultural heritage. On the basis of the survey of existing problems and requirements we have chosen the function representation as the basic mathematical model. From the analysis of the potential application areas we have selected several modeling problems and provided original solutions to localization and control of blending set-theoretic operations, general constraint free shape metamorphosis, modeling and rendering trimmed implicit surfaces.

The proposed methods and algorithms have been applied in several case studies related to cultural heritage. The bounded blending operation was used in modeling traditional Japanese lacquer ware in the Virtual Shikki project, which has resulted in a Web site with 3D models in HyperFun and VRML formats. The proposed space-time blending was used in the presented case studies of 2D metamorphosis in the Dancing Buddhas project, where an animation of Buddha shape transformation to a Chinese character was generated. The application of trimmed implicit surfaces for modeling spiral objects by M. C. Escher was presented. We also discussed different levels of utilization of FRep models in virtual environments.

References

[ACF*99] V. ADZHIEV, R. CARTWRIGHT, E. FAUSETT, A. OSSIPOV, A. PASKO, V. SAVCHENKO, HyperFun project: a framework for collaborative multidimensional F-rep modeling , Implicit Surfaces '99, J. Hughes and C. Schlick (Eds.), pp. 59-69.

[AKK*02] V. ADZHIEV, E. KARTASHEVA, T. KUNII, A. PASKO, B. SCHMITT, Cellular-functional modeling of heterogeneous objects, ACM Solid Modeling and Applications 2002 Symposium, K. Lee and N. Patrikalakis (Eds.), ACM Press, 2002, pp.192-203.

[ACK*05] V. ADZHIEV, P. COMNINOS, M. KAZAKOV, A. PASKO, Functionally based augmented sculpting, Computer Animation and Virtual Worlds, vol. 16, No. 1, 2005, pp. 25-39.

[BR02] F. BERNARDINI, H.E. RUSHMEIER, The 3D model acquisition pipeline, Computer Graphics Forum vol. 21, No.2, 2002, pp.149-172.

[HF04] S. HAVEMANN, D. FELLNER, Generative parametric design of gothic window tracery, Shape Modeling International, 2004, pp. 350-353.

[MSL02] LAI FENG MIN, A. SOURIN, K. LEVINSKI, Function-based 3D Web visualization, 2002 International Symposium Cyber Worlds: Theory and Practice 2002, IEEE Computer Society, 2002, pp.428-435.

[N97] P.J. NEUGEBAUER, Geometrical cloning of 3D objects via simultaneous registration of multiple range images, Shape Modeling and Applications (SMI '97), IEEE Computer Society, 1997, pp. 130-139.

[PAS*95] A. Pasko, V. ADZHIEV, A. SOURIN, V. SAVCHENKO, Function representation in geometric modeling: concepts, implementation and applications, The Visual Computer, vol.11, No. 8, 1995, pp.429-446.

[PAS*01] A. PASKO, V. ADZHIEV, B. SCHMITT, C. SCHLICK, Constructive hypervolume modeling, Graphical Models, vol. 63, No. 6, 2001, pp. 413-442.

[PP04] G. PASKO, A. PASKO, Trimming implicit surfaces, The Visual Computer, 2004, No. 7, pp. 437-447.

[PPK04] G. PASKO, A. PASKO, T. KUNII, Space-time blending, Journal of Computer Animation and Virtual Worlds, vol. 15, No. 2, 2004, pp. 109-121.

[PPK05] G. PASKO, A. PASKO, T. KUNII, Bounded blending for function-based shape modeling, IEEE Computer Graphics & Applications, vol. 25, No. 2, 2005, pp. 36-45.

[S01] A. SOURIN, Functionally based virtual embossing, The Visual Computer, vol. 17, No. 4, 2001, pp. 258-271.

[SFS*02] M.B.H. SHANAT, P.-A. FAYOLLE, B. SCHMITT, T. I. VILBRANDT, Haniwa: A Case Study of Digital Visualization of Virtual Heritage Properties, 20th Eurographics UK Conference, IEEE Computer Society, 2002, pp. 24-32.

[VPP*04] C. W. VILBRANDT, G. I. PASKO, A. A. PASKO, P.-A. FAYOLLE, T. I. VILBRANDT, J. R. GOODWIN, J. M. GOODWIN, T.L. KUNII, Cultural heritage preservation using constructive shape modeling, Computer Graphics Forum, vol. 23, No.1, 2004, pp. 25-41.

Efficient Field Capture of Epigraphy via Photometric Stereo

J. Paterson† and K. Cain‡

†Eykona Technologies Ltd
‡Institute for the Study and Integration of Graphical Heritage Techniques

Abstract
We describe a highly portable field technique for estimating surface normals, geometry and albedo from walls and other areas of archaeological sites using limited sets of digital photographs. Surface geometry and albedo are extracted from photometric calculations, yielding a complete model with estimated per-vertex colour. This technique is demonstrated to be practical in pre-production for the digital planetarium film Maya Skies*.*

Categories and Subject Descriptors (according to ACM CCS) I.3.3 [Computer Graphics]: Modeling – Object Scanning /Acquisition, Modeling – Appearance Modeling

1. Introduction

Photometric stereo has been shown to be an effective method for capturing high-resolution geometry and reflectance properties of ancient inscriptions [EHD04]. Classical photometric stereo [Woo80] requires a static camera pose for each photograph acquired in a given image set, while lighting varies. Our technique relaxes the fixed camera constraint required by previous systems in order to decrease the time required to document epigraphic inscriptions in situ. In practice, our technique obviates the need for a camera tripod and multiple light sources during capture, which can simplify field work. We demonstrate that efficient field capture for ~700cm^2 regions can be completed in ~15 seconds, and that subsequent processing can be completed quickly and with minimal user interaction.

2. System overview

Our technique offers a portable and convenient approach to photometric capture. Figure 1 shows the key components of the system. A standard digital still camera and flash unit are rigidly attached using a simple aluminium boom (Figure 1, shown right). This assures that the geometrical relationship between the camera and light source is fixed. The second component is a light gathering frame which contains a fiducial dot pattern and four cones (Figure 1, shown left). During acquisition, the frame is positioned such that the surface under inspection is visible through a central hole in the frame.

The position and orientation of the camera-flash system is varied during capture, yielding several photometric digital images. Camera localization is derived from the observed positions of the five fiducial dot markers in each image, and incident lighting direction is inferred from the shadows cast by the cones on the planar region of the frame. Knowledge of the geometrical relationships between camera, flash and frame allows photometric surface reconstruction under a changing camera viewpoint. The frame also provides image-based light attenuation correction [PCF05]. Typically the surfaces under inspection are well modelled by a Lambertian reflectivity assumption, although other Bidirectional Reflectance Distribution Function (BRDF) models could be applied [NRHGL77, PCF05].
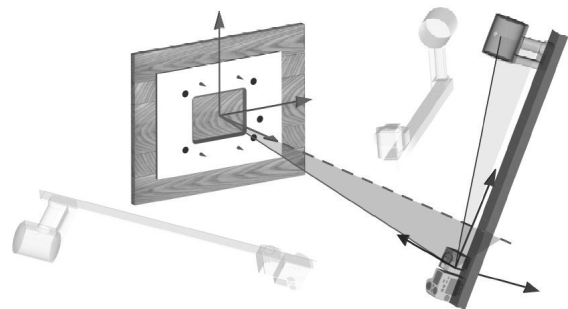

Figure 1: *System equipment. Light gathering frame (left) Camera and flash attached via boom (right).*

3. Geometry and texture estimation

3.1 Image acquisition

Our subject in Figure 2 is a small region of the Venus Platform, a structure in situ at the Maya site Chichén Itzá, located in Yucatan, México. At Chichén Itzá, we acquired image sets for twelve test regions during field work in October 2005. These sample areas were selected to represent texture variations observed throughout Chichén Itzá. The stone surfaces under study all feature a dominant Lambertian component in their BDRF, and therefore prove highly suitable for high quality reconstruction using photometric stereo techniques.
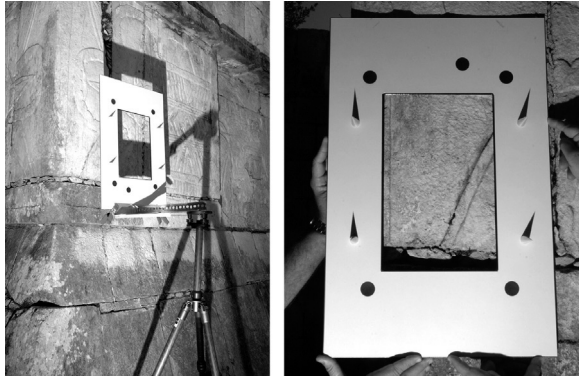

Figure 2: *Fiducial frame in-situ at Chichén Itzá (left). Image data, showing fiducial markers (right).*

3.2 Camera calibration and lens distortion correction

Camera calibration is a prerequisite to accurate optical localization, deriving specified parameters, e.g. focal length and a model of lens distortion. This is a well-explored topic in the literature, with several approaches in regular use. We have tested geometric reconstructions using images processed using 1) the Intel OpenCV library / Bouget camera calibration toolbox and 2) the Rational Function radial distortion model of [CLF05].

In the first case we rely on existing code and compute camera intrinsics using a sequence of checkerboard images (Figure 3). Here, lens distortion is modelled with a low-order radial polynomial along with tangential distortion. The software provides methods for resampling an input image to remove lens distortion.

The second approach instead models lens distortion effects using a rational function approach. Calibration can be achieved using a single image of a scene containing straight lines. Let x,y signify canonical image coordinates, and U the distorted version as a homogeneous vector, then:

$$U = A\begin{bmatrix} x^2 & xy & y^2 & x & y & 1 \end{bmatrix}^T \quad \textbf{(Eqn 1)}$$

where A is a 3x6 parameter matrix.

Both techniques yielded acceptable results. Correction for lens distortion proved critical in achieving quality reconstructions due to adverse effects of distortion on camera localization.
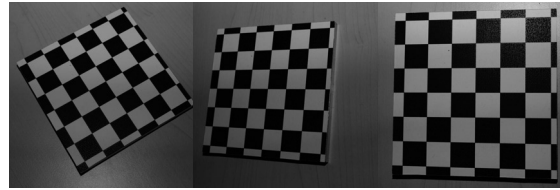

Figure 3: *Images used to compute camera intrinsics.*

3.3 Image processing

Our end-user application "SurfaceImager" encapsulates the complete reconstruction pipeline, incorporating means for user input where necessary. Having loaded the photometric images and calibration parameters, the user performs segmentation, defining the target area (Figure 4a). The fiducial markers on the frame are automatically identified and the camera pose estimated (Figure 4b). Finally, the effective position of the flash bulb is determined by searching for the shadows cast by the cones (Figure 4c), a task achieved in a manner akin to tracing the shadow of the gnomon on a traditional sundial. As the flash is fixed relative to the camera, information can be combined across multiple images in a global optimization.

(a)   (b)   (c)
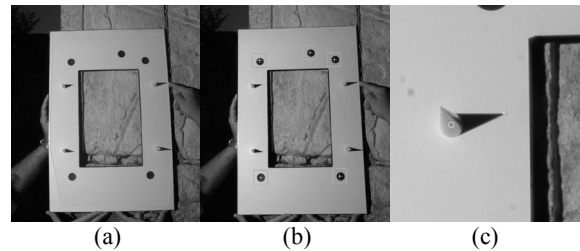
Figure 4: **(a)** *Interactive image segmentation.* **(b)** *Automatic fiducial detection.* **(c)** *Shadow tip localization.*

4. Results - Geometry and texture estimation

Photometric stereo estimates geometry as a set of surface normals, along with parameters specifying a model of surface reflectivity. This is done by inverting the model given a number of samples of surface intensity with known incident lighting direction. With a Lambertian surface model the camera observed surface intensity I is defined as:

$$I = \rho \vec{N} \cdot \vec{L} \quad \textbf{(Eqn 2)}$$

Where ρ indicates surface reflectance, $\vec{L}$ surface-relative lighting direction and $\vec{N}$ the surface normal. Standard photometric stereo maintains a static camera viewpoint. Photometric samples are acquired by varying light direction and observing intensity change at a single pixel. Denoting lighting direction and intensity at a given pixel across the N photometric images with subscript, then:

$$\begin{bmatrix} I_1 I_2 \cdots I_N \end{bmatrix}^T = \begin{bmatrix} \vec{L}_1 \vec{L}_2 \cdots \vec{L}_N \end{bmatrix}^T \vec{N} \quad \textbf{(Eqn 3)}$$

Clearly this can be solved by premultiplication with the pseduoinverse of the L matrix (this can be achieved in an efficient manner, for example via singular value decomposition), providing an estimated normal for each camera pixel.

To apply photometric techniques, our system first rectifies the input images to a common viewpoint. This can be done approximately using a planar perspective un-warping. Figure 5 shows a set of input images along with their corresponding rectified views. A 3D range map is then derived by integrating the recovered surface normals.

Total image acquisition time for the images shown in Figure 5 was ~15 seconds. Rectification and photometric stereo processing steps for a mesh with dimensions 1024x592 were completed in ~6 seconds, using an AMD x4600 processor running a 64-bit operating system. The final output was a 1024x592 albedo map (essentially an RGB texture map), and a 1024x592 height map providing ~600k independent height samples. This provides geometrical information equivalent to laser scanning the ~700cm^2 sample area at a resolution of ~300μ.
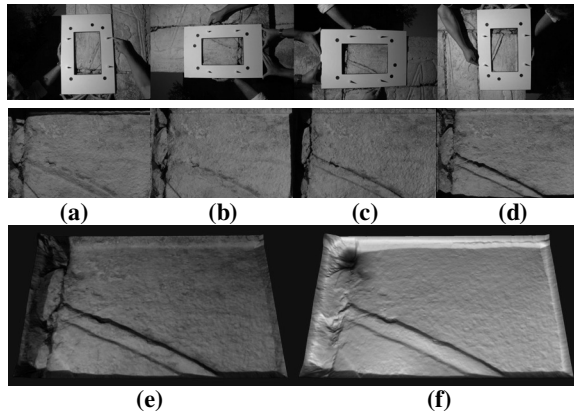

Figure 5: **(a) – (d)** *Input photometric images, captured with varying camera and lighting direction (top row). Rectified versions; note static viewpoint, moving illumination direction (bottom row).* **(e)** *Reconstructed 3D surface with lighted colour albedo.* **(f)** *Jet colouring scheme highlights detailed geometry.*

A discernable bevel is seen at the boundary of the reconstruction illustrated in Figure 5. This artefact is seen when, for a given pixel, the light-gathering frame casts a shadow onto the subject in one of the four input images. An approach in which shadowed pixels are excluded from photometric stereo calculations in a reliable manner is proposed in [CJ05]. In Figure 6, shadowed regions are culled in the reconstructions shown.
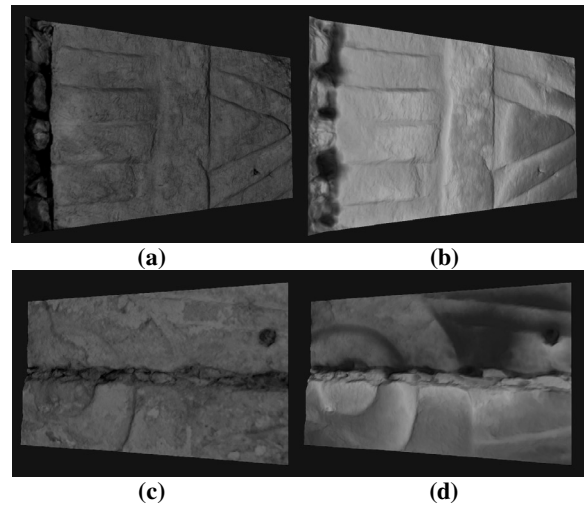
Figure 6. **(a)** *A second reconstructed 3D surface with lighted colour albedo.* **(b)** *Jet colouring scheme highlights detailed geometry.* **(c) – (d)** *Colour albedo and jet colouring for a third example.*

4. Downstream use in film production

Complete digital versions for specific structures at Chichén Itzá are required for the educational planetarium film *Maya Skies*. As the final rendered material will be presented on hemispherical screens measuring up to 70' in diameter, subtle epigraphic details will be clearly visible to planetaria viewers when geometry is placed near the scene camera. Even distant regions of the scene may require high levels of detail, since each rendered frame will be 4,096x4,096 pixels. Given the demands imposed by the full-dome output format, high resolution geometry and texture detail are highly desirable. However, since the required models must include highly detailed features of the type seen in Figure 7, mesh simplification is clearly required prior to rendering.

Figure 7. *Complex epigraphic detail seen at Chichén Itzá demands geometric simplification for efficient rendering while preserving the features seen above.*

Several techniques have been proposed to achieve a high level of detail at a relatively low geometric cost using

normal mapping, notably [CMSR98]. Using SurfaceImager, we export geometry with texture coordinate information in .OBJ format, accompanied by an image texture map in .BMP format. The output geometry is then decimated into a low resolution triangle model for use as a normal mapping basis. We compute the normal map using both the original output geometry and the decimated geometry; results are seen in Figure 8.
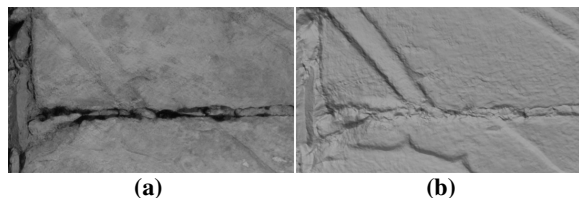

    (a)   **(b)**

Figure 8: (a) *Color albedo image from photometric stereo calculations.* **(b)** *Normal map for the same region, computed from SurfaceImager geometry.*

Next, we load the decimated geometry into Alias Maya, the application selected for lighting and rendering in *Maya Skies*. Here, we apply the original color albedo map exported by SurfaceImager and the computed normal map to the low resolution geometry. Results rendered from Maya with a single light source are seen in Figure 9.
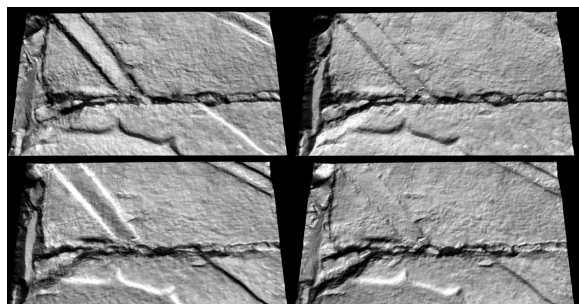

Figure 9. *Recovered geometry and color albedo, lighted and rendered in Alias Maya. A single light source (simulating sunlight) varies in position with each frame.*

Despite the high level of geometric simplification in the decimated base model, the normal map effectively preserves the details seen in the original photometric reconstruction. We found that automated rapid synthesis of normal maps from our photometric stereo approach was practical, requiring ~12 seconds to compute maps at 1024x1024.

5. Future work

We have found that geometry recovered using our system is free from low frequency noise often seen in close range laser scan data. Therefore, we believe this technique could be explored for sampling smaller subject regions than those shown in this paper, but with comparatively higher detail. In Figure 10, our current method is used to compute 1,024 x 1,024 samples over a 42 x 42mm surface region, giving a ~41 micron sampling in both x and y dimensions.
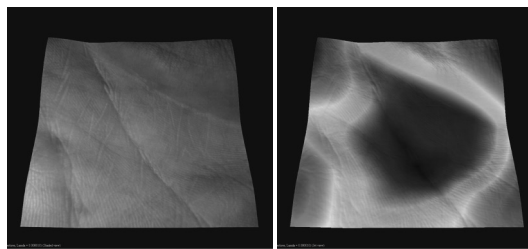

Figure 10. *~41 micron sampling of a human palm.*

6. Conclusions

We have demonstrated the application of a novel approach to surface geometry and albedo capture. The system requires only simple low-cost hardware and standard digital photography. Processing is rapidly performed on a standard PC using our "SurfaceImager" application with only minimal user interaction. The system has been shown to be capable of very high detail recovery for epigraphy, rivalling that of traditional laser scanning hardware. Having acquired this data, we have discussed how it may be processed to produce models suitable for use in modern rendering software, in particular for the production of photorealistic images in the educational film *Maya Skies*.

7. References

[CJ05] COLEMAN, E. AND JAIN, R.: Obtaining 3-dimensional shape of textured and specular surfaces using four source photometry. In *Computer Graphics and Image Processing,* 18:309-328, 1982.

[CLF05] CLAUS, D. AND FITZGIBBON, A: A Rational Function Lens Distortion Model for General Cameras. In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition* (2005) 213-219.

[CMSR98] CIGNONI, P., MONTANI, C., SCOPIGNO, R. AND ROCCHINI, C.: A general method for preserving attribute values on simplified meshes. In *IEEE Visualization 1998* 59-66.

[EHD04] EINARSSON, P., HAWKINS, T. AND DEBEVEC, P.: Photometric Stereo for Archeological Inscriptions. In *Proceedings of the SIGGRAPH 2004 Conference on Sketches and Applications*, ACM Press / ACM SIGGRAPH, Los Angeles, California, USA, August 2004.

[NRHGL77] NICODEMUS, F. E., RICHMOND, J. C., HSIA, J. J., GINSBERG, I. W. AND LIMPERIS, T.: Geometric Considerations and Nomenclature for Reflectance. In *Monograph 161, National Bureau of Standards (US)* (1977).

[PCF05] PATERSON, J. A., CLAUS, D. AND FITZGIBBON, A.: BRDF and geometry capture from extended inhomogeneous samples using flash photography. In *Computer Graphics Forum (Special Eurographics Issue)* vol. 4(3), (2005) 383-391.

[WOO80] WOODHAM, R. J.: Photometric method for determining surface orientation from multiple images. *Optical Engineering 19,* 1, (1980) 139-144.

Complex Documentation of Charles Bridge in Prague by Using Laser Scanning, Photogrammetry and GIS Technology

K. Pavelka, J.Svatušková, J.Preisler, V.Němcová, M.Nečesánek, J.Pazdera, R.Balík

Laboratory of Photogrammetry, CTU Prague, Faculty of Civil Engineering, Czech Republic

Abstract
The Charles Bridge in Prague is a worldwide known historical monument. It is on the World Heritage List (UNESCO) with the historical center of Prague and it belongs among the national symbols of the Czech nation. During catastrophic flooding in 2002, which the Charles Bridge resisted, some of its parts were damaged. A decision about a gradual reconstruction was taken then. The first logical step was a complex documentation of the bridge. From the last reconstruction in the seventies of 20th century, the documentation is not complete, some parts have not been found and its quality is not sufficient for today. The major measurements were made in 2005. The laser-scanning technology was used for determination of the bridge form lines and edges. The "wire 3D model" was created from the laser-scanning data set. Using the digital photogrammetry, the detailed 3D model with all stones was created after that. About 2000 images, more than 1000 geodetically measured control points; a boat and special climbing equipment were used. All of about 70 000 stones were processed in the 3D model in AutoCAD. As the second step, a special database for information about stones (quality, material, exposition, damage ...) was created. Mouse clicking on a stone in the model depicts the related data.

I.3.3 [Computer Graphics]: 3D Visualization

1. Introduction

The Czech and Roman Emperor Charles IV founded the Charles Bridge in Prague in 1357. After the catastrophic flood in 2002, which the Charles Bridge resisted, some parts were damaged. For the partial reconstruction the new documentation was needed. The major geodetic and photogrammetric measurements were made in 2005.

Figure 1: *Charles Bridge in Prague*

2. The laser-scanning technology

The laser scanning has been a very popular technology recently; it is a non-contact mass measurement of 3D points. This new progressive technology has been in practice since 2000. The laser-scanning technology was used for determination of bridge form lines and edges. The 3D edge model was created from the laser-scanning data set. The Firm GEFOS a.s created the basic vector model of the Charles Bridge with accuracy of about to 5 cm (Leica/Cyra). Some parts of the bridge were measured by using Callidus 1.1 system (Czech Technical University).

Figure 2: *Leica laser scanner (Gefos a.s.)*

Using the digital photogrammetry, the detailed 3D model with all stones was created after that. About 2000 images, more than 1000 geodetically measured control points, a boat and special climbing equipment were used. All of about 70 000 stones were processed in the 3D model in AutoCAD. For control point's determination, a new self-

reflecting total station (distance measurement without reflecting prism) was used; this device is very good for inaccessible points (Trimble 5000, distance measurement to 300m).

Figure 3: *Callidus laser scanner (CTU Prague)*

3. Project

Works started with image acquisition. During this phase first problems arose: due to inaccessibility it was not possible to scan some parts of the bridge and therefore it was necessary to locate them independently by using classic surveying methods. Photographic conditions represented another problem. The transformation itself does not require taking photographs under the same light conditions but when creating a model and visualizations it is necessary to have photographs of the same quality. Control points for transformation were acquired from the wire model or by direct measurement. Particular parts of the bridge are not flat and that's why an adjustment plane was used for each part and points of the model were projected to this plane. It was necessary to pay attention to deviations of individual points from this plane and in case that the deviation exceeded the value of 5 cm; the plane had to be divided into smaller parts. This way enabled to substitute 3D surfaces by 2D planes without decreasing the required accuracy of final schema of construction (planed absolute accuracy up to 10 cm max.). Particular arch rings represented a special case where it was necessary to divide the arch surface to more flat surfaces, which substituted the arch. A representative 3D model of the bridge giving an overview of particular schema of construction-joint location was created from schema of construction-joint and the wire model (AutoCAD). It was necessary to transform the 2D areas to 3D again. This work required a good orientation in space, a right selection of a coordinate system, in which the plane was put in to the model, and to consider the surface rotation or its splitting to smaller parts which fit to the 3D model as much as possible. Even though the surface manipulation was accurate, this way led to divergences in junctions of the edges in the wire model and the inserted surfaces or two adjoining surfaces. It was necessary to eliminate these problems using manual

editing. The created schema of construction-joint and the 3D model are also a part of the information database of the bridge. On the basis of this database, a geological prospecting of a part of the Charles Bridge is performed and therefore the next work concerning this historical monument will be eventually updating the reconstruction according to the research results. Furthermore, it is planned to add schema of construction-joint of bridge towers and subsequent visualization of the bridge. As the second step, a special database for information about stones (quality, material, exposition, damage …) was created. Mouse clicking on a stone in the model depicts the related data.

Figure 4: *Trimble 5000*

4. Information system

The development of our special application for data storage and processing started during the year 2004. At the time of searching for the optimal software solution no was found that would both meet all our requirements (connecting spatial and non-spatial data, 3d graphics etc…) and be financially acceptable (this work was low-cost with helping of PhD students). However, the software developed by us enables communication with other systems such as AutoCad or Microstation through vector format dxf. As a development technology, the programming tool Borland Delphi 2005, a graphic library OpenGL and more support components (database connection, XML technology support, and libraries for extended 2D projection) were used. The main program application of the information system is created for Windows 32 platform. In order to run it correctly it is necessary to have a standard PC with Windows operation system, a graphic card with OpenGL support and also network or Internet connection for connection to distant data source.

4.1. Structure of saved data

The saved data can be divided into spatial and non-spatial:
Spatial data – the system saves information to its own binary format named .scl. Using this way the data can be

saved right to a file on local disk or as meta-data to one record of the connected database table. Non-spatial data – can be divided into text data, pictures, sounds, videos and other unspecified data. The last version of the system is able to work with all these data types on local disk, only the text data can be also saved to a database table where one object of the 3D model is represented by one record in the database table. For simultaneous work with one model across several computers photographs were stored on the network disc – then it was possible to use the data on more computers at the same time. In this moment we are already developing technology that can save pictorial data into the database. In case that the text data are saved on the local disk, they are saved in XML format. Mutual connection of spatial and non-spatial data is ensured via a unique identifier related to each object of the 3D model. This identifier is created automatically during a model creation but can be easily modified by the user. IDs are assigned automatically to make-work easier. Then, a user can change them without limit. If an existing ID is entered, the system will automatically warn the user that there is a conflict – the same ID already exists.

4.2 3D model creations

An existing model created in some of external 3D CAD applications (AutoCAD, Microstation, 3D Studio etc.) can be used as the 3D model. In this case a universal vector format .dxf is used for import. Integrated editor (vectorization) can be used to refine the 3D model, this procedure can be used for instance for digitalization of smaller flat parts of the 3D model. A special editor have been written which biggest advantage is its connection with 3d model – vectorized data are transformed into 3d model in the real time so you can see the result of the vectorisation process immediately. It is also possible to add non-spatial data in the editor directly. In case of the Charles Bridge model creation this procedure was used for schema of construction-joint creation of flat surfaces of the model. The 3D model can be also created by direct entry of coordinates or by import of spatial coordinates from a text file.

4.3 Vectorization

A special tool for transformation/vectorization of 2D background data (photographs most often) was made in the application for details creation of the basic 3D model. It is a transformation of a photograph into 3D model created with laserscanner – improvement of the rough model. As identical points we used the anaclastic points and the relevant points from the photo. The biggest problem of transformation as such is of course the right selection of anaclastic points; the selection of the relevant point is done manually. This tool was primarily made for the creation of particular bridge surfaces. To place a 2D object from 2D background data to a 3D model, several types of transformation can be used. These transformations can be combined at large, even within one 2D background data. Identical points (2D background data to 3D model) are used for transformation of key calculation. When vectorizing mainly the flat surfaces, a simple affine or projective transformation can be used. In reality there are mainly general surfaces. Such a bridge, as the Charles Bridge has almost no flat surface. It was necessary to create a special type of transformation for these surfaces. Particular steps of this transformation (2D to 3D) can be described in the following way: Transformation of identical points to plane (a plane is always formed by the three most distant identical points); a projective transformation is used for creation of triangular network of identical points finding the nearest triangle of the transformed point 2D to 3D transformation, vertexes of the appropriate triangle are used as identical points. To perform the transformation it is necessary to know at least 3 identical points but due to sequence of particular surfaces of the whole object it is necessary to enter a maximum number of known identical points.

4.4 2D presentations

Concerning the necessity to present the 3D model also in printed form, the system has an integrated tool for simple presentation creation. Within one document it is possible to create a number of presentations; each presentation can consist of a number of sheets. Texts, geometric formations and 2D presentations of spatial objects (automatically calculated from the 3D model) can be placed on every sheet.

4.5 Object selection according to criteria

One of the main project goals was to create a simple tool for filtration of particular objects within the whole 3D model according to various criteria. The final application enables to apply filtration on geometric characteristic (e.g. an object larger than 1m) as well as data characteristics of objects (characteristics saved in external XML file or database). The selection can be simply saved and eventually a setting of a color and solid style in which the object will be displayed can be made. Selections saved this way can be called out anytime. Several selections can be displayed in one 3D model at the same time. In case that some object is a part of more selections, it will be displayed in the color and style of the selection found as the first. Each object can be a part of any number of selections but in the same moment a selected object may be highlighted by 2 selections only (full colour + crosshatch). When the selection is deleted, objects, of course, remain intact but if the object itself is deleted information about selection/s of the deleted object is lost too.

4.6 Outputs

An important part of the whole system is also represented by tools intended for data export to external formats, eventually for preparation of print sets. The main output tools are:

- 3D drawing – any part of the 3D model can be exported, for instance it is possible to export a part of the model defined by selection, .dxf format is used as the export format
- text data – it is possible to export characteristics of selected objects, the exported data can be saved in

.XML format and in .CVS text file (particular records separated by semicolon)

•print outputs – using a connected printer it is possible to print a prepared presentation and also a simple list of selected objects.

5. Conclusion

This report is focused on documentation of Charles Bridge in Prague (UNESCO, Czech Republic) by using laser scanning, photogrammetry and GIS. This project is sponsored by grant Czech Grant Agency Nr.205/04/1398.

References

[PD03]   PAVELKA K., DOLANSKY T., Using of non-EXPENSIVE 3D Scanning Instruments for cultural heritage documentation, *Symposium CIPA, WG 6, A*ntalya, Turkey, (Sept.2003), 237-241

[PAV05]   PAVELKA K.: Komplexní fotogrammetrická dokumentace Karlova mostu a jeho výsledky, *Seminar „Aktuální problémy fotogrammetrie a DPZ"* ISBN 80-01-03417-8, FSv ČVUT Prague, (Dec.05), 115-124

[PAV05] PAVELKA, K., Dokumentace a průzkum pat pilířů č.8 a 9 Karlova mostu, *Seminar „Aktuální problémy fotogrammetrie a DPZ"* ISBN 80-01-03417-8, FSv ČVUT Prague, (Dec.05), 135-141
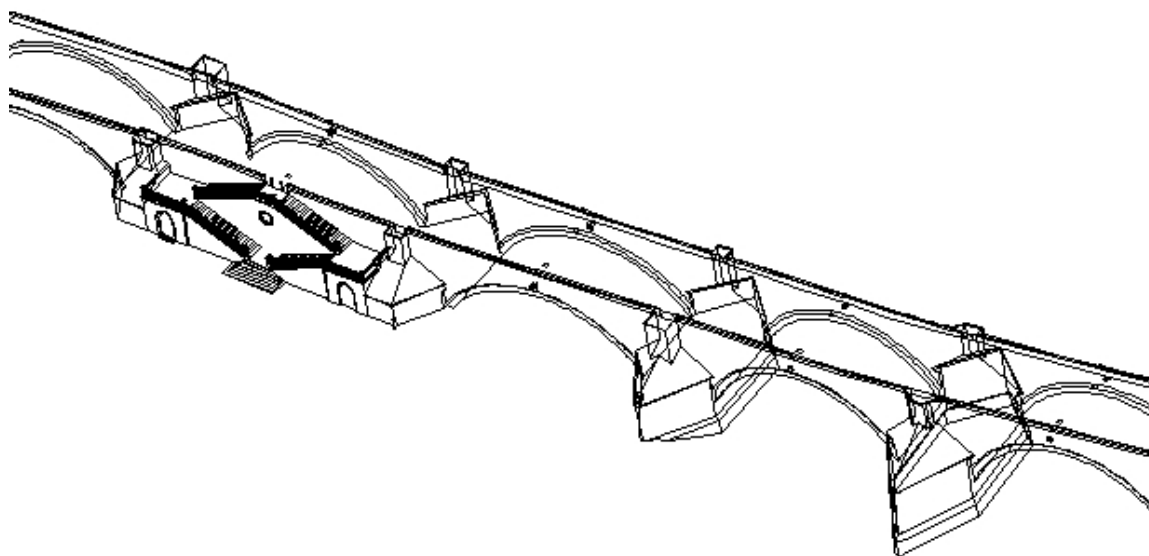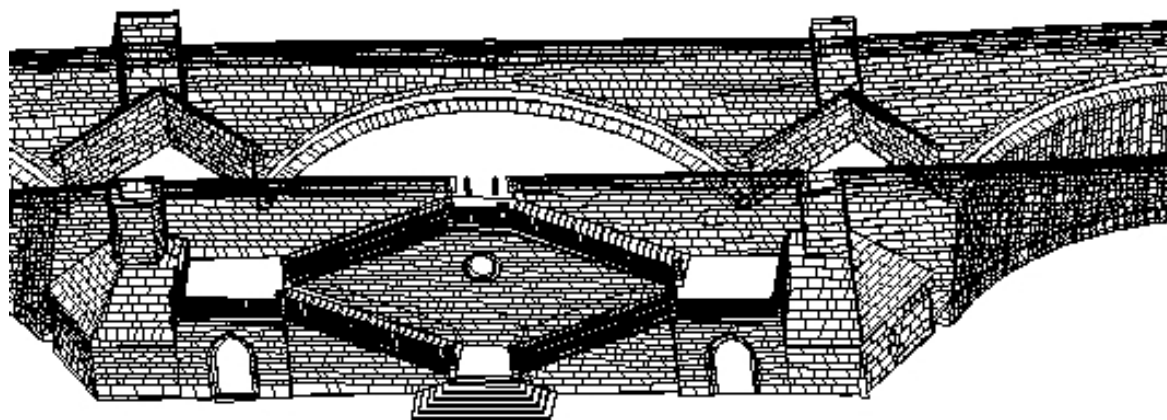

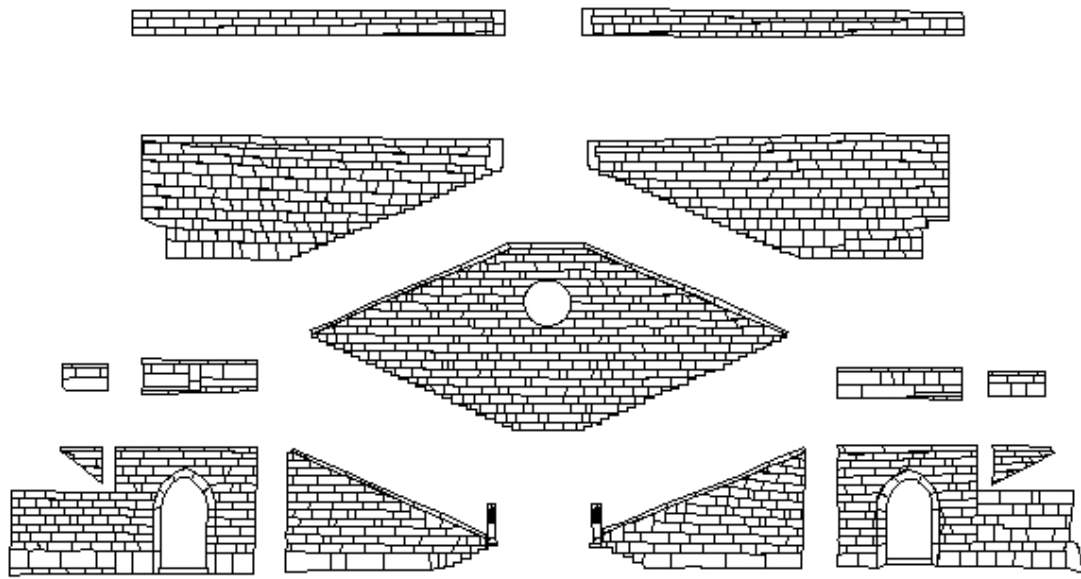**Figure 5:** *Edge vector model (Firm Gefos a.s.)*

Figure 6: *3D model*
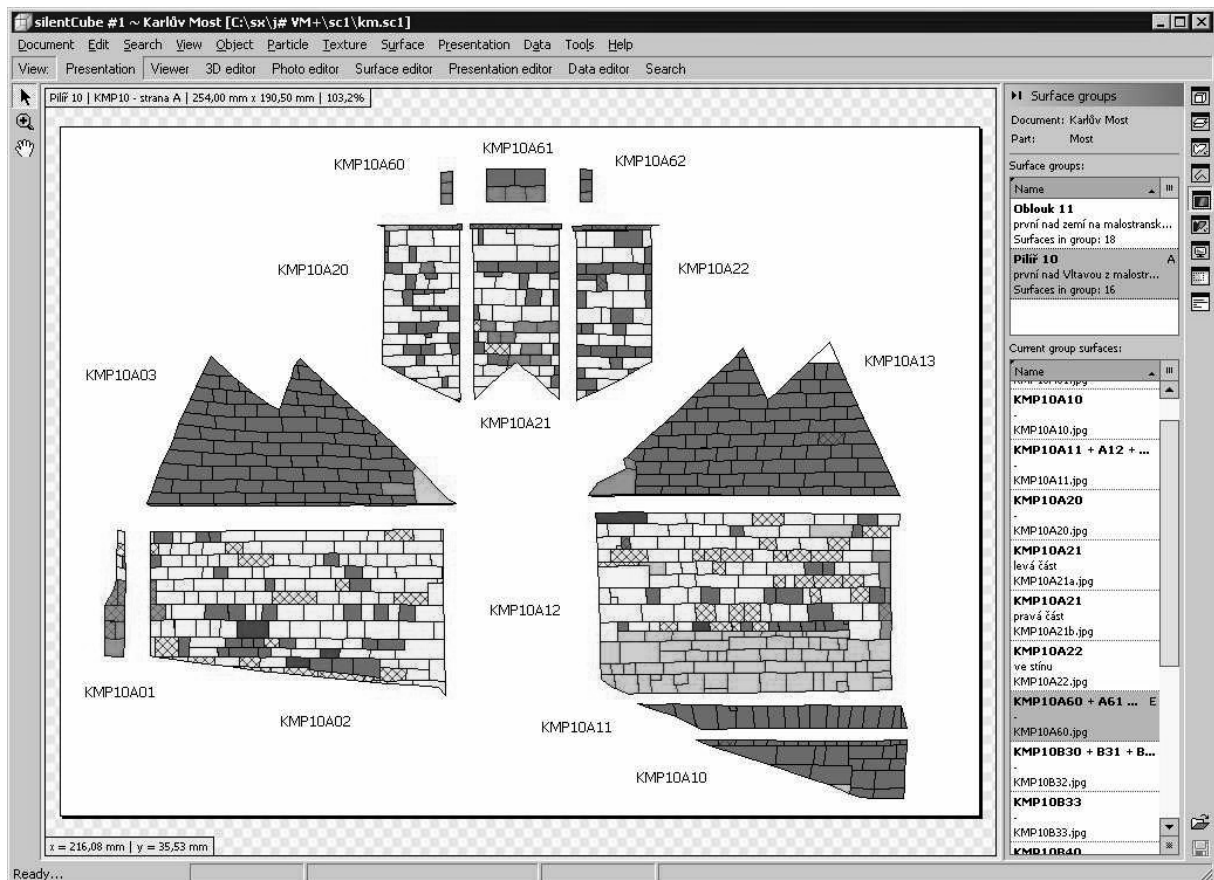
Figure 7: *2D planes*
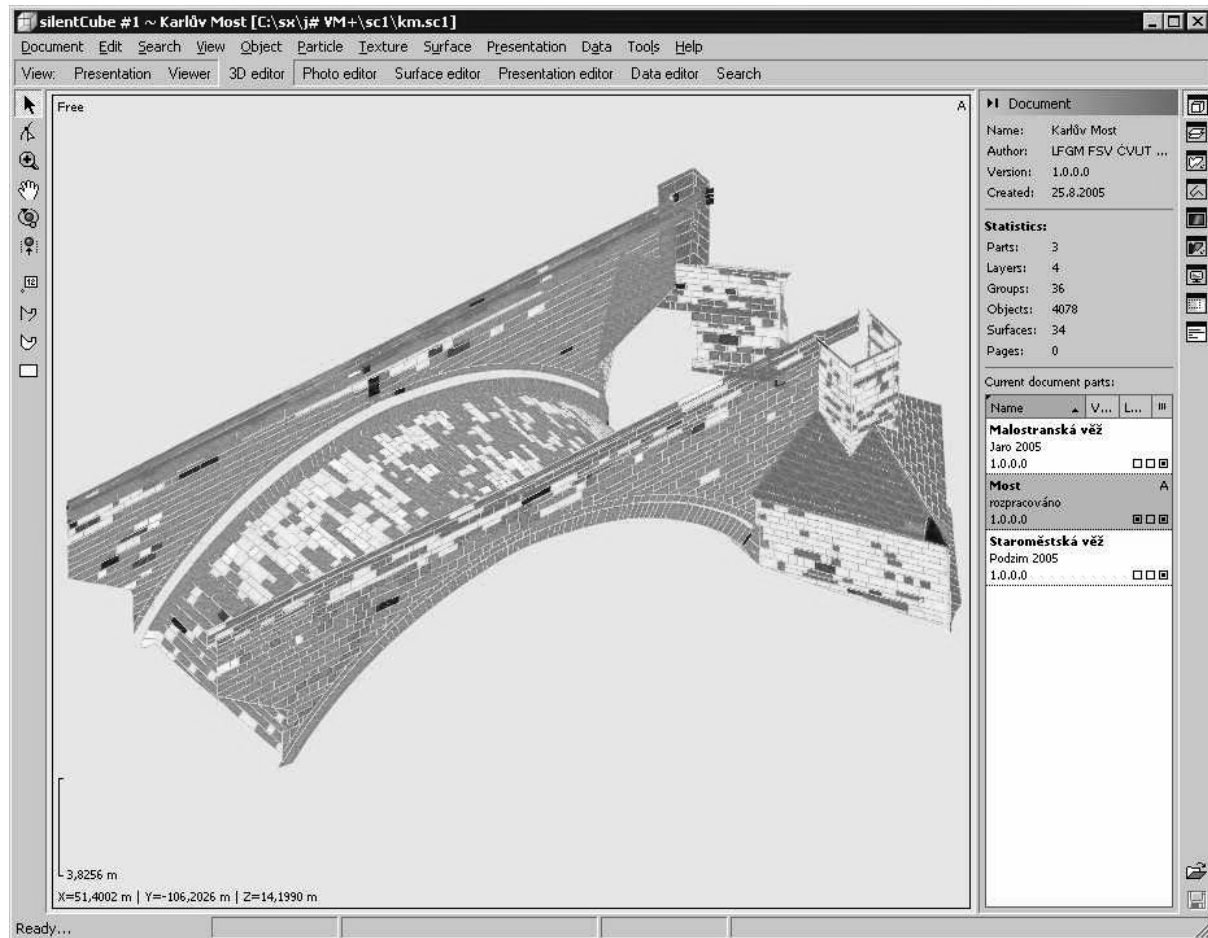

Figure 8: *2D outputs*

Figure 9: *3D database of Charles Bridge*

Figure 10: *Documentation of Charles Bridge*

Graphical Annotation of Semantic Units in a 3D GIS for Cultural Heritage Research and Presentation

T. Reitz[1], J. Haist[1] and D. Wigg-Wolf[2]

[1]Fraunhofer - Institut für Graphische Datenverarbeitung, Germany
[2]Deutsches Archäologisches Institut, Johann-Wolfgang-Goethe-Universität, Germany

Abstract

This paper is to show that an interoperable 3D GIS with support for semantic information can be used for very finely granulated objects as well as for objects covering vast expenses, thus allowing to link models of an archaeological find, its surroundings and the larger landscape in a single system. For this, a common model that allows the management of semantic data which is loosely coupled to features, or parts of these features, of the real world, has been designed. It permits to give objects multiple meanings, depending on the concepts of the individual users, as well as to give semantic data specific areas and levels of validity. This approach is then explained by showing two use cases – one in a numismatic context, the other one exploring the development of wall paintings over time. In both cases, even minor elements in the images used can be defined as semantic areas and be annotated with information, both for expert and amateur users. By providing a Java-based Internet tool, these users can collaboratively work on these interpretations and annotations. Finally, the time component is shown to be important for both cases, and ways of presenting changes over time are given.

Categories and Subject Descriptors (according to ACM CCS): H.3.5 [Information Storage and Retrieval]: Online Information Services, H.3.7 [Information Storage and Retrieval]: Digital Libraries

1. Introduction & Objectives

A multitude of technologies is currently being investigated for their applicability in the context of cultural heritage applications [OBP04]. These technologies include geographical information systems (GIS), used for the visualization, management and especially for the mapping of finds. Like cultural heritage itself, GIS research is a wide field in which a multitude of engineering and scientific fields are touched. For the context of this work, the applicability of an interoperable, net-based 3D GIS with temporal support (also known as a 4D GIS) is researched for several use cases in cultural heritage. One of these is the collaborative annotation and scientific use by archaeologists, another is the presentation of information to a greater public, and the final one the use of such a system for education. More specifically, the stakeholders that can benefit from this work are:

- *Experts* in the cultural heritage field like archaeologists wishing to interpret and analyze finds collaboratively. This can be done by selecting finds, annotating them,

reading other's annotations and also commenting on these annotations. The collaborative work is ensured by providing access to the annotations and 3D data via an interoperable GIS, consisting of a server and a specialized client for the advanced annotation interactions described in this paper. These experts also have a need of publishing their data in a searchable and retrievable way in the Internet.

- So called *intermediate users* [Coo03], i.e. users with a high interest in the subject and preexisting knowledge on the topic. Examples for this group are teachers and hobbyists (numismatics wanting to know where their items were found and the like)

- *Casual* users, i.e. tourists or other groups without specific knowledge on the topic. The system could be made accessible on-site or at a museum for this audience.

Generally, 3D content creation systems are being used to visualize reconstructions, to give both experts and amateurs alike an additional way receiving insights into old settlements or other structures. A 3D GIS aims to allow both,

that is, to manage the actual, complete data including 3D shapes and attached attributive data, and to create rich visualizations. However, the uses mentioned above also have specific requirements, especially when it comes to scientific work, like analyzing finds and trying to interpret them. For this, our system makes use of social software concepts, like the Wiki. A Wiki is a system in which everyone can change or add information, to create a set of linked hypertexts. Wikis have the advantage of reflecting a lot of knowledge that is otherwise implicit in a society since they animate every user to contribute his specific knowledge ([Wag04], [Hef04]). Another concept used is tagging, a process in which a user can assign simple words that represent a concept to an item, thus categorizing the item. Tagging is used throughout social software, be it for annotating images (`Flickr.com`), links (`del.icio.us`) or scientific publications (`connotea.org`), mainly to convey semantic information. As knowledge management systems, these approaches have received some criticism [Car05], but at the same time, they enjoy continued support and have grown to a considerable size.

Together with the data management and visual capabilities of our GIS, which include non-photorealistic rendering as well as simple environment simulations, these concepts form a system that can be used by the described user groups in a variety of ways, such as the following:

- Visualization of the changes of elements of time, specifically of wall paintings. One example where this can be applied would be to see modern reconstructions or various phases of paintings in churches or other buildings.
- Selection and annotation of areas within the 3D scene by using a specialized picking tool and a dialog-oriented 2D interface.
- Commenting and adding on annotations that have already been given, thus enabling a discussion between experts in the actual context of the finds.
- Reading of information that is assigned to specific areas of a 3D scene, e.g. characteristic units of a wall painting or of areas that have a common meaning, such as a finding. This visualization can be customized towards a user group by specifying an intended audience for each annotation.

Our hypothesis is that these use cases can be covered by a 4D GIS with support for semantic and thematic data by using the geographical context as the connecting element, and that such a 4D GIS can bring with it a series of specific advantages to cultural heritage users:

- Data with a geographical reference can be linked into a 3D environment from all kinds of sources, freeing experts from the requirement of modeling the environment themselves.
- Attributive data from the field of cultural heritage, like the distribution of finds, is presented in a rich, interactive way and in its context.
- Both spatial and thematic data are accessible, can be fil-

tered by various properties and be researched by various user groups.

What needs to be done to link a system with these capabilities to the user groups is the development of domain-specific tools, in this case for cultural heritage research and and to view this information in a user-customizable and filterable way. These are described in the following chapters.

In comparison to standard GIS, this system is special in that it can be classified both as "feature-driven" and as "domain-data-driven". In a "feature-driven" system, which is the most common modeling structure in GIS, information is connected to physical features of the real world, while in a "domain-data-driven" system spatial regions, features or other classes of localizations are attached to data from all kinds of domains. This approach gives us the flexibility required to employ a single system for the described applications and wide group of users.

2. Related work

The usage of a 3D GIS or even GIS with temporal support alone is not a new idea. Especially for presentation purposes, 3D GIS, in some cases with an Internet client, have been used, such as in [GWMS03]. Also, the presentation of dynamic objects or objects with temporal uncertainty has been a subject of research. However, in practical work, the use of a 3D GIS with Internet support is still not very common. For presentation purposes especially, purely presentation-oriented systems like *Shockwave* are used, with relatively limited degrees of interaction, especially with other users.

When looking for systems that allow to annotate geographic areas, one will find that this concept is quite commonly used currently, with the most prominent applications being based on Google Earth. In this software and applications based on it, locations can be tagged or enriched with information by using the KML interface to Google Earth. However, these annotations are limited to simple 2d-Points. Also, there is a lot of social software employing comparable approaches, like the aforementioned *Flickr.com* or *Blogwise*, which allow to add a geographical location to an image or text.

Using a 3D or 4D GIS for data management in cultural heritage seems to be rather uncommon, Most of the time, the formats specific to the technology employed for capturing data are using, like specific 3d scanner formats. For thematic data, simple databases that are customized towards the specific type of finds or other requirements are used. Often, theses are desktop databases connected to a database application, which make it hard to share the contents.

For managing the semantic aspects of cultural heritage data, there has also been research in applying semantic web technology on the specific data and issues that cultural heritage brings with it. An interesting approach was presented

in [SLM06], where a system using ontologies and mappings between these used data from four content providers was demonstrated. This is very much akin to the handling of ontologies in our system, where so-called core ontologies are used to map between various domain-specific ontologies.

Regarding the user interface, so called 2.5D WIMP GUIs are still widely regarded the most usable class of interfaces, even though in research many other concepts have been tried. These GUIs have been improved over the last 25 years and are capable of offering many views on the same monitor, multiple windows stacked on each other and employ embedded 3d scenes or effects. An example for such a GUI is the current MacOS interface. There have been some attempts to use complete 3D GUIs, among them the Looking Glass Desktop from SUN and also interfaces for immersive environments, like a CAVE. However, these interfaces usually shine only in a small area of applications, and give no advantage to reading or writing text, for instance.

Since much of the information that will be linked in into our system is text-based, we have decided to not integrate the annotations as a whole directly into the 3d windows of our system, but instead to use multiple windows that are opened when a user selects the appropriate tools and annotations from the 3d scene. This allows a gradual shift between the 2D and the 3D UI paradigms and plays on the strengths of each concept in a complementary way. There has been some criticism regarding these dimensionality breaks, but this criticism was mainly directed at immersive stereoscopic systems, where the eyes actually have to adapt to varying object distances.

While both individual elements employed in the concept, 3D-GIS and the digital presentation of semantic information, are regularly used separately by the stakeholders, the combination of both in a single module is this form is new. Museums and archaeological websites often present animated 3D-reconstructions of sites and objects, and in particular the former employ electronic media with different content levels to reach both the expert and the lay visitor. However, the quality and quantity of semantic information, in particular for the expert, are generally limited. Sources of electronic content for the expert are generally restricted to classic databases or else 2D graphic presentations (e.g. www.findsdatabase.org.uk).

The concept presented here not only seeks to combine the best of previous approaches, it goes further than the individual elements, improving the quality of both visual and semantic content. In particular, the provision of a facility for the expert stakeholder to annotate fields in this form opens up new possibilities for academic discussion.

3. Using a 4D GIS to integrate and create information

For this work, the core aspect was to provide a set of usable tools to heterogeneous groups to add annotations to 3D

scenes and to link their thematic data into a 3D GIS. This is done by the provision of a set of interactive tools, from which the back-end concept is then developed.

Figure 1: *Selection tool for annotating a texture image in a richly textured 3d scene of a latin caldarium.*

3.1. User View

The first and most basic tool is for the selection of an area in the 3d scene, as displayed in Figure 1. This marquee can be either an area (e.g. a rectangle) or a volume, like a box. The selection and marking of annotations is implemented by using variants of the virtual pointer ray-casting and aperture UI metaphors [BKLP04]. This means that a ray is calculated from the virtual camera position to the mouse cursor when the user clicks, which is projected into the 3d scene. For the creation of scopes, this metaphor is extended to an aperture metaphor, where clicking for several times will create a selected area with a direct visual feedback.
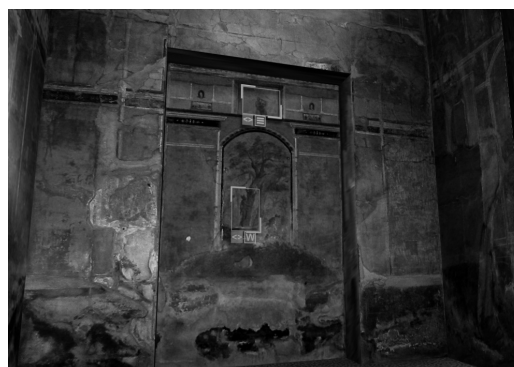

Figure 2: *Annotated Regions of a 3d scene.*

For example, the tool for creating a rectangle required two clicks, while three are required for a box. The area picker can be used on any geometry, like a cave wall or a church portal, as long as a continuous surface exists and the starting and end points are visible to the user. This means that in the

case of a column, the tool is limited to selecting a portion slightly less than half of the column. More complex forms can also be covered, like a closed polygon. This requires a relatively complicated user interaction and will be reserved to advanced users, and also not implemented in the first version.

Figure 3: *Creation of a WikiAnnotation by using a dialog and the typical MediaWiki syntax.*

When such a marquee has been created, it can be modified, so that it fits the intended region in a better way, and its border type can be defined. When a user thinks his selection is correct, he can click on one of the icons displayed below the selection. Each of these icons represents one of the annotation types that are available. Following this selection, a dialog is created that contains the input elements specific to that type of annotation (Figure 3). However, creating information is just one step. The second step is using and visualizing that information. For this, a filter panel is used that allows a user to preselect the information he is interested in by thematic, spatial and time criteria, as well as by user-specifiable criteria like a full-text search. The annotations that match these filter criteria are then displayed as marquees in the 3D window, with the annotation types already attached to a scope in inverted tones. Clicking on one of these icons allows the user to view the "deposited" information in a window created on top of the 3d scene.

An additional type of selection tool available in the spatial annotation view also allows to display time-variance in the state of the objects inside the selection, if this data was acquired. This tool can be used for example to compare different wall paintings that have been painted on top of each other, or to compare a wall painting before and after a restoration. This can help both amateurs and professionals to directly understand these developments and reconstructions.

3.2. Scopes

As mentioned, another important aspect in the design phase of the system was to allow the system to be driven from var-

ious information directions. To achieve this, each information object, including the annotations as well as metadata, gets assigned to a scope. A scope can be of different types, for example of these:

- *Global:* The selected area is expressed relative to the global coordinate reference system.
- *Local Object:* The selected area is expressed relative to the transformed coordinate reference system of a geometric object, like a building.
- *Local Surface:* The selected area is expressed relative to the transformed coordinate reference system of a surface of a geometric object, like a single wall.

When a user now wants to use his thematic information by linking it to the system, he can do so by importing the data. For the creation of the scopes for the imported data, several strategies can be used. The easiest way is the availability of coordinates attached to the thematic data (Global Scope). However, attribute-matching to Features can also be used (Local Object Scope). Attaching the information automatically to local surfaces in a common way is rather difficult, so we have provided an interface in the style of the *Strategy* pattern, that is, the user has to provide an implementation that "knows" how to attach the thematic information to surfaces. In this approach, the data remains with the creator and does not need to be copied to another resource. It can be made available to others by publishing it as a data model, but that is not a necessary precondition. In this way, the data can be easily used in various applications and can also be kept in a structure reflection the individual requirements, as opposed to a central data store with a fixed scheme.

3.3. Information management and Back-End

Leaving the level of user interaction and the visible objects, another core aspect of this work is, as described, to also provide the back-end framework to collaboratively annotate geometric representations of cultural heritage sites and to filter and read this information. For this goal, several preconditions need to be fulfilled. One of these is a data model capable of handling the complex relationships between the data, as shown in Figure 4.

We are using a data model that describes both geometric data of all kinds (the so-called common functional model [Rei05]) as well as quality information, thematic data and semantic information. This latter data is linked to geometric data via a concept of areas of validity. Generally, such an area of validity is rather abstract. It can be defined in 2D or 3D space and include a time component, be described by simple geometric form like a rectangle or a complex form like a NURBS surface. Furthermore, the concept allows to select between absolute borders, uncertainty areas and smooth borders by supplying the *Section* with a characteristic curve (Figure 5).

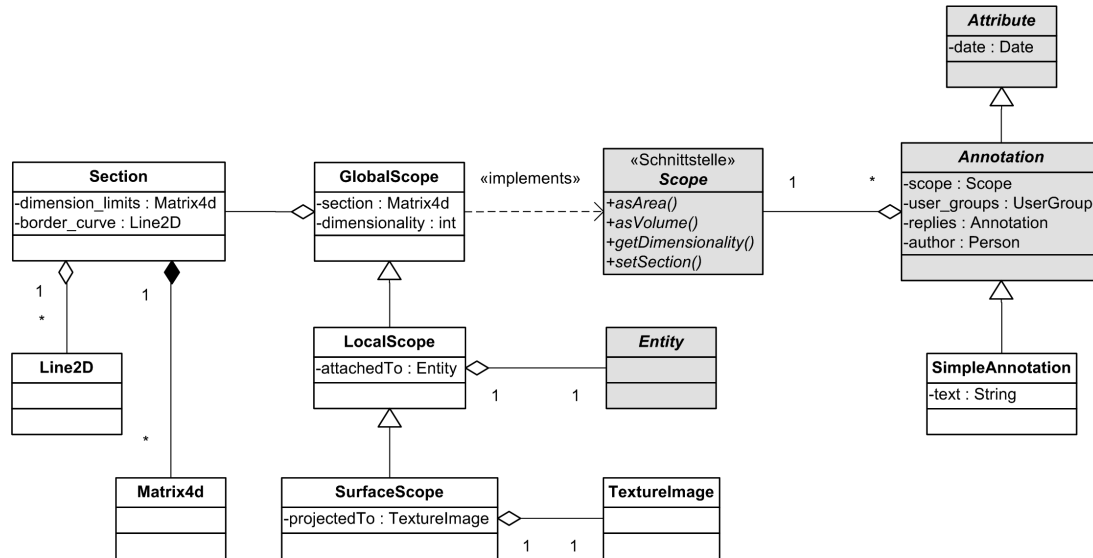Annotations are modeled as Attributes in the common

Figure 4: *A simplified UML class diagram showing the relations between information elements (Attributes and Annotations) and spatial elements (Entities and TextureImages).*

functional model, which are a general container class for all kinds of thematic data, ranging from semantics to binary multimedia data. Annotation types supported in our implementation are:

- *SimpleAnnotation:* A simple text annotation, without additional media linked in, or advanced formatting. This can efficiently be used for discussions, via the children attribute inherited from the abstract superclass Annotation. We are using this type to provide a Usenet-style threaded discussion capability.
- *ConceptAnnotation:* This type represents the attachment of a concept in the sense of an element of an ontology. In social software, this ontology is usually built dynamically by the users by tagging, as described in the introductory chapter. Both basic structures can be very useful; using a given ontology will be the rule if a specific schema exists for a certain area of scientific work, while the dynamic variant will be useful in cases where such a common nomenclature does not already exist. In our case, we are evaluating whether so-called micro-formats [Kin05], structures that have resemblances both to a formalized ontology and a dynamic ontology, can be created in such an environment. When entering a ConceptAnnotation, the system suggests concepts to use by querying what other Annotations are incident with the new scope.
- *WikiAnnotation:* In this implementation, this is simply modeled as a link-in to a Wiki page, that is, a document that can contain markup, text, links and images, is saved in a specific format and usually rendered in HTML by a browser. An Annotation-Tree can only have one WikiAnnotation (children of the same type are not allowed).

- *ImageAnnotation:* This annotation has been included as an example of adding other media than (hyper)texts. The ImageAnnotation can either access a local resource or an Image available via http.
- *RatingAnnotation:* RatingAnnotation: This Annotation type can be used to express the quality of another annotation, that is, it can only be used as a child to another Annotation.

One can always add multiple annotations to a scope; a typical range would be a *WikiAnnotation*, a *SimpleAnnotation* (with subsequent discussion elements) and a *ConceptAnnotation*. Optionally, an Annotation can also have a target domain, that is, a reference to a certain user group. This allows the author of an annotation to declare at what kind of people his work is targeting.

Figure 5: *Various border definitions, the first without a fall-off line, the second with a fall-off resembling a Gaussian normal distribution, and the first one defined by an additional polygon defining the starting of the decay.*

On the level of persisting the annotations, we have decided to keep only a minimum of information in a central

core database, with the actual annotations being saved in the system that matches them best. For example, the WikiAnnotations are saved in a MediaWiki, with only the scope, some metadata like the date and the author and finally the URL being saved in a linking database. In the same way, multimedia content is linked, since there is no benefit to be gained from centralizing these often very big objects.

4. Evaluation

The evaluation of this concept is done by implementing it and then providing the system to two user groups, one being researchers who specialize in the analysis of ancient coin finds. The sample area for this case is the Martberg, where both celtic and roman settlements were located and where more than 10.000 finds were already made [WW98]. The data that these archaeologists have collected consists of several databases, each with information on where a find was made and will be interpreted by a team of scientists. For the evaluation, a set of questionnaires will be used to determine whether the capabilities of the system and the user interface cope with the requirements for their work, especially with the aim of providing a scientifically usable and accurate tool.

A second evaluation scenario is based on the wall paintings of the same settlements. These have been reconstructed carefully from fragments [Gog06] that were found and are now being annotated with the various elements. The aim of this scenario is to have both a data entry phase, but also to have a presentation platform for the intermediate and casual users. Again, evaluation will mainly follow the established usability research methodologies.

5. Conclusions & Outlook

With the implementation of the concept currently being finalized, we can not yet draw final conclusions, but the need for the described tools has shown itself in interviews with field experts. Regarding the presented concept, it has already shown itself to be very versatile and is also being used in other projects, e.g. to represent points of interest. With respect to the developed tools, our aim was to keep them simple in a first step by limiting the forms that can be created; however, additional capabilities will be necessary later on.

Besides these implementation details, one of the main aims we are following for future development is to enable everybody to publish his thematic data into the geospatial domain. For this, one of the most important aspects is to make the linking of this data to other thematic information and the GIS data as easy but at the same time as flexible as possible. This requires the additional investigation into concepts on how semantic information can be easily mapped from one thematic domain to another, an area where we think that many of the concepts coined under the term of social software can be used. These strategies will then have to be adapted to specific user groups, and be tested.

References

[BKLP04] Bowman D., Kruijff E., Laviola J., Poupyrev I.: *3D User Interfaces*. Addison-Wesley, 2004.

[Car05] Carr N.: The amorality of web 2.0. (online resource: www.roughtype.com/archives/2005/10/the_amorality_o.php).

[Coo03] Cooper A.: *About Face 2.0*. John Wiley & Sons, 2003.

[Gog06] Gogräfe R.: Die wandmalereien im tempelmodell des mars-lenus-heiligtums auf dem martberg bei pommern. In *Der gallorömische Tempelbezirk auf dem Martberg bei Pommern* (2006), pp. 97–157.

[GWMS03] Grabner M., Wozelka R., Mirchandani M., Schindler K.: Web-based visualization of virtual archaeological site. In *Proceedings VAST, 2003: The 3th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage* (2003).

[Hef04] Hefke M.: A framework for the successful introduction of km using cbr and semantic web technologies. In *Proceedings of I-KNOW '04* (2004).

[Kin05] King R.: An evolutionary revolution. (online resource: theryanking.com/blog/archives/2005/04/07/an-evolutionary-revolution/).

[OBP04] Owen R., Buhalis D., Pletinckx D.: Identifying technologies used in the cultural heritage. In *Proceedings VAST 2004: The 4th International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage* (2004).

[Rei05] Reitz T.: Architecture of an interoperable 3d gis under special considerance of visualization applications. Master's Thesis, Furtwangen University.

[SLM06] Sinclair P., Lewis P., Martinez K.: Semantic web integration of cultural heritage sources. In *Proceedings. International World Wide Web Conference* (2006).

[Wag04] Wagner C.: Wiki: A technology for conversational knowledge management and group collaboration. *Communications of the Association for Information Systems 13* (2004), 265–289.

[WW98] Wigg-Wolf D.: Coins and cult at the martberg: a case study. In *Studien zu Fundmünzen der Antike, Band 19* (1998), Verlag Philipp von Zabern.

New Trends in High Resolution Survey for the Cultural Heritage Metric Survey Applications for Restoration

F. Rinaudo[1], L. Bornaz[1], L. Peretti[1], C. Porporato[1]

[1] Politecnico di Torino – DITAG – Torino – Italy

Abstract

High resolution 3D survey systems have long existed especially for mechanical applications. Prototyping high resolution instruments have also been developed and used in the Cultural Heritage field in order to create accurate 3D models able to form a strong basis for reproduction, restoration and conservation purposes. Different solutions have been proposed that are: laser distance measurements on controlled mechanical tables, self-controlled harms, stand-alone instruments, etc. Different measuring principles have been successfully adopted: laser distance measurements, structured light, laser triangulation, etc.

All these systems have some limitations from an economic and technical point of view. The technical problems are due to the stability of the acquisition reference systems during the survey or to the need to have direct access to the object. The economic problems are due to the high costs of the instruments.

A new generation of high resolution and high precision scanners have recently been introduced: these try to solve both the previously mentioned problems. At a cost of less than the usual amount for a terrestrial scanner of low accuracy and with a direct survey in a 3D reference system materialised on the object, or nearby, these new instruments (the so-called third generation scanners) allow a complete surface of convex and concave objects to be scanned avoiding the necessity of moving the object from its natural location and without heavy instrumentation.

The paper describes this new generation of instruments, recently acquired by the Research Group, and a first comparison with old instrument generations is made in order to point out the new opportunities offered by them; the new applications in Cultural Heritage documentation and further developments of reverse engineering and prototyping in this domain are underlined.

Categories and Subject Descriptors (according to ACM CCS): J.6 [Computer-aided Engineering]: Computer aided Manufactory

1. Introduction

3D surveying is becoming more and more important in many applications fields.

In land, architecture and archaeological surveying applications the old approach concerning the 2 ½ D modelling has been replaced by modern technologies such as LIDAR, GPS, digital photogrammetry (generally called direct geo-referencing technologies) which allow an easy and attractive solution to a complete 3D survey approach.

While the previously described goal was achieved in the last decade, the complete 3D approach, with a high degree of accuracy (less than 1 mm), was approached in the past by many other industrial and scientific applications (e.g. Animation, Archaeology, Architecture, Dentistry, Education, Fashion and Textiles, Foot Wear, Forensics, Games, Industrial Design, Manufacturing, Medicine, Movies, Multimedia, Museums, As-built Plants Rapid Prototyping, Reverse Engineering, Sculpture, Toys, Mold Making, Web Design, etc.).

Many surveying principles have been adopted (e.g. triangulation, LIDAR technology, structured light, photogrammetry, holography, etc.) and the 3D survey has been realised using different solutions in order to

guarantee the stability of the reference system.

The accuracies range from 20 µm up to 0.2 mm and a wide range of software solutions offer the technicians a complete and affordable approach to the 3D survey.

2. The stability of the 3D acquisition reference system: possible solutions

The accuracy of the 3D survey systems depends on two main factors: the accuracy of the single point acquisition and the stability of the reference system used during the acquisition of the whole surfaces.

As far as the accuracy of the single point acquisition is concerned, the adopted techniques are able to reach the required accuracy: LIDAR, triangulation, holography, digital photogrammetry, structured light, if well used, are able to obtain all degrees of accuracy.

The stability of the reference system during the acquisition process was solved in the past by considering the object as being movable inside an equipped laboratory or situated in a site where it is possible to install the instruments.

Laboratory instruments are based on two different solutions:
- a more classical approach, where the stability of the reference system is guaranteed only by using mechanical solutions (see Figures 1 and 2);
- advanced solutions, where the stability of the reference system is controlled by a mechanical and stable system and by a remotely controlled solution (see Figures 2 and 3)

Figure 1: *Left - CAM³ᴰ an optical 3D sensor for fast and high-precision object shape scanning / Right - The FARO Laser ScanArm the first ever seven-axis contact/non-contact measurement device with a fully integrated FARO Laser Line Probe*

Some portable Laser Scanner can be considered in the same class of high resolution instruments as a possible solution for reducing the volume of the instruments to be moved when the object cannot be displaced from its original location. In this case, the reference system is fixed by using a tripod and can be moved quite easily around and inside the object to be surveyed (see Figure 4).
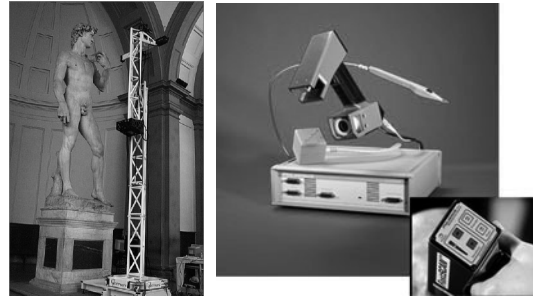
Figure 2: *Left - Laser scanner used in the Digital MichelangeloProject / Right - FastScan Cobra a single camera laser line scanner. It uses a built-in magnetic tracker to obtain the position and orientation of the scanner.*

Figure 3: *Leica T-Scan laser remotely controlled by the Laser Tracker*

Figure 4: *The Minolta VIVID Laser Scanner*

An analogous solution is the one adopted in hand-held scanners which use a built-in magnetic tracker to obtain the position and orientation of the scanner during the survey (the limitation is that only non metal objects can be surveyed because of interferences with the

magnetic tracker. See Figure 2).

All the previously shown solutions consider the stability of the reference system during the acquisition to be guaranteed by the mechanical stability of the used structures and, obviously of the floor where these structures are located on.

If these conditions can be satisfied inside an ad-hoc laboratory and if the object has to be surveyed in other sites, the scanning is only possible if all kinds of vibrations are avoided during the acquisition phase. High resolution scanners usually have to be placed very close to the object and if a scaffold is needed, the reference system cannot be considered as stable as in the level of accuracy that is typical of this kind of instruments.

In order to avoid this kind of problem the solutions adopted is not to fix the reference system inside the instruments but on the object itself. These instruments are mainly based on a photogrammetric approach. (see Figure 5)

Figure 5: *TRITOP photogrammetric*

In these cases, an accuracy of less than 1 mm can be achieved by using calibrated digital cameras, strong image blocks and the scans of the recorded object have to be performed using special digital photogrammetry software (e.g. autocorrelation at a sub-pixel level, etc.). The acquisition phase is quick, but a control network has to be build and the post processing of the primary data can be heavy in terms of time.

The stability of the reference system is achieved assuming that the surveyed object is a rigid body during the image acquisition and the camera is stable during the exposition time.

3. Practical considerations

All the solutions that were rapidly and not so completely described in the previous paragraph have been realised to satisfy particular needs, so it is obvious that not all the possible external survey conditions can be managed in a proper way.

In addition, if the shape of the object is very complex (convex and concave surfaces like a pot or a jar or a statue) the mentioned systems can mean many scans have to be performed in different configurations of the system itself: in this last case, the single scan has to be registered at the end of the acquisition phase. Sometimes the object is small and many of the available systems cannot perform the scan due to the dimension of the devices.

A new 3D scanning system is described in the next paragraphs. This new solution (presented at the end of 2005) adopts some new solutions which can be useful to overcome the limits of the old systems, especially in the field of architectural and archaeological high resolution 3D surveying.

4. The HANDYSCAN 3D by CREAFORM

Produced by CREAFORM, a Canadian Technological centre for reverse engineering and 3D digital solutions, HANDYSCAN 3D has been classified as the third generation instrument of high resolution 3D scanners.

It has been presented as the first self-positioned hand held scanner in the world.

The basic idea of this instruments is very simple (it is a digital photogrammetric system) but the adopted solutions represent a true novelty from different points of view in the Cultural Heritage surveying field.

The first interesting aspect is the dimension and the weight of the acquisition unit which can be handled for long periods without stress for the operator and it allows the possibility of obtaining all the details even in the case of very complex objects.

The second attractive aspect is the possibility of acquiring objects of different dimensions: from small objects (e.g. rings, fragments, etc.) to very large objects (e.g. statues, large epigraphs, etc.).

Figure 6: *Handyscan 3D: the acquisition unit (980 g, 160 x 260 x 210 mm, ISO accuracy: 20 μm + 0.2L/1000)*

Finally, the third attraction is the price, which is lower than the current quotations of the less accurate terrestrial laser scanners, even considering the laptop for the storage and the visualisation of the acquired data.

4.1 The acquisition phase

The acquisition unit (see Figure 6) contains two digital cameras mounted onto a rigid body. Four laser spots are

placed around each lens and, at the bottom of the handle, there is a special laser tracker which is useful during the acquisition process to mark the surveyed points.

Before starting the survey, the instruments have to be calibrated both as far as geometry an radiometry are concerned.

The geometric calibration is performed by using a special control plate which is provided with the instruments (see Figure 7). The scope of this phase is to refine the relative orientation of the two digital cameras in order to avoid small movements of the mechanical components that accour during the transportation or due to the change in environmental conditions and so on. The geometric calibration fixed the base of the photogrammetric system and so the scale of the survey.

The radiometric calibration aims at setting the photographic parameters for the two camera lenses and the intensity of the laser tracker in order to speed-up the measurement process. The radiometric calibration is performed by acquiring some parts of the object with a common texture. If the object has different colours and/or illumination conditions this procedure has to be repeated before starting the acquisition on the portion of interest. (see Figure 7).

Figure 7: *The geometric and radiometric calibrations of the HANDISCAN*

Before starting the 3D survey, the reference system has to be fixed. Several reflective targets (small 6 mm diameter circles) are fixed to the object using an irregular mesh with sides that can reach up to 10 cm. Using the two stereoscopic cameras and the eight spots around them, the reflective targets are surveyed and placed in a unique reference system which is now fixed on the object. If the object cannot be marked directly, it is possible to build-up a control network using other solutions.

In addition the operator defines the volume in which the object (or a portion of it) is contained. This volume is subdivided into voxels. It is possible to choose among three different resolution levels: low, medium or high. For the low resolution, the surveyed box is divided into 2.1 Mega voxels; the medium into 16.8 Mega voxels and the high into 134 Mega voxels. There is therefore a ratio of 1 to 8 between the medium and low resolution voxel numbers and the same between the high and medium resolution voxel numbers.

Figure 8: *Placing the reflective targets on the object.*

The dimension of the voxels (the resolution of the survey) depends on the dimension of the acquisition volume. If high resolution is required, the object has to be split into different scans which are oriented in the reference system of the acquisition thanks to the previously acquired reflective targets. The accuracy is always the highest accuracy of the instruments (see Figure 6 comments). Finally, the acquisition can be started: the operator has to check the distance between the acquisition unit and the object (red and green leds on the top make this possible in a practical way) and, by looking at the laptop, control the completeness of the acquisition that is displayed in real time as an STL format model.

During the survey, the stereoscopic cameras perform the absolute orientation using the previously acquired reflective targets.

At the end of the acquisition, the recorded data are: the target positions, directly acquired points, STL format 3D model.

4.2. Data processing

The handling of the data can be performed using one of the well known software packages (e.g. RapidForm, 3Dmax., etc.). CREAFORM has a special link with Geomagic Studio which can directly manages the data from the HANDYSCAN3D system.

The accuracy of the acquired data, their flexible resolution and the real time check of the completeness of the acquisition phase are the best requirements for a quick and correct model approach.

5. First experiences

The Geomatic research group of the Politecnico di Torino is the first Italian institution equipped with this system and it is testing possible applications of the HANDYSCAN3D in the field of Cultural Heritage Documentation. The activities are supported by the Italian Ministry for Research in a National project (PRIN2004), coordinated at a national level by Prof. Carlo Monti.

The first experiences were developed on two different objects: the Melograno Fountain (in the Issogne - Valle d'Aosta Region –Italy. Melograno means pomegranate tree) and some damaged parts of the Holy Shroud Guarini Chapel (in Turin – Piedmont Region – Italy. Destroyed by a fire in 1997 and now under restoration).

Figure 9: The Melograno Fountain and the Holy Shroud Guarini Chapel after the fire.

5.1 The Melograno Fountain 3D model

The Melograno Fountain requires a protective covering of the inside part of the stone made base because the water is destroying the old stones.
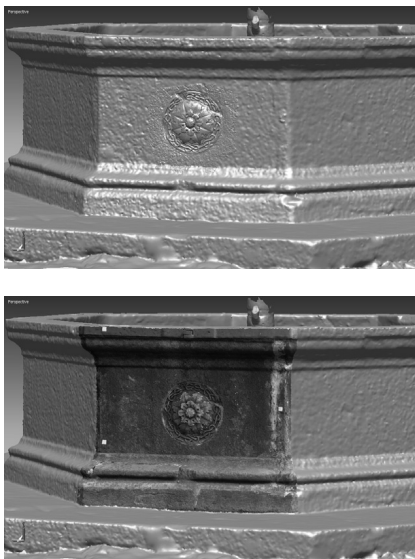

Figure 10: *The multiscale model of the Melograno Fountain (surface and image mapped surface)*

The restorers decided to protect the stone using a special plastic material which had to be modelled exactly following the shape of the interior (see Figure 11). The accuracy required is of about 2 mm. No terrestrial scanners can be used because the lack of accuracy that occures during the modelling process. The surface to be scanned is very large therefore the placing of the reflective targets was a long process and it was subdivided in 8 different scans. The exterior surfaces of the stones was surveyed using a terrestrial laser scanner (RIEGL LMS-Z210) and the decorations again using the HANDISCAN3D. All the three types of scans have been connected using a control network surveyed by traditional topographic instruments. Figure 10 shows the result of the integration in a multiscale 3D model of the stone parts of the Fountain.

5.2 The Holy Shroud Guarini Chapel restoration

The restoration of the Guarini Chapel requires many different professional skill. A multidisciplinary team (coordinated by Arch. Mirella Macera) is working on the different aspects using the most advanced techniques.
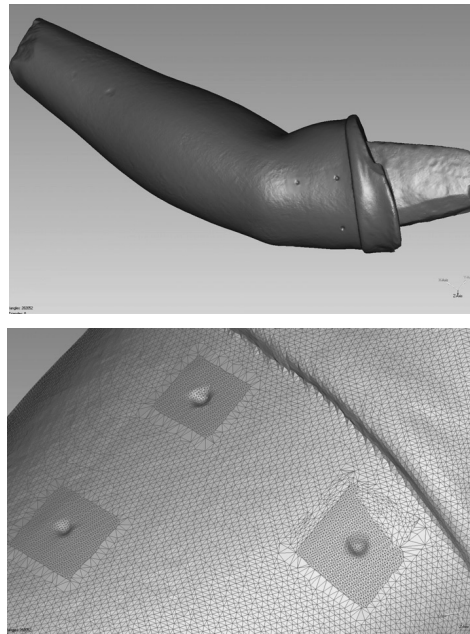

Figure 11: Guarini Chapel: 3D model of a part of a statue's arm (above) and the multiscale model .

As far as the restoration of the decorative stone part of the inside surface of the dome is concerned, the restorers have two main problems: for the restoration of the chapel, they want to replace the destroyed elements

with original materials (mechanical carving stones) or other synthetic materials. For the restoration of the statues, the specialists need a 3D model in 1:1 scale in order to design the mechanical solutions for the placing of the original parts detached by the fire.

Figure 12: *Survey of the stone decorative elements of the Guarini Chapel on a scaffold and 3D model*

HANDYSCAN3D was used in both cases, thanks to its adaptability to extreme work conditions. The survey of the stones to be replaced by 1:1 models had to be done from a scaffolding (see Figure 12) and with an accuracy of about 1 mm, no traditional instruments could therefore be used due to the vibrations of the scaffolding. The replica of the detached components of the statues requires final accuracies of less than 1 mm.

5.3 Practical considerations

Considering the two previously described experiences and other tests performed on different shaped objects it is possible to highlight some interesting properties of the HANDYSCAN3D.

The system is easy to transport and can be managed by a single person.

The acquisition software is very easy to use and self documented: the short course (2 days) provided by the CREAFORM team (EUROFORM3D for Europe) is sufficient to be independent in the acquisition phase of the 3D model. The real time check of the STL model during the survey allows the holes of the scanning to be completed on the field and the subsequent data processing for segmentation and modelling are therefore, quicker and simpler to perform.

The acquisition runs very rapidly therefore the required time only depends on the shape and complexity of the object to be surveyed.

The reference system fixed on the object (or around it) allows acquisition in all cases where more traditional instruments with the same accuracy can make a survey impossible or at least very difficult.

The possibility of using different scan resolutions allows a logical and coherent acquisition: high resolution only has to be applied when necessary.

This possibility avoids the need of strong decimation of the data during the modelling process.

6. Final considerations and "to do list"

Obviously, it is not possible to give a definitive answer concerning the use of HANDYSCAN3D in Cultural Heritage Surveying, but the first results are surely encouraging.

In the next months our research group will:
- expand the test fields in order to test different materials and shapes;
- study the techniques that are useful to orient digital images in order to map the 3D models;
- analyse the metric accuracy of the instruments in different acquisition procedures.

CREAFORM has set up a "HANDYSCAN User website" where the users can share experiences and contact the development team: this is a good initiative to offer producers interesting subjects to improve the performances of this instrument.

References

[BHM01] BOEHLER W., HEINZ G., MARBS A.; The potential of non-contact close range laser scanner for cultural heritage recording (Sept. 2001). International Archives Of The Photogrammetry, Remote Sensing and Spatial Information Sciences. vol. XXXIV-5/C7, pp. 430-436 ISSN: 1682-1750.

[LK02] LIONIS G.S., KYRIAKOPOULOS K.J.: A laser scanner based mobile robot SLAM algorithm with improved convergence properties (2002). IEEE/RSJ International Conference on Intelligent Robots and System. Vol 1, pp. 582-587 ISBN 0-7803-7398-7

[EFP04] EL-HAKIM S.F., FRYER J., PICARD M.: Modeling and visualization of aboriginal rock art in the Baiame Cave. (Jul. 2004) International Archives Of The Photogrammetry, Remote Sensing and Spatial Information Sciences. vol. XXXV-part B, pp. 990-995 ISSN: 1682-1750.

[H00] HEBERT M.; Active and passive range sensing for robotcs (Apr. 2000). Robotics and Automation, 2000. Proceedings, ICRA '00 IEEE International. Vol. 1, pp. 102-110 ISBN 0-7803-5886-4

Photo-Tacheometry

- Recording Geometry and Creating a 3D-Model On Site and in One Step –

M. Scherer

Geodesy in Civil Engineering, Ruhr-University Bochum, Germany

Abstract

Photo-tacheometry very tightly combines elements of classical photogrammetry and tacheometric polar coordinate determination. It is a fast, highly automated method, predestined for mainly flat-surfaced regular shaped buildings and monuments. Geometry and photo realistic 3D models are obtained in one step on site. So completeness and correctness of the recording are controlled step by step when establishing the model. There are different automation levels in photo-tacheometry. A rather high degree can be reached when using a motorized total station, which is the method described here. A first example is given for its practical use. The need for futural developments is discussed and ways for the augmentation of its effectivity are shown. A main matter of concern is to make potential users curious to adopt this new comparatively inexpensive method into their own spectrum of recording methods.

Subject categories: photo-tacheometry; laser scanning; photogrammetry; low cost technology; 3D-model, architectural surveying; video-tacheometer; cultural heritage documentation

1. Introduction to an innovative measuring method

The term photo-tacheometry indicates that this is a very close synthesis of core elements of the well known recording methods photogrammetry and tacheometry. There is no similar approach to be found in literature except some former papers of the same author (SCH5 a, b, c). Although developed in the last three years photo-tacheometry has still to be called an innovative method for architectural recording: its working mode and its effectivity are not yet in the mind among experts. Photo-tacheometry is now in a state where the optimisation of practical aspects gains importance. Although it is a fast cost saving method it is hardly known and not practised by the users. Reason for this is that in general "geodetic" recorders are not familiar with the photogrammetric components while recorders with photogrammetric background are not familiar with the possibilities of notebook controlled motorized total stations.

Photo-tacheometry has many different facets; there are different stages of operation, different degrees of precision attainable, different methodical ways to come to results and to control them. In this short paper it is not possible to demonstrate all different functionalities of photo-tacheometry. However apart from some more general information some components are explained and a practical example is given.

2. Main features of photo-tacheometry

Application of photo-tacheometry only requires a few well known, common instruments: a reflectorless measuring notebook. Preferable is the use of a motorized total station, which is connected with the notebook by Bluetooth. The motorization and the spatial separation between the controlling notebook and the instrument enable some special measuring modes and a high degree of automation. This will be shown later.

The main idea behind photo-tacheometry will be explained using one typical very simple example, which demonstrates, how coordinates and texture can be generated together in one step.

A precondition for every work with images in photo-tacheometry is their exterior orientation. This preparatory procedure is closely integrated into the workflow; since the total station is used on site, identification and referencing are done fast and in one step. After orientation the image is fixed with the (global) coordinate system and available for all ongoing work as well as for possible densification of the network to be done much later.
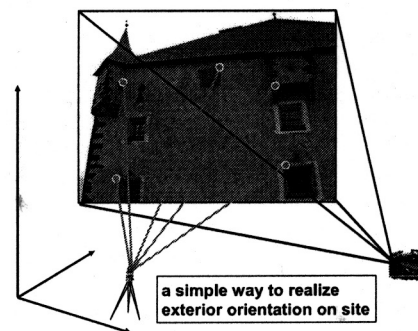

a simple way to realize
exterior orientation on site

Figure 1: *Preliminary step of exterior orientation*

Afterwards the typical proceeding of photo-tacheometry may start. Coordinates are determined by a mixed tacheometric-photogrammetric procedure:
In the example the user decides that the surface in question is represented by a plane. **First** its geometry in **general**, that means their position (not the dimension of the wall and not the boundary) is determined by tacheometric measurement. In the **next** step a rather simple approach follows: boundary points in the image are clicked at, defining the boundary of the shape derived from the tacheometric measurement. The intersection of the image-rays (starting from the projection centre through the image boundary points) with this shape provides the enclosure of the surface; this is the photogrammetric part in photo-tacheometry. In this second step the coordinates are calculated from the intersections **and** the texture of the surface is cut out from the image at the same time. In practise the second step is realized by a simple click into the image reconstructing the ray from the oriented camera position to the object. This general mode of operation is possible because the preliminary exterior orientation of the image was done. The simple procedure is demonstrated in figure 2.
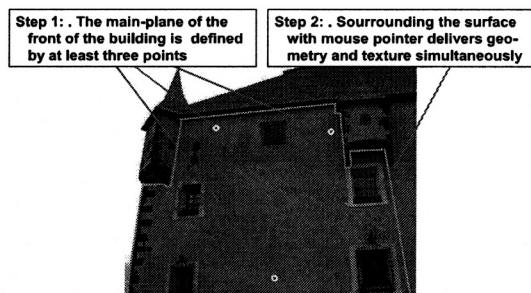

| Step 1: . The main-plane of the front of the building is defined by at least three points | Step 2: . Sourrounding the surface with mouse pointer delivers geometry and texture simultaneously |

Figure 2: The *general procedure- a fundamental tool*

Again: the general form and the position in space of the (regular, i.e. flat) shape of a building are determined with the total station while the point **coordinates and** the **texture** result from the intersection of the reconstructed image rays with this shape. This way to act is fundamentally different from the well known approaches with multiple images. It is possible in this way because tacheometers nowadays allow reflectorless measurements.
Using a motorized total station enables to measure the shape faster: The image as well as the total station are oriented in the same coordinate system. This allows to steer the instrument **exclusively** by click into the image.

So after the images are oriented the user is free to work close to the building taking advantage from the Bluetooth connection from the notebook to the instrument.
In order to show the fundamental differences to the well known recording methods a brief description of these approaches is given: The aim of all methods is to create a virtual model of the object with as few characteristic points as possible. In laser scanning in order to achieve this, a huge number of single points is recorded of which none has a direct connection to the object. This point cloud is used to generate regular surfaces which then are intersected to get a geometric model. Finally this model will be covered with texture from the image of the object. - In photogrammetric image based modelling object geometry is generated from intersections of directions from the positions of the cameras to the object. A disadvantage is the need for overlapping images, taken from different points in space and the fact that the accuracy depends on the distance to the intersection points. - Using traditional tacheometry the geometric model is defined by point measurement and often the texture is derived from rectified images, which is a rather time spending procedure.
So, what are the advantages of photo-tacheometry?
The procedure explained here at first glance seems to be rather complex and neither economical nor simple. However, the process itself is in fact rather fast, comfortable, robust, exact and efficient, usable without detailed knowledge about the theoretic background and therefore a real alternative to photogrammetry as well as laser scanning or conventional tacheometric recording. This of course also depends on the individual characteristics of the object. In the procedure described above, the surfaces of the building have to have sufficiently regular shapes like plane, conic, cylindrical or spherical. In this case there are large advantages in comparison to the other methods (see figure 3). Results are obtained immediately on site. So correctness and completeness of the 3D-Model can be checked immediately.
In comparison to photogrammetry distance to the camera does affect the accuracy much less: in photogrammetry there are at least two straight lines intersecting at an angle depending of the basis' length; in phototacheometry only one straight line is intersecting a solid (in the example a plane) more or less orthogonal. A study dealing with this theme will be published later. - In comparison to laser scanning the method is more efficient as long as the recorded object is not too complex.
On the other side irregular planes may be captured quickly

	Phototacheometry	Laser Scanning	Photogrammetry (image based modelling)	Traditional Tacheometry
acquisition cost	moderate, instruments often already available (1) moderate (1)	high (3)	moderate (1)	instruments available (1)
regular expenses		domestic evaluation (2)	domestic evaluation (3)	high (3) (as method is slow)
overlapping of images	not necessary (1)	not necessary (1)	necessary (3)	not necessary (1)
results on site	yes (1)	no (3)	no (3)	no (3)
accuracy	relative high (1)	relative homogenous (2)	depending on base to distance ratio (2)	high and homogenous (1)
recorded complexity	low - medium (2-3) in the actual state	low-high (1)	low-high (1)	very low (3)

Figure 3: *Comparison of photo-tacheometry with familiar methods when visualizing regular shaped objects (from 1= good to 3=bad)*

as well, using a representative net of triangulation points (see below).

However, only long-term practical use of the method under different conditions in the field will provide more accurate information. In the preceding chapter a typical functionality of photo-tacheometry was explained. However the combination of different tools embedded in a workflow is of special interest for practical work.

3. Examples for the work with different tools

Thanks to the notebook-controlled, motorized reflectorless measuring total station a manifold automated measurement procedure is possible (more comments on extensive automation in chapter 4). It has to be stressed again that the method allows the determination of the geometry and the texture-elements not only in an extremely effective, fast and comfortable way, but also featuring comparatively high geometric precision (see figure 3) with redundant control of the process [Sch05a]. The software relieves the user of many decisions and considerations.

In the example depicted in figure 4 the step of exterior orientation was done (see figure 1). This allows to steer the instrument exclusively by click into the image. So by three simple clicks the main plane of the building is defined. It has to be remarked that **positioning** these points has not to be very exact, because they only define the exact position of the shape in space but they do not serve for the direct determination of the **dimensions**. Like demonstrated already (identical to figure 2) the geometric model is obtained in the next step by cutting out the surface texture polygonally. Simultaneously with the texture by these clicks into the image the 3-D geometry is calculated.

In the next step (step 3 in figure 4) the knowledge about the parallelism of planes is used to minimize the effort. If one can assume that the surface of the oriel is flat and sufficiently parallel to the main plane defined in step 1 it is sufficient to tell the software to define a parallel plane and to make one single click onto this plane. This will cause the total station to turn to this point and to measure the coordinate corresponding to the clicked point in the image.

The software calculates the parameters defining the parallel plane. In next step (4 in figure 4) the texture is cut out polygonally and the corresponding 3-D coordinates of the oriel are calculated automatically in the same step. As there are often parallel or rectangular planes work proceeds rather fast, using adequate software tools.

In figure 4 some more steps are denoted. It is very helpful and time saving for all following steps that those points already measured are marked in the layer of the image. These may be points which are either measured directly with the total station or calculated by means of photo-tacheometry in the former steps. The outcome is a 3D-object model (see figure 5) on site.

In the preceding chapter regular surfaces were defined by tacheometric measurement followed by mathematical modelling of the shape. If the surface however is not sufficiently regular (a possibility to control is mentioned at the end of chapter 4) it may be helpful to create a triangulation net of points simply by mouse-clicking on characteristic image points. As explained before the total station is then steered in an automatic process to the corresponding point of the object. The coordinates of this point are determined automatically and the texture of the triangles is cut out. In both cases the very efficient tacheometer-control and the steering by a simple click on image points with the cursor are responsible for the method being highly economical. All the time the user exclusively uses the notebook which is linked to the total station by the bluetooth connection.

Thus someone is able to select the characteristic object-describing points of an irregular object surface on site and face the object directly: this provides notable advantages in order to achieve high quality recordings. In this measuring mode no direct manual contact is necessary to operate the instrument, no movements around the tripod do occur et cetera. Thus the total station may potentially be situated at an elevated point guaranteeing a better view to the object.

Obviously, this procedure is excellently suited for fast and cost effective recording of an object's surface-topography. An analogy to topographic terrain-surveying is unmistakable:
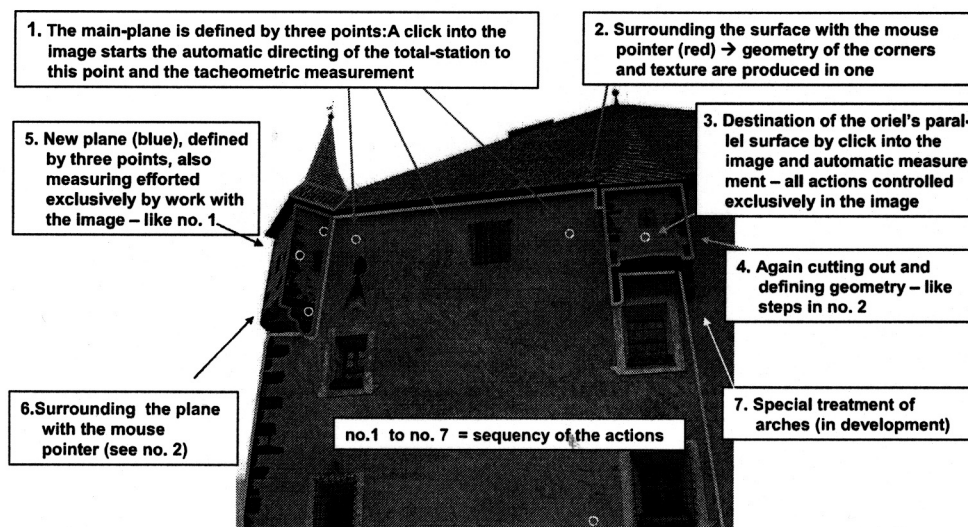
1. The main-plane is defined by three points: A click into the image starts the automatic directing of the total-station to this point and the tacheometric measurement

2. Surrounding the surface with the mouse pointer (red) → geometry of the corners and texture are produced in one

5. New plane (blue), defined by three points, also measuring efforted exclusively by work with the image – like no. 1

3. Destination of the oriel's parallel surface by click into the image and automatic measurement – all actions controlled exclusively in the image

4. Again cutting out and defining geometry – like steps in no. 2

6. Surrounding the plane with the mouse pointer (see no. 2)

no.1 to no. 7 = sequency of the actions

7. Special treatment of arches (in development)

Figure 4: *Example for the work with geometrical primitives: all functions steered by the image*

Relatively few points may be needed to record an area while still obtaining a good model of the surface (see rocks in fig. 5). The recording of the morphology of an irregular surface enables deformation-faithful recording of the object in one step. Besides the manual construction of a triangulation network also a regular grid may be used. In this case a slow, but fully automatic recording of smaller regions is possible. The resulting point cloud may be treated analogous to the proceeding in laser scanning (example in SCH05c)

Time consumption for this way of recording (from the beginning up to the final model) is shown in table figure 6. According to this the work steps marked with three different colours in figure 4 do require approximately 5 minutes.

Figure 5 shows the resulting virtual 3D-model (VRML).

As long as the object's surface is not too complex, not too irregularly bent and/or not too ornamentally designed, photo-tacheometry is superior to the other methods mentioned above. All the other approaches also do not offer the possibility to control accuracy and completeness at any time and on site.
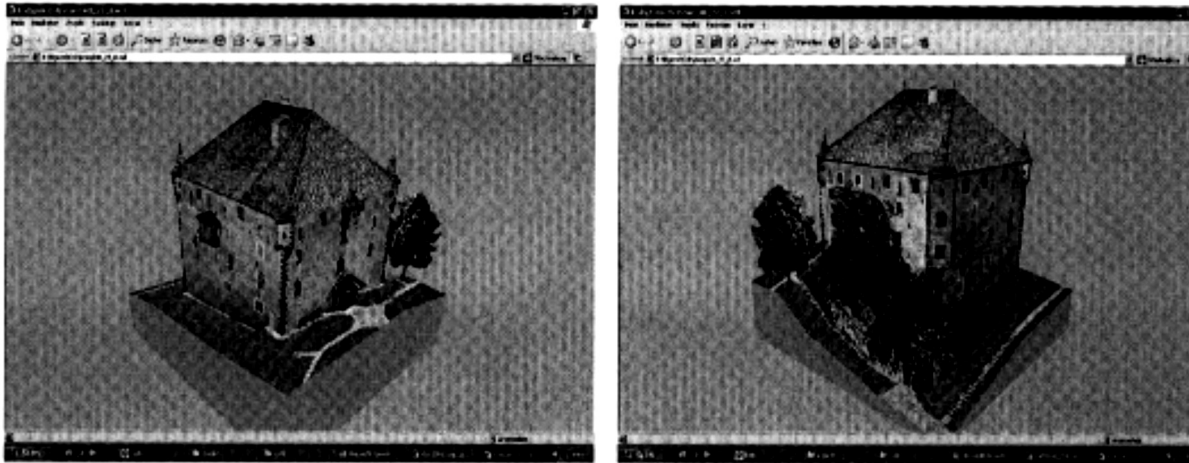

Figure 5: *3D-model of Ciastel Colz in La Villa, Alta Badia, Northern Italy*

preparational work (i.g. similar in photogrammetry and laser scanning)	positioning the total-station	5 min
	orientation in the network	2 min
	take a picture	1 min
	orientation of an image	2 min
work with the image	- select an image	20s
	- define a main-plane by 3 or 4 points	20-25 s
	- „cut" to define coordinates and texture	4s/pt
	- definition of a parallel plane	10 s
	- definition of a perpendicular plane	20-25s
	- cone / cylinder	1min
	add a segment	30-40s
	define boundaries	4s/pt

Figure 6: *Time involved*

4. Some additional aspects

- It is frequently desired to be able to work on site very close to the architectural object, like for example in the fields of building research and building documentation. In these cases the phototacheometric way of measuring as shown here is predestined. However, if time on site is short, only minimum requirements have to be fulfilled: In the example in figure 4 only the coordinates of those points marked with circles would have to be measured on site, which are the ones determining the geometrical primitives. The rest of the data required to recover the geometry and the texture can then be generated off site in the office.

- While surveying large objects or in case high accuracy is crucial the network of surveying points has to be adjusted. However, there is no conventional polygonal net necessary. The net may rather be constructed in a more organically way by adding the local net of each standpoint, using easily identifiable natural object points. That way it can expand together with the project.

-The grade of detail can be augmented any time later as there are well destined points of high quality everywhere available at the object.

- Figure 7 shows three different levels of development of the method: a simple manual one (no1) , the motorized way as illustrated and recommended in this paper (no 2) and the future photo-tacheometry equipped with video total station as an extension of the motorized total station (no 3). In order to work with photo-tacheometry basically (no 1) it is not obligatory to work with a motorized total station. However it is much faster and giving more possibilities to control the measuring procedure. Video total stations do already exist and have been tested [Jur05] [Top05] [Wal05]. This new type of instruments featuring built in cameras to observe the object directly –and also combined with "externally" made images like described here- will surely have an impact on automation. They will make measuring more efficient in two ways:

a. some steps will run faster and improve performance   b. more sorts of building details may be recorded in a

Expansion stage	Tacheometer	Camera	Notebook	Conclusion
1 simple	reflectorless measuring total-station	good consumer-camera	connected to the total-station by cable	time of recording much longer than in stage 2; offers low comfort
2 recommended and described in this paper	motorized reflector-less measuring total-station	good consumer-camera or photo-grammetric camera	control of total-station without cable (bluetooth here)	high degree of automation, minimum recording time; redundant control
3 fully available in the near future (?)	video-total-station (= image assisted total-station = IATS)	see above	see above	feature extraction, extensive automation

Figure 7: *Stages of expansion depending of different hardware*

simple way by extended capability in regards to small-scale objects.

This will be possible by using feature extraction in image interpretation [Rei04].

-In the former paragraphs was said that correctness may be controlled on site. Off course this may be done more visually by controlling the growing 3-D model, however there is also the possibility to use the fact that the total station is motorized for a sort of automatic control of the coordinates derived from cutting out surface (shape) surroundings: the total station can be told to point to the calculated object coordinate and then make an independent measurement. This method may also be used as a certain control how good the geometric primitive (i.e. plane, cylinder) fits with reality. Questions of precision and accuracy will be discussed later in another paper.

- There are often some special structures to be found at architectural monuments which appear repeatedly. They have for example the form of fascia or there are recurring single elements. We are going to develop specific tools to enable recording of this kind of object geometry quickly and accurately especially with regard to visualization. Generally the efficiency of photo-tacheometry has to be augmented for applications on objects with more complicated surfaces.

- At present the software controlling the instrument and the image processing is being improved continually. The integration with AutoCAD as visualization platform is realized. The implementation of some more special tools will help photo-tacheometry to become a more and more respected method alongside the well known and well established ones.

5. Summary

In this paper initially the fundamental functionality of photo-tacheometry is explained, namely the destination of coordinates derived from only one oriented image on one side and from the shape of the surface of the object (only the geometric primitive which is determined from measurements with a total station. and not the 3D-model !) on the other side. Especially in this context it is of interest that the motorized total station may be steered but by the image. A practical example for the use of different tools and for the workflow is given. Some comparisons with the

common methods used for visualization show that it is worthwhile for users and providers of services in the field of recording of buildings and monuments to get familiar with photo-tacheometry as a fast time-saving recording method using no special hardware but hardware which is widespread. Explaining the operating mode of photo-tacheometry has proven to be rather difficult. However it has to be underlined that in practice the method is easy to handle. For its use no deeper knowledge of photogrammetry or intelligent tacheometry is necessary.

5. References

[Jur05] Juretzko, M.: Reflektorlose Video-Tachymetrie - ein integrales Verfahren zur Erfassung geometrischer und visueller Informationen. DGK Reihe C, Nr. 588, München, 1995,122S.;Internetversion.
http://129.187.165.2/typo3_dgk/docs/c-588.pdf

[Rei04] Reiterer, A.: A Knowledge-Based Decision System for an On-Line Videotheodolite-Based Multisensor System. Dissertation TU Wien, 2004

[Sch05a] Scherer, M.: Visualisierung und simultane Erfassung der Geometrie mit Tachymeter und Digitalkamera - Eine Alternative zum Laserscannen in der Bauaufnahme – Zeitschrift für Flächenmanagement und Bodenordnung 6/2005, S. 283-290

[Sch05b] Scherer, M.: Photo-tacheometry and intelligent scanning – an alternative to 3D-laser scanning. Proceedings of XX CIPA International Symposium. 26.09. – 01.10.2005, Torino, CD-ROM und Internat. Archives XX, Vol. 1, S. 529-533

[Sch05c] Scherer, M.: Architectural Surveying and Visualization Using "Photo-Tacheometry". FIG Working Week 2005 and GSDI-8. From Pharaohs to Geoinformatics. 2005

[Top05] TOPCON (Hrsg.): DVD Optical Product line-up, 2005, GTP7000.pdf

[Wal05] Walser, B.: Development and Calibration of an Image Assisted Total Station. IGP Mitteilungen Nr. 87/2005 Zürich, 168 Seiten

The e-volution of Stereoview Technology in CH data

W. Schuhr[1] and E. Kanngieser[2]

[1]Faculty of Civil Engineering, University of Applied Sciences Magdeburg, Germany
[2]Department of Geomatics, HafenCity University (HCU) Hamburg, Germany

----

Abstract
This paper promotes the replacement of subjective interpreted manual sketches by objective stereoview Technology, which, in the field of Cultural Heritage is more than overdue.
It is liked to emphasize, Stereoviews, possibly better known as 3D-imagery, are extremely well suited, to become a common approach for particular e-documentation of World Cultural Heritage.
This paper provides both, current research as well as practical results in this field of 3D-visualization Techniques as state-of-the-art tools for recording, documentation, interpretation etc., concentrating on Cultural Heritage.
After this introduction chapter it is intended to submit an idea of the outstanding documentary value of 3D-images and of its broad range of applications by presenting masterpieces for historic as well as for recent 3D-photography. In this context it is also liked to refer to the authors`RecorDIM-website 3dsite.icomos.org. Since these samples represent huge collections of Heritage Stereoviews, the following part deals with international 3D-image-archives.
The next chapter is on gaining "3D-niche-photography" based on a telescope-rod-platform Lite. This means ground born (!) extremely high resolution (digital 3D-) aerial photography, showing about 10 m height, which for large scale Cultural Heritage mapping obviously promises a great future. It is anticipated, this digital low budget Technology will spread enormous in the very next future.
In the following are highlighted advantages for the practical use of Heritage stereoviews,e. g„
    - the still underestimated effect of gaining a complete additional dimension and
    - advantages of 3D-visualization for the enhancement of spatial structures, as well as
    - pointing to the extremely high detail resolution and to
    - the queue "sketch, 2D-photography, 3D-photography, which is strongly understood as an increasing degree of comparison!
Finally there will be presented a completed list of virtual 3D-visualization-methodology, including "Down-Under"and Felix-Solid-State type 3D-screens to replace the 2D-PC(-screen).

Categories and Subject Descriptor (according to ACM CCS): I.2.10 [Documentation]: 3D/Stereo-scene analysis

1. Introduction

This paper promotes the replacement of subjective interpreted manual sketches by objective stereoview Technology, which, in the field of Cultural Heritage is more than overdue.

It is liked to emphasize, Stereoviews, possibly better known as 3D-imagery, are extremely well suited, to become a common approach for particular e-documentation of World Cultural Heritage.

This paper provides both, current research as well as practical results in this field of 3D-visualization Techniques as state-of-the-art tools for recording, documentation, interpretation etc., concentrating on Cultural Heritage.

As a homage to the Joint Conference on the e-volution of Information Technology in Cultural Heritage in Nicosia, Cyprus, Figure 1 shows a masterpiece of a Heritage stereoview of the ruins of the temple of Apollo in Curion
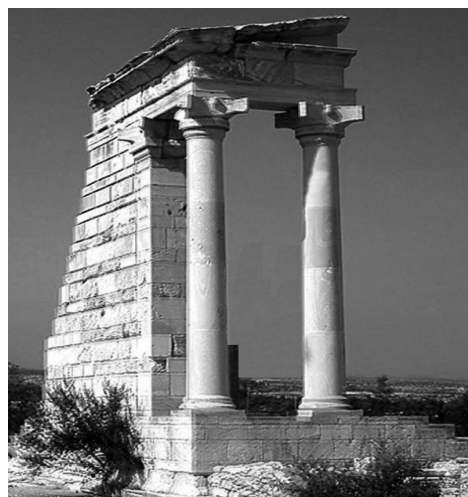

Figure 1: Masterpiece of a Heritage stereoview of the ruins of the temple of Apollo in Curion (Cyprus)

Figure 2: *Manual sketch of the ruin of the temple of Apollo in Curion (Cyprus) (modified according to Witte), compare Figure 1*

Figure 3: Two Masterpieces of the Keystone-Mast Collection representing approx. 50000 historic heritage Stereoviews, dating approx. 1905: -Buddha of Kamakura "Dalbutsu"in Japan(top)& -Interior Throne Room Beijing, China (below)

(Cyprus) in the color anaglyph mode. Use red/magenta color anaglyph glasses to catch the full 3D impression.

A comparison of Figure 1 and 2 already proofs the superiority of Heritage Stereoviews over manual sketches. There is no doubt, the importance of Heritage Stereoviews will increase with the digitization rate with sufficient resolution, expecting an "e-volution" of Stereoview Technology in Cultural Heritage

2. Masterpieces of Heritage Stereoviews

It is intended to submit an idea of the outstanding documentary value of 3D-images and of its broad range of applications by presenting masterpieces for historic as well as for recent 3D-photography. In this context it is also liked to refer to the authors`RecorDIM-website 3dsite.icomos.org. Since these samples represent huge collections of Heritage Stereoviews, the next chapter deals with international 3D-image-archives.

The following samples of outstanding existing historic masterpieces for Heritage Stereoviews today are part of the famous Keystone-Mast collection, see Figure 3 until Figure 5 and Chapter 3.

Figure 6 and Figure 7 show recent masterpieces for Heritage Stereoviews, taken under "expedition-constraints" with a single lens-camera, after the processing of color anaglyphs, finally to convince the user, *the queue "manual sketch,* 2D-photography, 3D-photography", strongly should be understood as an increasing degree of comparison. This means, sketches would never allow to obtain the brilliance of color Stereoviews.
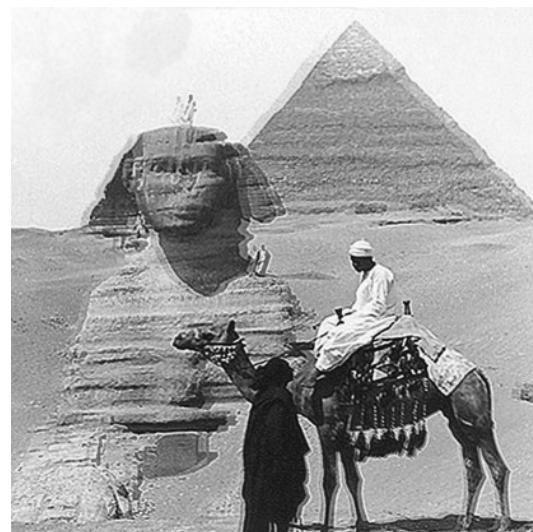
Figure 4: Early Heritage stereoview of Egypt, dating approx. 1905 presented as color anaglyphs (recognize a person climbing the Sphinx)
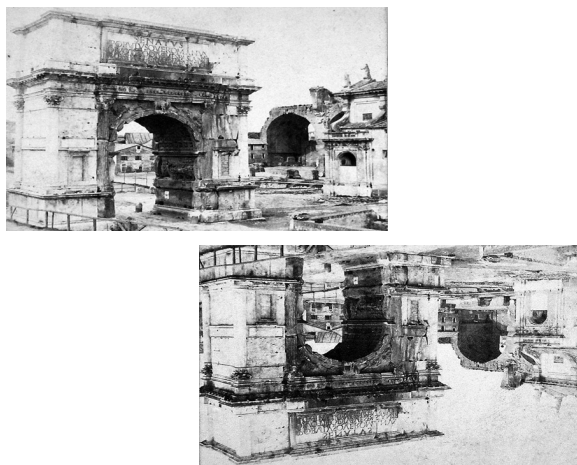
Figure 5: The Titus Arc of the Forum Romanum presented in the "Down Under" mode for stereo- strip- and/orfor stereo-panorama--imagery. Use a mirror to percept the right beside the left image.

Figure 6: Heritage stereoview Masterpiece: column base:Antoninus Pius(138-161AD) (Martian field, Rome: Vaticano Museum) by W.Schuhr
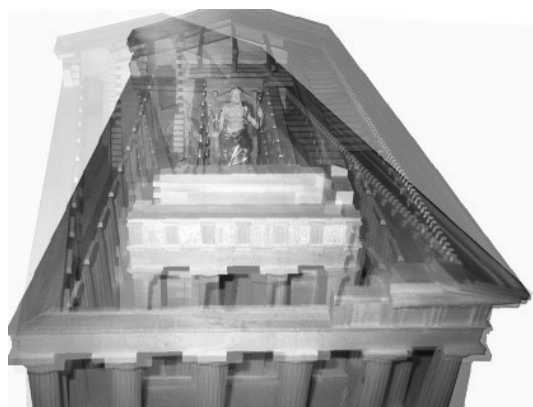

Figure 7: Current Heritage stereoview of the Zeus statue in Olympia (Greece), one of the 7 wonders of the world (author's 3D-image of a model)

3. International 3D-image Archives

3D-images are a particular key to the spatial past, a real treasure, still waiting for a rediscovery!

A synoptic overview over international archives, collectors and distributors with particular reference, but not limited, to the United States, see[W02]. The current main activity in the e-volution of Stereoview Technology is managed by Steve Thomas head of the CMP/UCR Keystone-Mast Collection, where approximately 50000 historic Heritage Stereoviews, of a total amount of 350 000 Stereoviews, will be digitized, see Figure 2 until Figure 5 for samples

The HAN 3D archive in Seoul (South Korea) is another sample of a very important archive for unique specimen of National Stereoviews.

Beside gaining some 10 000 recent international Heritage Stereoviews, the authors purchased a so far unknown historic collection of stereo-glass plates (unicats) from Switzerland.

To maintain the list of archives of 3D-photography, our international colleagues are kindly requested to continue in informing the authors under the email address as mentioned before, about so far unknown and/or not distributed collections of Stereoviews, "which show no www-presentation".

First attempts have been made, to define an optimum pixel size for the digitization of Heritage Steroviews (see Figure 8): In case of Figure 8 an original stereo pair of a conventional aerial photograph showing a 1:50000 scale has been interpreted with respect to different types of objects, like buildings, traffic lines, topographic objects, the DTM etc.. In addition this stereo pair has been digitized with ground pixel sizes ranging from 2,5 m until 40m. As expected, the stereo effect of the original model gives the highest interpretation aid. But it is liked to point out, the interpretation of the model showing 2.5m ground pixel size is almost like the interpretation of the original, while an increasing pixel size shows a decreasing confidence in the interpretation. From this the minimum digitization rate for a Heritage stereoview should be not less than 500 dots per inch, which here corresponds to the 2.5m groundpixelsize in 1:50000. Of course further practical research work in this field of e-volution is very welcomed and highly recommended, compare [FGM01].

4. 3D-niche-photography

It is the authors' concern, for documentation purposes, consequently to replace subjective manual sketches by objective (3D-) photography to the greatest possible extend,

To tackle this task, first time extremely high resolution low altitude aerial (3D-) photography from an 11m carbon telescope-rod, like in Figure 9 and from captive balloon (see Figure 11) successfully has been applied and will more and more become an objective tool for a huge range of documentation purposes, in particular in archaeology, see Figure 9 to 12. Depending on the height, the base length for the light digital SONY Cyber Shot 5 Mega pixel cameras showing and remote control has been varied. This"3D-niche-photography"is also well an 11m carbon
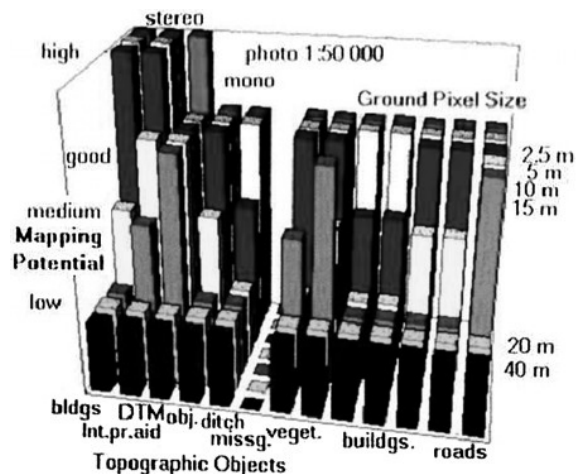
Figure 8: The optimum resolution for the "e-volution" of Stereoview Technology in Cultural Heritage

Figure 9: The digital 3D-Rod-Camera Lite with remote control doubtless becomes the most common sensor for extremely close range aerial photography (experimental study)

telescope-rod, like in Figure 9 and from a captive balloon (see Figure 11) successfully has been applied and will more and more become an objective tool for a huge range of documentation purposes, in particular in archaeology, see Figure 9 to 12. Depending on the height, the base length for the light digital SONY Cyber Shot 5 Mega pixel cameras showing and remote control has been varied. This"3D-niche-photography"is also well suited under expedition constraints and promises a great future.

As a matter of fact, in many cases Cultural Heritage Stereoviews can be obtained with single lens cameras, preferable showing in maximum 5 degree convergence angle for the directions of the optical axis., see also [SchK05].

It is highly recommended, to take a sequence of stereo mates with different baselines and to decide for the optimum stereo model afterwards, instead of believing in the a priori calculation of just one optimum base length, which might produce disappointing results regarding the expectations of the spatial perception.

5. Advantages of Heritage Stereoviews

3D-visualization Techniques are increasingly becoming state-of-the-art tools for recording, documentation and interpretation purposes etc., not only in CH.

The enumeration of the long list of possible applications of stereoviews in the areas of Arts and Science, Engineering, Economy, Information Technology, in the social as well in the daily life, ranging from, e.g., 3D-Newspaper to 3D-TV and from public 3D to the virtual museum, already exceeds this paper. Therefore in the following are highlighted some practical aspects in gaining and in applying 3D images, concentrating on CH.

3D imagery show particular advantages for the visual enhancement of spatial structures (e.g., relief enhancement), see Figure 11 and 12.

Heritage stereoviews become increasingly used in Rock Arts and in the field of inscription perception in CH (compare Figure 11) etc.

Figure 10: Sample for a low altitude Heritage stereo pair to replace out of date manual sketches (captive balloon 3D view of the Ecclesiasterion in Patara,Turkey; carried out by Dipl.Ing.St.Kiel)

The stereoview of a carved stone of the antique theatre in Tlos (Turkey) in Figure 12 is a sample, which, due to a proper choice of the base-to-distance ratio (here of about 1:2) clearly enhances near plan structures and is clearly superior even over so called expert sketches, compare [ABCL03]. Figure 12 also indicates the extremely high geometric and radiometric detail resolution of about 1mm pixel size and even better(!), which so far is superior to any

other 3D-medium- range surveying methods, including 3D Laser scanners, see also [AR05].

The combination of the left image of a stereo model from 1978 with a recent right image in Figure 13 stands for using Steroviews for Change Detection purposes.

Figure 11 Sample for Inscription enhancement by Heritage stereoviews in Tlos (Turkey)

Figure 12: Heritage 3D view enhancing the spatial structures of a carved stone of the antique theatre in Tlos (Turkey),

6. The completed list of virtual 3D-visualization methodology

For high resolution 3D-perception even historic stereoscopes like, e.g., of the Wheatstone and Holmes type etc., are still in use. Today, in the digital age, there seem to be tendencies, to create a kind of "digital stereoscope" for everybody, by suited software on a PC. In case, stereomates of an object are available, it is highly recommended, to process so called color anaglyphs for this stereomates. The perception of color anaglyphs in magenta and cyan allow an effective and cheap perception of digital stereo images in color. Yellow/cyan glasses instead of magenta/cyan glasses might even show a slightly better color perception. The Felix Solid State type 3D-screen

even seems to be a candidate to replace the 2D-PC(-screen) generation in the next future, at least partly.

Figure 13: Multitemporal Stereoviews for Change Detection purposes near the Monument of Otto v. Guericke (Magdeburg, Germany)

7. Conclusions

This paper deals with new aspects of the e-volution in 3D-visualization Techniques as state-of-the-art tools for object recording and documentation,, as well as for interpretation and application purposes, with particular respect to CH. It shall convince not only professionals but also amateurs, to prefer 3D photography instead of still sticking to common 2D snapshots.

Summarizing, the popularity of 3D-Visualization Techniques, including samples and applications, still is not in coincidence with its importance [SchK00]. Though the progress in the field of 3D Technology recently increased enormously, there are still gaps for important practical as well as for research work, like, e.g.,

- to convince amateurs and professionals of the still underestimated effect in gaining a complete additional dimension. Beside others this holds for the enhancement of spatial structures by suited 3D-visua-lization Techniques, as well as for the achievement of extremely high detail resolution etc.

Though amateurs and professionals can gain own stereoviews even with single lens cameras, the 3D photography still is not very common and should be increasingly promoted.

- A survey for a systematic listing of existing international archives for stereo views, including the archives contents and access is highly recommended.

-A Peer reviewed and definitely complete synopsis of the virtual 3D-visualization Technologies with sufficient information content is still missing! Already from first systematic steps in this field the "DOWN UNDER" 3D-visualization method recently has been invented, by the authors, see Figure 5 and Table1.

- The authors appeal again to the professional community, to replace manual sketches for docu-mentation purposes by at least 2D-, but preferable by (geometric adjustable) 3D-photography!

Table 1: The Complete list of <u>Virtual</u> Spatial Visualization Techniques (Status: October 2006)

1. 3D visualization of in minimum two over-lapping stereo mates, vertical or horizontal arranged, but "<u>projected without contact</u>"; for "ortho" or "pseudo" as well as for normal and/or cross 3D visualization:
1.1 Autostereoscopic view of horizontal mounted 3D views, see Fig. 3, 11 and 15
1.2 MAGIC EYE / random dot
1.3 CYBER SPACE
1.4 Stereoscopes:
1.4.1 Lens Stereoscopes
1.4.2 Mirror Stereoscopes with lenses
1.4.3 Mirror Stereoscopes without lenses; vertical Mirror: PIGEON
1.4.4 Mirror Stereoscopes without lenses; horizontal Mirror: DOWN UNDER, see Fig. 5
1.4.5 Prism-Stereoscopes for horizontal mounted stereomates
1.4.6 Prism-Stereoscopes (with optical wed-ges) for vertical arranged stereo-strip and/or stereo-Panorama imagery: KMQ
1.4.7 Prism-Stereoscopes for vertical interlaced (even "multi")-stereomates: LENTICULAR LENSES (e.g,"3D postcards")
2.Methods for the virtual spatial visualization Technology based on stereo mates, "<u>projected in contact</u>", using alternate projection and/or different color
2.1b/w&colorANAGLYPHS:complementary color: green/red or blue(magenta)/red or magenta/yellow separation,see Fig1,4,6,7,10
2.2 CROMADEPTHS (spectral color separation)
2.3 POLARIZING FILTER Techniques
2.4 (Liquid Crystal-) SHUTTER glasses
2.5 NUOPTICS(PULFRICH):3D(-TV) for (relative) moving objects through "one-eye sunglasses"
3. Methods using **VIRTUAL** 3D MODELS:
(3.1 different types of mirrors)
(3.2 3D-crystals)
(3.3 3D CAD and CNC)
3.4 (FELIX 3D-) Rotating Screen
3.5 (FELIX 3D-) SOLID STATE
3.6 HOLOGRAM Technologies

- Intense dealing with "3D-niche-photography" based on telescope-rod and/or captive-balloon promises a great future.
- Receipts and samples for gaining, processing and applying Stereoviews are still required for different disciplines.
- There is still a gap for operational "stereoview adopted software".

It is liked to emphasize, the authors, who chair the RecorDIM task Group on "Collecting, Compiling and Sharing International Heritage Stereoviews", maintain the non-commercial website 3dsite.icomos.org, which is also prepared for contacts and cooperation.

Finally, to emphasize the great future potential of the 3D Technology it is expected, the FELIX Solid state type 3D screen is a real candidate, at least partly to replace the current 2D PC-screen generation.

8. References

[ABCL03] ANDREWS, D., BLAKE, B., CROMWELL, T., LAE, R. and LUNNON, S.: Measured & Drawn,. English Heritage Publication ISBN 1 873592 72 8 Product Code 50729 2003.

[AR05] ARDISSONE P., RINAUDO F.: A GIS for the Management of Historical and Archaeological Data. Proceedings of the *CIPA 2005 XX International Symposium* Torino, Italy (2005).

[FGM01] FANGI, G,. GAGLIARDINI, G., MALINVEMI, E.S.:Photointerpretation and Small Scale Stereoplotting with digitally rectified Photographs with Geometrical Constraints, in Proceedings Cipa Symposium Potsdam, Germany, 2001, pp. 161-167.

[SchK00] SCHUHR, W. and KANNGIESER, E.: Basics of Spatial Data Visualization. SDH 2000 Symposium Proceedings, Beijing (China), 2000.

[SchK05] SCHUHR, W. and KANNGIESER, E.: International Stereoviews to save the World's Cultural Heritage, CIPA Symposium Proceedings, Turin (Italy) 2005.

[W02] WALDSMITH, J.: Stereo Views, Krause Publications; Library of Congress Catalog Number 2001099523, 2nd edition, Iola, Wisconsin (USA), 2002.

The Encyclopedic Concept in the Web Era

A. Sideris[1]

[1]Foundation of the Hellenic World, Athens, Greece

Abstract
The paper deals with the online encyclopedias of historical and cultural content, attempting a reassessment of the encyclopedic concept for its web versions. It draws inspiration and examples from the encyclopedia under construction in FHW, dedicated to the Hellenic Civilization. The issues discussed include the content structure and the information organization, the ontological approach, the search and the information retrieval, as well as the hypertext and hypermedia issues, along with their content and form requirements.

Categories and Subject Descriptors (according to ACM CCS): H5.4 [Hypertext/hypermedia]: Architecture, Theory, User Issues, J5[Arts and Humanities]

1. Introduction

This paper focusing on the general methodological issues of the web encyclopaedias is the result of the theoretical research done in the frame of a project of the FHW, the online *Encyclopaedia of the Hellenic World* (www.egiklopedia.gr, 2006), and it owes much to the inspiring discussions with my colleagues, Cleopatra Ferla and Yorgos Tzedopoulos [FST03]. It benefited as well from an earlier study of the author on behalf of the ICS-FORTH, Creta, Greece [Sid05].

2. The encyclopedic concept in brief

The first encyclopedias have been conceived long before the word "encyclopedia" itself became of common use, as a result of the desire to organize the available information of a more or less defined knowledge field. Most of them have been thematic and saw the light in the inspiring and creative milieu of the Alexandrian library. They continued on for centuries with practically no other methodology than the alphabetical arrangement of their entries and some of theme became highly normative. They first raised claim for universality of the encompassed knowledge during the 'century of the Lights', through the famous intellectual movement named precisely "Encyclopedic".

The main reason for any organizing or taxonomic action springs out from the constitutional cognitive qualities of the human being, his linguistic and intellectual consciousness, and frames his interaction with the physical and the social environment [Mor86]. From antiquity to present day, encyclopedias and similar projects justify their existence by the accumulation of enormous amounts of information and knowledge, non manageable by a single person's memory and structuring capacities. Digital online encyclopedias do not innovate in this aspect, but they do follow the same pattern in their proper environment: the web. Web encyclopedias begun to appear in late nineties, when an already considerable amount of information –of highly varying reliability of course- made its way online. The web communities, foremost the academic, research and educational ones, felt their imminent need, although the institutional and public authorities have been for long, and partially they still are rather circumspect and reserved in encouraging such projects.

3. Content structure, organization and digitization

The main challenge all along the history of encyclopedic projects has been the validity and justification of the content organization. The conventional supports for the, up to now mainly textual, content being linear and of limited extend, they faced the unsurpassed barrier of the semantic isolation. According to the *Tarski's Logic*, there is no semantic system, which can fully explain itself [BFF04]. The result was the choice of an apparently neutral criterion for the organization of the content, which in reality was only extremely arbitrary: the alphabetical lining up of the entries.

The application in the twentieth century of some mathematical principles on the knowledge organization allowed the creation of data bases, which represent far more complex and sophisticated types of relations than the linear juxtaposition of the entries [BC05]. Furthermore, the content itself has been substantially enriched with a multitude of non textual forms of information and

knowledge, usually clustered under the generic and imprecise term of *multimedia*. These data bases, which have been and still are in use for online encyclopedias, are mainly relational, and although they offer much more flexibility in the content organization, they proved to be insufficient for the unquantified (or unquantifiable?) data of the humanities. In consequence of the *Gödel's Theorem*, according to which a complex standardized system cannot find in itself the proof of its own validity, various ideas are attempting to cure this self-cognitive insufficiency [Fra05]. They proceed so by developing and establishing a meta-system able to encompass and consider the semantic systems of the humanities (particularly those of history and culture) as system-objects [ZOM05].

4. Ontology

These ideas introduced the notion of *entity* as a self-contained and integral cognitive element to the field of the humanities. Each entity has a name, a description, some characteristics and qualities and it forms hierarchical, relational and/or dependential relationships with other entities. In the encyclopedic works under consideration here, these entities should be mostly understood as wider thematic units of geographical, temporal and/or cultural nature, appropriate to depict and include data, events and phenomena, their causal relationships and their usually divergent interpretations [GPCFL04].

From a practical point of view as an entity may be considered also each individual entry or its constituent parts. The ideal and strict conformity to this ontological approach should lead to object-oriented data and knowledge bases, which for the time being have no practical application in any web encyclopedia, mostly due to the lack of a properly elaborate model, wide and flexible enough to cover the semantic system of history and culture. A substantial step to this direction has been accomplished in the museology field by the elaboration of the CIDOC Conceptual Reference Model [CDGS*04]. However, many of the analytical elements of such an ontology may be preserved, such as structuring the information by using superclasses, subclasses, and/or related classes, establishing properties between classes, ranges and domains according to the inheritance instances and the property quantifiers, recognizing the subjects and objects in the discussed relationships, and distinguishing between abstract, specific, collective, endurant and perdurant entities (to randomly name some of them). Moreover, the characteristics of the entities may be maintained as close as possible to a formal ontology, with the qualitative characteristics unstructured and the quantitative ones following the standardization of the relevant discipline, while the examined depth of chained causality may remain limited.

A web encyclopedia, although still close to the conventional encyclopedic projects regarding its information morphology, may be open to modern knowledge theories and ontologies and may potentially adapt its form and structure wherever and whenever it seems necessary, thanks to its flexible digital character [TWR06]. The web encyclopedias may in sum inherit from the knowledge base systems theory the *Open World Assumption,* assuming precisely that the information stored in them is incomplete relative to the universe of discourse they intend to describe.

5. Search and information retrieval

Another innovation of the digital encyclopedias, which particularly applies to the online ones, is the possibility for search and information retrieval. The need for this effort- and time-saving feature becomes evident when one considers the growth rhythm of the available information on the web in general and in the online encyclopedias in particular. Some of them count already hundreds of thousands of entries, each entry consisting sometimes of several thousands of words and of abundant audiovisual items. The most widespread technique is based on the search of keywords, which are indexed and stored by the powerful search engines of the web [Cho03]. The same pattern is also in use for the encyclopedias. Most of these search facilities offer a refinement of the results by means of use of Boolean factors, but it seems that only one out of three users is able to formulate adequately his query.

The main challenge of this procedure is the consistency of the indexing. As long as it relies on the human factor it is unacceptably slow and hazardously inconsistent due to the age, linguistic, educational, cultural and ideological characteristics of each individual. Automated information retrieval systems have been called to cure this inconsistency, but the semantic multitude (polysemy and synonymy) of the words represent the main obstacle for the conceptual indexing. Two methods have been developed to overcome the obstacle: the Vector Space Model and the Latent Semantic Indexing [Kow97]. The first, practically already abandoned, used a *term-document matrix.* The second is based on the hypothetical *underlying structure* of the text [Suw06]. For the time being no conceptual indexing is available for a web encyclopedia, though it is already in use on the web, mostly through the development of the *Semantic Web* [GPE05] [Leu06] [DSW06]. The LSI emerges as the most promising alternative for the enrichment and precision of the search recall, especially in relatively defined and controlled domains of knowledge, such as the thematic encyclopedias [GPvB02] [GMvBM05]. The search for audiovisual content (not relying on keywords or other textual attributes) is still in embryonic state, even though some progress occurs in form, color, texture, and frequency sequences pattern recognition [RH05] [SK05] [KMS06].

A. Sideris / The Encyclopedic Concept in the Web Era

6. Intertextuality and "Interknowledge"

In the conventional encyclopedias the notional relation of an entry to another was signaled in the former with a reference to the later, under the familiar form of "see entry …" This system could be effectively operational only with internal references. For the external references (bibliography) the reader was depending upon the wealth and updating of documentation of the library in which he was studying. Nowadays a huge variety of books, papers and research documents are available on the web in their full version, transforming thus the external references into a matter of course, and simultaneously raising questions about their choice criteria, their relevance, reliability, placement and commendation.

Furthermore, references may equally lead to an admirable variety of audiovisual material, ranging from pictures and graphs to geographical models, video and music files. The notion of intertextuality (borrowed from the literary theory, later transfigured to 'hypertextuality'), which has been crucial in early web years for the understanding of the new knowledge implementations [Tre03], proves to be poor for the description of the current situation, where the textual, verbal, and audiovisual information are tightly interwoven into an integral knowledge net. The absence of a satisfactory neologism for this phenomenon led us to coin provisory the otherwise unhappy term *interknowledge*.

7. Content requirements

The web encyclopedias of historical and cultural content (under which fall also most of the universal content encyclopedias) do not differ from the conventional ones in their scientific methodology. The issues of micro- and macrohistorical perspectives remain crucial, as well as the management of the sources. Nevertheless, the digital format allows more easily the narration of multiple or parallel historical discourses, records and compares more forms of event sequences, while at the same time different definition networks become visible, as well as different importance hierarchies and multiple fields of validity of the historical and cultural information are brought out.

The most ambitious of the online encyclopedias aspire to answer questions beyond the traditional «who? when? why? what?», such as which are the forms of cultural continuity and discontinuity, what are the components that constitute an event, what sort of serial situations can be traced, what criteria of periodicity should be adopted, what sort of relational systems should be emphasized (hierarchy, dominance, escalation, strict determinism, circular causality). For the purposes of such an analysis, the traditional tools of history are not sufficient and one should turn to methodological standards elaborated by the totality of humanities or even proper to the natural

sciences. Some of the above questions have already affected - and have found satisfactory expression in - the data and knowledge base systems theory. The theoretically unlimited scale down or scale up of the time and space parameters, together with the rigorous chapter structure of the entries may produce a babushka-like effect, when an entire entry is included in another wider one, which in turn is also included in another even more wide. At the same time, comparable chapters of different entries may be brought together to build up an entirely new entry. Following this logic the same multimedia material may be integrated into various, apparently non related entries.

During such a process, it is anticipated that the question of sources will be posed. From the very beginning of history as a science, the sources were used, questioned and were the object of many discussions – not only on whether they are honest or deceiving, informed or ignorant, original or altered, but also for the role they can play regarding the reconstruction of reality, the organization and origin of the various versions and finally, the interpretation. A web encyclopedia should still rely on them, but keeping an especially watchful eye on the reliability of its online sources. It may express its critical concern for the scientific discourse while integrating the sources in the body of the historical narration, both as documentation (footnotes and references) as well as the object of the historical process (long quotes). This was an unimaginable feature for the conventional encyclopedias, limited by cost, volume and deadline boundaries. The sources in an online encyclopedia are not merely a "dead museum exhibit", but the objects that the editor is called to present, structure and elaborate in order to make them "history".
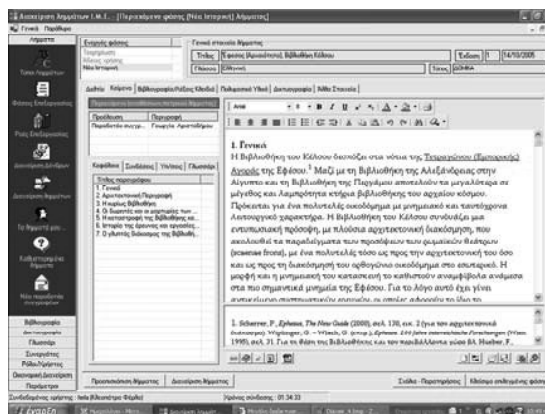
8. Form requirements

Figure 1: *A screenshot of the administrator's tool for the management of chapters, endnotes and internal links within the entry "Library of Celus at Ephesus".*

The electronic format and especially its online version introduced a series of requirements, which are totally independent from the content itself. The length of the presented texts in connection with the limited space of a computer screen may raise obstacles in the navigation and the simultaneous vision of related components of one or more entries (i.e. reference in the text and footnote content, image and caption, abbreviation and full length reference, link in the text and relevance of the linked document, number of clicks to reach the furthest component, etc.). Most of these obstacles have already found solutions in the general web documents with mouse-on pop-ups, "jumping" forward and backward, enumeration of the invisible pages or items to follow, and similar techniques.

Things are more complicated with the multimedia material, its accessibility and its copyright protection. Even today's (2006) very fast connections and streaming techniques do not allow the transmission of high resolution video files nor do they support voluminous files of 3D models and 2D drawings. Yet it seems that this is only a matter of time to come up with the appropriate solutions. The copyright protection of the audiovisual material, as it is connected to the lucrative activities of various content providers, accomplished in recent years more successful steps. All the above issues however have limited interference with the operability of an online encyclopedia and they do not really affect its fundamental differentiation from a conventional version.
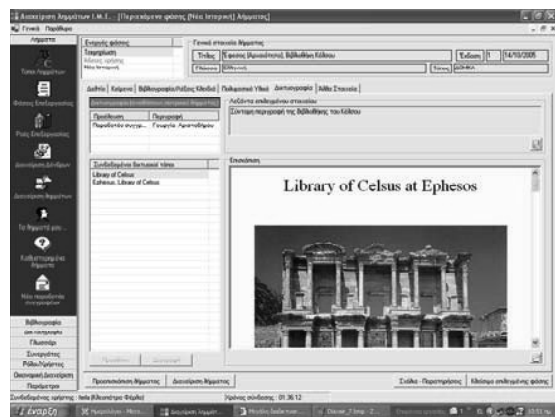
9. Administrator's / editor's needs

Figure 2: *A screenshot of the administrator's tool for the insertion of web links in the entry showing a web page presenting the Library of Celsus at Ephesus.*

The first concern of the administrator, who most often identifies with the editor of the content, is the management of the incoming contributions. He needs to begin with an administrative tool, which will allow him to read, correct, complete, edit, validate and publish the contributions on the web, as in Figure 1. A more serene and more distant consideration will come later. He then will ask to modify the catalogues and the content, to update the aged information, to correct the factual errors, the syntactic and conceptual mistakes, to add new entries and complete the old ones, to establish or to suppress internal and external links, to publish and un-publish, to add new multimedia material, to produce finally new editions of parts or even of the whole work, as in Figures 2 and 3.
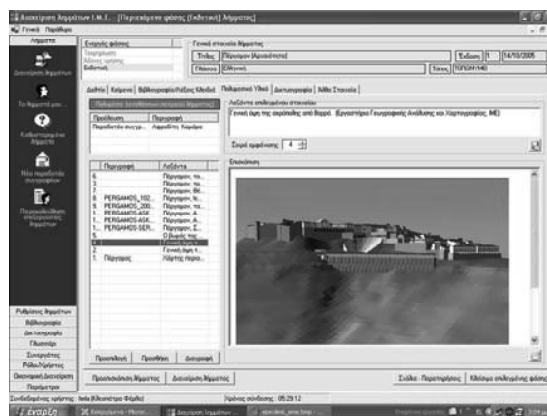

Figure 3: *A screenshot of the administrator's tool for the insertion of multimedia in the entry showing a VRML model of Pergamon.*

This is the paradise of the editor! But it may be a very deceitful paradise, since both the eternal pursuit of the perfection and the exaggerate trust on an ulterior intervention may prove detrimental for the work itself.

Another concern of any serious editor is to attract numerous and qualified contributors, and in this direction may help an online reporting on which parts of the project are finished, which are under elaboration, and which are still unattributed and available to potential collaborators, as seen in Figure 4.
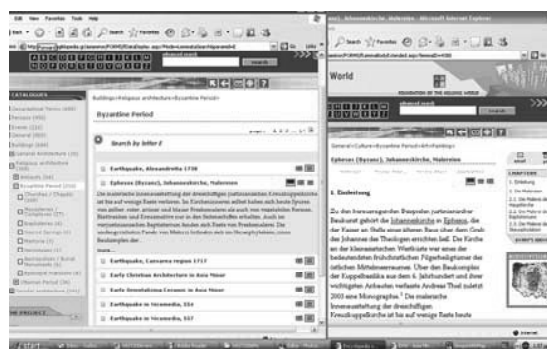

Figure 4: *A screenshot of the EHW site with an entry in German (summery and full text).*

Along with this last concern comes the need for online submission of contributions, for communication with the contributors, and last but not least for logistic management (Who has to submit what and when? Has he a valid contract? How much he has to be or he is already paid for? What has been applied for in various content providing institutions and at which cost? etc.).

At last a smart administrator / editor, who wants to facilitate his job, will ask for some basic reports on the global situation of the project, presenting entities, entries or items per phase of the workflow. And if he is really mean, he will ask to be allowed to modify these administrative tools according to his changing but anticipated needs. In an apex of peculiarity he may even ask to be allowed to control the access of users, as well as to modify the appearance of the user's interface in order to promptly respond to users' feedback. Then, if he wants to drive mad his system designer or supplier, he will ask his precious data to be stored in several servers, automatically updated and in formats and systems compatible with all current platforms and browsers, plus with their future development.

10. User's expectations

Any user of any encyclopedia seeks information and/or knowledge. And although nobody ever dreamed to judge a conventional encyclopedia by the compatibility of its volumes with the height of his own bookshelves, the user of a web encyclopedia expects it to be compatible with his hardware and his software!
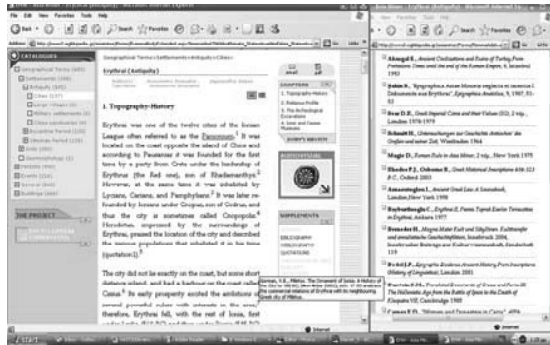

Figure 5: *A screenshot of the EHW site with the entry on ancient Erythrai showing the functions of endnotes and bibliography.*

He also expects it to be easily navigable and searchable, that is to say, with clear structure, unambiguous instructions and abundant orientation facilities. Furthermore, most users expect to find a printer friendly version, and those with visual or acoustic

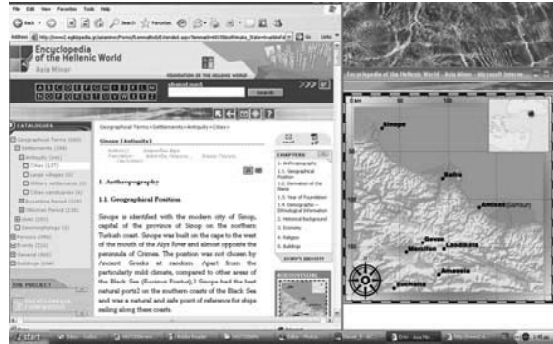difficulties to find versions, which make the content available to them too.

Figure 6: *A screenshot of the EHW site with the entry on ancient Sinope and its map.*

Figure 7: *A screenshot of the EHW site with the entry on the Artemis Temple at Sardis with its architectural redrawing.*

As far as it concerns the content itself, the user expects it to be up to date, of controllable accuracy and reliability, and easy for citation. That is to say, in each entry the author, the sources, the date in which it has been composed and the right way to cite it must be clearly stated. The user also expects the entry to follow the standards of the relevant discipline, to refer to other relevant and controlled resources on the web, and to document the subject with as much non textual material as possible, as in Figures 5-7. In multilingual encyclopedias whenever a verbal or a textual element appears in a multimedia object, it has to be translated in the language of the entry.

11. The encyclopedic concept in the web era

For the editor and the user of a web encyclopedia, there are several concerns beyond those, which apply to any conventional encyclopedia too (i.e. reliability, accuracy, density of information, multidisciplinarity in the approaches, novelty, wide range of scientific tendencies and internationally acknowledged contributors).

The way these concerns have been treated may serve as indicators of the encyclopedia's success. Among these indicators one should count the thematic clarity, the subject definition, the setting of the geographical and temporal borders, as well as the civilization and cultural focus. The content of a successful web encyclopedia is characterized by its integrity, originality, novelty, polymorphy, complementarity, and last but not least, its multilingual presentation. Both the editor and the user are bound to define the target group, but the experience on the web has already shown that "more is never too much". Thus web encyclopedias are expected to satisfy the highest academic and scholarly standards, and in the same time offer the necessary tools, which will allow the non specialist audience to take advantage of the gathered knowledge (glossaries, choice of basic bibliography, comments on webliography etc.). Web encyclopedias are expected to be really in the web and take advantage of the *interknowledge*, to refer to other resources with pertinence, to provide dating of their components and commendation of their links. From a more technical point of view one may expect an easy navigability and searchability, the adoption of the semantic indexing techniques, a print friendly environment, the compatibility with the current and upcoming platforms and software, the extendibility, the accessibility by volume and design, and the interoperability with other similar systems.

As for the EHW, which is essentially bilingual, Greek and English, in FHW we tried (and we are still trying) to implement all the above requirements as often as possible and we believe we succeeded most of the times. The work is now online expecting completion of the content and improvements in its function, which will be better targeted according to the comments of the users.

References

[BC05] BRESSAN S., CATANIA B.: *Introduction to Database Systems.* McGraw-Hill Education, 2005.

[BFF04] BURDMAN FEFERMAN A., FEFERMAN S.: *Life and Logic.* Cambridge University Press, 2004.

[Cho03] CHOWDHURY G. G.: *Introduction to Modern Information Retrieval,* Neal-Schuman Publishers, 2nd edition, 2003.

[CDGS*04] CROFTS N., DOERR M., GILL T., STEAD S., STIFF M.: *Definition of the CIDOC CRM.* ICOM/CIDOC Special Interest Group, 2004.

[DSW06] DAVIES J., STUDER R., WARREN P. (eds): *Semantic Web Technologies: Trends and research in Ontology-based Systems.* John Wiley & Sons, 2006.

[FST03] FERLA K., SIDERIS A., TZEDOPOULOS Y., *Encyclopaedia of the Hellenism in Asia Minor: A Methodology*, FHW, 2003.

[Fra05] FRANZEN T.: *Gödel's Theorem: An Incomplete Guide to Its use and Abuse.* A. K. Peters, 2005.

[GMvBM05] GIL Y., MOTTA E., V. BENJAMINS R., MUSEN M. (eds): *The Semantic Web – ISWC 2005 Proceedings, Galway, Ireland,* (Nov. 6-10, 2005), Lecture Notes in Computer Science, Springer.

[GPvB02] GOMEZ – PEREZ A., BENJAMINS V. R. (eds): *Knowledge Engineering and Knowledge Management Ontologies and the Semantic Web, 13th International Conference, EKAW 2002 Proceedings, Singuenza, Spain,* (Oct.1-4, 2002), Lecture Notes in Computer Science, Springer.

[GPCFL04] GOMEZ – PEREZ A., CORCHO O., FERNANDEZ-LOPEZ M. (eds): *Ontological Engineering : with examples from the areas of Knowledge Managment, e-Commerce and the Semantic Web.* Advanced information and Knowledge Processing, Springer, 2004.

[GPE05] GOMEZ – PEREZ A., EUZENAT J. (eds): *The Semantic Web : Researcgh and Aplications : Second European Semantic Web Conference, ESWC 2005, Proceedings, Herakleion, Crete, Greece,* (May 29 – June 1, 2005), Lecture Notes in Computer Science, Sprienger.

[IJ05] INQWERSEN P., JARVELIN K.: *The Turn: Integration of Information Seeking and Retrieval in Context.* The information Retrieval Series, Springer, 2005.

[KMS06] KIM H.-G., MOREAU N., SIKORA T.: *MPEG 7 Audio and Beyond: Audio Content Indexing and Retrival,* John Wiley & Sons, 2006.

[Kow97] KOWALSKI G.: *Information Retrieval Systems: Theory and implementation,* Kluwer Academic Publishers, 1997.

[Leu06] LEUF B.: *The Semantic Web: Crafting Infrastructure for Agency,* John Wiley & Sons, 2006.

[Mor86] MORIN E. : *La méthode. La connaissance de la connaissance,* Edition du Seuil, 1986.

[Orr03] ORR M.: *Intertextuality: Debates and Contexts,* Polity Press, 2003.

[RH05] RAFFERTY P., HIDDERLEY R.: *Indexing Multimedia and Creative Works: The Problems of Meaning and Interpretation,* Ashgate Publishing, 2005.

[Sid05] SIDERIS A.: *Semantic Organization of Data for Online Encyclopaedias of Cultural Content, ICS-FORTH,* 2005.

[SK05] STAMOU G., KOLLIAS S.: *Multimedia Content and the Semantic Web: Standards, Methods and Tools,* John Wiley & Sons, 2005.

[Suw06] SUWANNAJAN P.: *Evaluating the performance of the latent semantic indexing,* ProQuest / *UMI*, 2006.

[TWR06] TANIAR D., WENNY RAHAYU J.: *Web Semantics Ontology* (Idea Group Publishing, 2006)

[Tre01] TREND D.: *Reading Digital Culture,* Blackwell, 2001.

[ZOM05] ZHOU L., OOI B. CH., MENG X. (eds): *Database Systems for Advanced Applications: 10th International Conference DASFAA 2005, Beijing, China, Proceedings,* (Apr. 17-20, 2005), Lecture Notes in Computer Science, Springer.

Presenting uncertainty in archaeological reconstructions using possibility theory and information visualisation schemes

M. Sifniotis[1], K. Mania[1], P. Watten[1], M. White[1]

[1]Centre for VLSI and Computer Graphics, University of Sussex, U.K.

Abstract

We present a prototype implementation of an alternative approach to visualising three-dimensional reconstructions of historical structures by taking into account archaeological uncertainty. The approach presented applies possibility theory to represent confidence levels in reconstructions. Feedback from an expert archaeologist is given to the system and results are integrated within information visualisation schemes, which vary according to uncertainty rankings. Changes in schemes are applied in real-time utilising X3D shaders and range from variations in colour, hue, opacity and saturation among others.

Categories and Subject Descriptors (according to ACM CCS): J.2 [Physical Sciences and Engineering]: Archaeology I.3.7 [Computer Graphics]: Color, shading, shadowing, and texture; I.2.3 [Deduction and Theorem Proving]: Uncertainty, "fuzzy," and probabilistic reasoning;

1. Introduction

Three-dimensional reconstructions of cultural and archaeological structures have become more prominent during the last decade. Virtual walkthroughs and photo-realistic rendering are now the norm and are employed in site visualisations, museum kiosks [3DK06], digital archiving [ARC06] etc. However, archaeology as a discipline is inherently uncertain; it is a destructive process used to gather what available evidence remains in order to better understand ancient cultures. Since an archaeological site is never recovered to its exact ancient proportions, it is safe to say that archaeological hypotheses and interpretations also contain the element of uncertainty. Virtual reconstructions of such sites do not usually display the uncertainty inherent in archaeological interpretations. It is more often the case where the user is able to navigate through virtual structures that make no distinction between the real and the reconstructed parts.

The archaeological community has stressed the need to acknowledge the availability of other possible hypotheses as well as the difference between what was found and how it is interpreted [MR94]. As a result, new approaches have come forward that take these alternatives under considera-

tion, and attempt to contain them in a virtual reconstruction. Recovered remains are differentiated from their interpretation by using a dividing line and different colour in [Eit98]. In [SMI99] the reconstructed portions are displayed as sketch-lines and transparent overlays. Methods to present uncertainty are introduced in [KD05] where the use of colours, transparency and rendering are suggested as ways of representing ambiguity. A more technical approach is given in [ZCG05] which compares different information visualisation schemes to display uncertainty through time.

In [HN04] fuzzy logic is introduced as a basis for quantifying reliability in virtual reconstructions. A reliability number is assigned, ranging from 0.0 (low reliability) to 1.0 (highest reliability), for each reconstructed part of the structure. By combining the values using a fuzzy logic union, an overall reliability index of the reconstruction is calculated. Our approach differs in that it uses *possibility theory* combined with perception-based information visualisation schemes in order to calculate and visually represent the uncertainty in reconstructed buildings. We define uncertainty as the hypothesised factor and the extent of expert knowledge included in the visualisation of an archaeological

structure. Archaeologists piece together available information from evidence of excavated features, artefacts, ecofacts, comparisons and ancient texts into a speculative version of the past. This version becomes more certain as the evidence increases.

This paper presents work in progress on the visualisation of archaeological uncertainty using possibility theory in combination with information visualisation. Section 2 introduces possibility theory and how it relates to elicitation of human judgement. Section 3 describes the methodology adapted in this research, the use of possibility theory and information visualisation schemes. Section 4 presents the prototype application while section 5 concludes with a discussion on further work.

2. Possibility theory

Possibility theory handles uncertain and incomplete information. Initially, an extension of fuzzy sets, it was first introduced by L. Zadeh [Zad78] and further developed by Dubois and Prade [DP88], into a calculus of uncertain logic. Like fuzzy logic, possibility theory has its roots in the theory of fuzzy sets. However, while fuzzy logic reasons about vague knowledge, possibilistic theory mainly deals with uncertain and incomplete knowledge [DP94]. More specifically, fuzzy logic is concerned with statements having truth values; in other words, to what extent a statement is close to the truth. In fuzzy logic scenarios, fuzzy set rules are used to describe the gradual nature of properties, e.g. to what degree a fragmented tile belongs to the family of Roman tiles. Possibility theory has uncertainty degrees and does not model truth values but expresses the fact that the truth value is unknown. The uncertainty degrees support assessment of the most *plausible* truth value. Consider the following example: an archaeologist has recovered a fragment of a column, x. The available evidence suggests that it is Ionic or Doric, these options are represented in the set $\Omega(x)$ which contains all possible interpretations (ω) of the column. If $\omega = Ionic$, a possibility distribution $\pi(\omega) : \Omega \rightarrow [0,1]$ expresses the extent that the actual value of x is ω; e.g. the possibility that the column part belongs to an Ionic column.

Let us suppose that A is an interpretation of the above scenario: $\Pi(A)$ represents the level of possibility that the column belongs to an interpretation from the above group. As a result: $\Pi(\Omega) = 1$ and $\Pi(\oslash) = 0$. The possibility that the column belongs to at least one of these two types is equal to the value of the most plausible of the two: $\Pi(A \vee B) = max[\Pi(A), \Pi(B)]$. This contrasts with probability theory where the same equation is additive. Additionally, possibility has a dual measure: necessity. This represents the possibility of the contrary event, e.g. $N(A) = 1 - \Pi(\neg A)$. As a result $N(A \wedge B) = min(N(A), N(B))$. A final important difference from probability is that in possibility theory, $\Pi(A)$ and $\Pi(\neg A)$ are weakly dependent. In other words, possibility theory allows us to state: *while I am quite sure that the fragment belongs to an Ionic column, I accept the slight possibility that it may be Doric* thus $\Pi(A) + \Pi(\neg A) >= 1$. Similarly, for duality $N(A) + N(\neg A) <= 1$. This illustrates that possibility measures can flexibly express partial ignorance.

A crucial issue about possibility theory is that the range [0,1] can be described in a purely qualitative way and is not restricted by a numerical representation-such as an ordered scale from uncertain to certain. In [RNM03] possibility theory, with qualitative ordinal values, is successfully used to describe human judgement in medical scenarios where doctors express their belief on the interpretation of a medical diagnosis. It also has been shown that it is difficult to elicit separate necessity and possibility measures at the same time from the expert due to the close nature of both scales. As a result, a Ψ scale is used which combines Π and N to $\Psi(A) = 1/2[\Pi(A) + N(A)]$.

For the purposes of our research we are adapting the above-mentioned Ψ scale to describe the uncertainty an archaeologist has on a specific reconstructed part.

3. Methodology

Our approach is focused on 3D reconstructions of archaeological structures. Our goal is the implementation of a visualisation system where the archaeologist, by describing their uncertainty on every part, influences the appearance of the reconstruction. Uncertainty values are directly related to the information visualisation scheme chosen. As a result, there are two distinct components in the system: the possibility calculations and the visualisation. These are now explained more analytically.

3.1. Possibility theory and archaeological uncertainty

We have identified three categories through which uncertainty could be expressed:

1. Expert judgement: the archaeologist goes through each reconstructed part of the building and selects how sure they are about the interpretation from a list containing linguistic expressions of uncertainty. The simplest form for these expressions can be described as a Likert-style scale [Lik55] (Totally uncertain, Fairly uncertain, Somewhat uncertain, Neither certain/uncertain, Somewhat certain, Fairly certain, Totally certain).
2. Expert judgement with influencing factors: this second category asks the archaeologist, to supply expert judgement and also identify any evidence which may influence judgement for the specific part-these influencing factors gathered so far from archaeologists are discussed in 4.2.
3. Influencing factors: it would be interesting to observe whether by solely identifying available evidence one could estimate the uncertainty of each part.

3.2. Visualisation schemes for displaying archaeological uncertainty

Information visualisation techniques encompass a wide range of approaches developed to help people visually interpret data. Colour visualisation schemes [War04] are of importance when visually interpreting uncertainty levels, especially ordinal perceptually-ordered pseudocolour sequences. Pseudocolouring is a technique for representing varying values using a sequence of colours. In archaeology it is mostly used in Geographical Information Systems (GIS) representation. Ordinal perception means that colour grading follows an order (black to white, hue/saturation increase, etc); the crucial requirement is the change towards opponent colour space. If a data value Y lies between X and Z, in an ordinal pseudocolour sequence the colours should have the same ordering scheme to allow for the visual perception of the ordering of values. Fig. 1 illustrates commonly used pseudocolour sequences. For the purposes of this research, once an archaeologist has assigned values to the parts, the results from the possibility model will be fed to the information visualisation scheme.
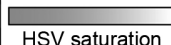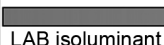
Figure 1: *Commonly used pseudocolour sequences*

4. Implementation

A Romano-British building [MR05] located in the area of Fishbourne, East Sussex, UK has been chosen as the first case study of the research (Fig 2). The structure, referred to as Building 3, is located near the grounds of Fishbourne Roman Palace. Building 3 nencompasses little evidence besides its foundations. Currently there are two interpretations related to its past form: one suggests its function was of a military nature, while the other attaches a religious purpose.

4.1. System prototype

A 3D model of the building is composed of different parts (hypothetical and recovered) such as the various walls, roofs, etc. The model is displayed using X3D [X3D06], which is an open format for communicating 3D objects using XML. The system prototype, illustrated in Fig. 3 is divided in two interacting components: control (A) and visualisation (B). The control component allows the user to select different parts of the model through a user interface (1) and assign uncertainty values (2). Once all the values have been assigned, the user can choose from a set of visualisation schemes to be applied to the model (3). These schemes are implemented
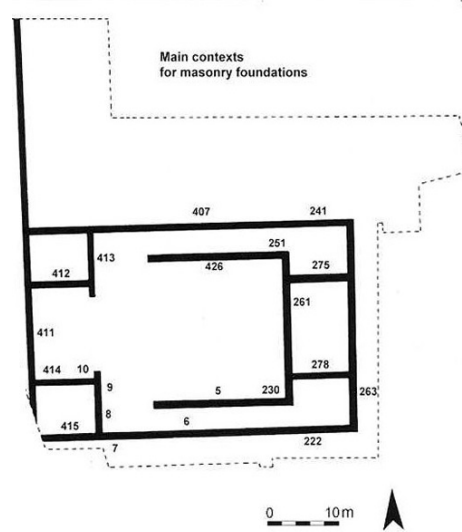

Figure 2: *Plan of Fishbourne Building 3*

using X3D shaders [dCGP04], which support real-time adjustment of textures, opacity, colour, position and direction of the object. The use of X3D shader nodes allows us to embed GLSL/HLSL shaders in our scene, and as a result swap between different visualisation schemes. The use of shaders opens up possibilities of visualisations such as a combination of texture maps with varying colour overlays. Finally, the visualisation component displays the model that supports user navigation and interaction with the scene. The system provides bidirectional information transfer between the control component and the scene.
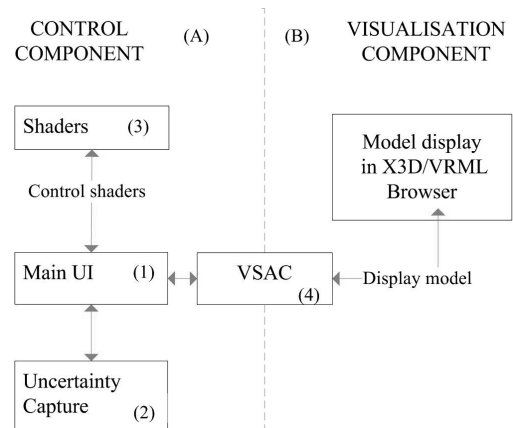

Figure 3: *Diagram of the system*

The underlying visualisation and communication services are supported by VSAC (Visual Simulation Attribute Connector). VSAC (4) is an author-friendly, run-

time configurable X3D interaction system; it utilises its own X3D/VRML prototype node, VSAM (Visual Simulation Attribute Messenger). VSAM provides all input and output events for all data types supported by VRML/X3D browsers (Octaga, Cortona, Xj3D among others). All VSAM fields are optional at design time; the fields can be configured dynamically at runtime if required. As a result, objects in the scene are identified by this prototype and can be manipulated in real-time. Fig 4 shows the building with varying transparency; the visualisation window is to the left and the controller to the right.
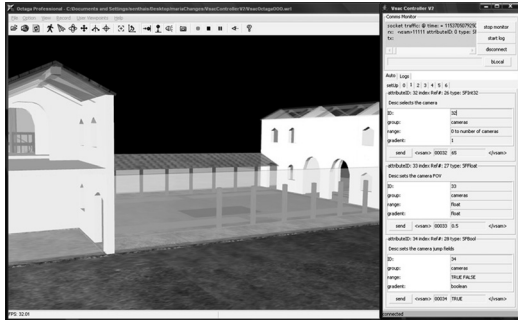

Figure 4: *Fishbourne Building 3 in the prototype application*

4.2. Influencing factors in interpretation of archaeological structures

As briefly introduced in 3.1, in order to create a reconstruction, archaeologists piece together available evidence. Through discussions with archaeologists we have identified the following categories of evidence:

- Features: any non-portable remnant of human activity
- Artefacts: objects made or modified by human culture
- Biofacts: objects located in a site but not altered by human hands - seeds, bones, wood, etc
- Topography: environmental layout and information
- Textual material: references from ancient texts
- Absolute comparisons: comparison of building with similar buildings of the period
- Contextual comparisons: comparison of the building in its context with similar buildings and their contexts
- Peer influences: discussions with peers, outside advice

We suggest that according to the evidence available for each part, the certainty of the archaeologist will increase or decrease. By using questionnaires and interviewing archaeologists, we are currently evaluating whether certain types of evidence (stand-alone and in combination) are considered *stronger* than others. For example, we investigate whether archaeologists often consider structural evidence more significant than biofacts.

It is understood that for different archaeological periods, respective archaeologists may place importance in different evidence types. For example, an archaeologist studying the Middle Ages may place more importance on textual evidence (a wide range available), than would an early Anglo-Saxon one (almost no textual evidence available). This leads to the development of varied setup schemes for the possibility engine.

For this reason, the questionnaires mentioned above, are focused on Roman period archaeologists, which is the era relative to our case study. However, any preference in evidence that may be derived can be easily changed in the system.

5. Discussion and further work

In this paper we have described an approach for visualising archaeological uncertainty in ancient structures by combining possibility theory and information visualisation. Possibility theory provides us with a means to model human uncertainty; in its simplest form it expresses the degrees to which a statement should be considered possible and plausible. Changes in the uncertainty of an expert are visually represented by ordinal, perceptually-ordered pseudocolour schemes. We analyse the design of a prototype application that controls the visualisation. Models are displayed in X3D, and visualisation schemes as well as uncertainty values, can be manipulated in real-time. The schemes are implemented with X3D shaders, offering the possibility of a wide range of visual transformations. A Romano-British building is selected to serve as a testbed for an initial case study, modeled in X3D and manipulated through the application.

We are using formal questionnaires to determine whether influencing factors, such as a preferential order in different evidence types, can affect an archaeologist's uncertainty. Integration of influencing factors in our prototype will incur weight factors in the calculation of uncertainty, hence acquiring statements which could be less or more plausible. The next step would be to test how the resulting visualisations would reflect the calculated uncertainties and whether the perceived uncertainty based on the visualization scheme would match the impression of the archaeologist. The ultimate goal of this system is to identify visualization schemes which are able to reflect uncertainty levels based on complex information, thus offering a technological tool which would aid archeological discovery.

References

[3DK06]   3DKIOSK: 3DKIOSK: The Epoch 3D multimedia kiosk, accessed July 2006.

[ARC06]   ARCO: ARCO:Augmented Representation of Cultural Objects, accessed July 2006.

[dCGP04]   DE CARVALHO G. N. M., GILL T., PARISI T.:

X3d programmable shaders. In *Web3D '04: Proceedings of the ninth international conference on 3D Web technology* (New York, NY, USA, 2004), ACM Press, pp. 99–108.

[DP88]   DUBOIS D., PRADE H.: *Possibility Theory: An Approach to Computerized Processing of Uncertainty.* Plenum Press, New York, 1988.

[DP94]   DUBOIS D., PRADE H.: Partial truth is not uncertainty: fuzzy logic versus possibilistic logic. *IEEE Expert 4* (1994), 15–18.

[Eit98]   EITELJORG H.: Photorealistic visualizations may be too good. *CSA Newsletter XI*, 2 (1998), –.

[HN04]   HERMON S., NICCOLUCCI F.: A fuzzy logic approach to reliability in archaeological virtual reconstruction. In *Proceedings of the 2004 Computer Applications in Archaeology (CAA) Conference* (2004).

[KD05]   KENSEK K., DODD L. S.: On the nature of representation, the san bernardino convent. In *Proceedings of Hawaii International Conference on Arts and Humanities* (2005).

[Lik55]   LIKERT R.: A technique for the measurement of attitudes. *Archives of Psychology 140* (1955), 55.

[MR94]   MILLER P., RICHARDS J.: The good, the bad, and the downright misleading: archaeological adoption of computer visualisation. In *Proceedings of CAA Computer Applications in Archaeology CAA '04* (1994), Hugget J., Ryan N., (Eds.), pp. 19–22.

[MR05]   MANLEY J., RUDKIN D.: *Facing the Palace: excavations just east of Fishbourne Roman Palace (Sussex, UK) 1995-1999,.* Sussex Archaeological Collections (SAC) 141, 2005.

[RNM03]   RAUFASTE E., NEVES R. D. S., MARINÉ C.: Testing the descriptive validity of possibility theory in human judgments of uncertainty. *Artif. Intell. 148*, 1-2 (2003), 197–218.

[SMI99]   STROTHOTTE T., MASUCH M., ISENBERG T.: Visualizing knowledge about virtual reconstructions of ancient architecture. In *Proceedings of IEEE Computer Graphics International CGI '99* (1999), The Computer Graphics Society, IEEE Computer Society, pp. 36–43.

[War04]   WARE C.: *Information Visualization: Perception for Design.* Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2004.

[X3D06]   X3D: WEB3D website, accessed July 2006.

[Zad78]   ZADEH L.: Fuzzy sets as a basis for a theory of possibility. *Fuzzy Sets and Systems 1* (1978), 3–28.

[ZCG05]   ZUK T., CARPENDALE M., GLANZMAN W.: Visualizing temporal uncertainty in 3d virtual reconstructions. In *Proceedings of the 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (VAST 2005)* (2005), The Eurographics Association, pp. 99–106.

Beauty or Beast?: A Review of the CIDOC-CRM Applications and Thesauri in Archaeology

G. Sugimoto [1]

[1]PIN: Servizi Didattici e Scientifici per l'Università di Firenze

Abstract
The CIDOC-CRM may be a growing standard within the museum and cultural heritage sector. In fact, some museum experts and technicians are almost spell-bound by it, particularly because it is now in the process of receiving ISO standard. Without doubt it is an interesting and well-organized idea, but is it that popular? Have we agreed to use it as a world standard? This paper reviews some applications of the CIDOC-CRM and explores the issues about thesaurus. Although many examples of the theoretical uses of the CIDOC-CRM are found on the web, not enough practical implementations have yet been undertaken. In addition, consideration should be given to the conceptual gap of domain experts, the uncertainty of the area of domain, the interpretation and explicitness of the CIDOC-CRM, and the lack of its dissemination. It is not the aim of this paper simply to criticize the CIDOC-CRM, but to provide a better understanding of it and offer possible solutions for several problems, from an archaeological point of view.

Categories and Subject Descriptors (according to ACM CCS): H.3.7 [Information Systems]: Standards

1. Prologue

The CIDOC (the International Committee for Documentation) of ICOM (the International Council for Museums) has developed a domain ontology called CIDOC-Conceptual Reference Model (CRM) in order to provide a framework for the exchange of cultural information especially within museum community [Cid06]. The ontology does not define descriptive schema for the cultural domain, and also does not mention any issues related to technical implementation. It rather provides a common ground for information exchange and integration by conceptualizing the domain of cultural heritage. The CIDOC-CRM encourages cultural specialists to clarify semantic structures and relationships among information they deal with, by means of an object oriented approach. This object-oriented model facilitates the harmonization of maximum details of information, and the extension for more specialized fields of application would be performed without semantic loss. The first version of the model was published in 1998. Subsequently, the version 3.2 has been submitted to the International Standard Organization (ISO). For these reasons cultural professionals including museum curators, information specialists, librarians, archivists and archaeologists have started to use the CIDOC-CRM.

In spite of the fact that there are several on-going projects using the CIDOC-CRM, few have overviewed its applications in the cultural heritage arena. It seems that approval for this standard overwhelms the opposition, yet the number of critical reviews has hitherto been quite limited. Since the CIDOC-CRM may soon acquire an ISO standard (ISO/PRF 21127, current stage on 2006-06-06: 60:00 international standard under publication), an overall analysis and critique are long overdue. It is understandable that the CIDOC-CRM is appealing and attractive, particularly taking into consideration the state-of-the-art technologies such as Semantic Web and object oriented model. These technologies are clearly giving some sort of impact in the world of information management. However, the potential and the risks of the CIDOC-CRM are also not well known in the same way that existing international documentation standards have not yet become widely known and used. With a view to understanding the CIDOC-CRM better, the author has undertaken a web-based survey for its applications and available thesauri. In particular the focus is placed upon the current state of the development from an archaeological point of view. This paper, thus,

will evaluate some applications of the CIDOC-CRM in archaeology, and give some suggestions for the future of the CIDOC-CRM, in relation to archaeological thesauri probably required for its practical use.

2. CIDOC-CRM applications

It is not the purpose of this paper to review all projects related to the CIDOC-CRM, rather it outlines the intentions of some projects as well as their problems and potential.

From the early days of the CIDOC-CRM, some papers have been available online. Most of them tried to test the validity of the CIDOC-CRM by mapping existing standards/metadata schemata into it. They include Dublin Core Metadata Element Set (DCMES), Art Museum Image Consortium (AMICO), MDA SPECTRUM, Research Libraries Group (RLG) Cultural Material XML Schema and DTD, Encoded Archival Description (EAD), Functional Requirements for Bibliographic Records (FRBR), ABC Harmony and OPENGIS [CDG03]. These results have convinced the CIDOC-CRM inventors that the ontology functions perfectly for a wide range of cultural subjects. This is natural, because the CIDOC-CRM can express cultural phenomena in a much richer way than other metadata schemata. [Doe00] argued that the mapping from the CIDOC-CRM to DCMES was tedious due to the richness of the CIDOC-CRM path. Indeed, the validation for the compatibility with cultural standards is probably enough. But, as a result of these formal mappings, not so many examples of practical implementations are widely available. It is really high time to move from a theoretical validation to a practical one.

More recent developments can be seen in different projects particularly all over Europe. The SCULPTEUR project involves the Uffizi, the National Gallery and the Victoria and Albert Museum, the Musées de Cherbourg and the Centre de Recherche et de Restaration des Musées de France (C2RMF) [SGL*05]. The rich data of these museums were mapped to the CIDOC-CRM, and the project achieved interoperability using a Z39.50 search and retrieve web service (SRW). The concept browser is an idea of grouping concepts by theme (people, art objects, events, and techniques etc). The semantic relationship among the themes will be hyperlinked by the CIDOC-CRM ontology, and a visualization tool called TouchGraph enables users to navigate such concepts easily. mSpace was also adopted in order to avoid the visualization of complicated structure by filtering concepts. One of the key functions of SCULPTEUR is a content-based retrieval system for 2D and 3D objects. The performance of such retrieval would be slightly disappointing; however, with the help of metadata and ontologies, more and more sophisticated data retrieval systems will be constructed in the future. The project is innovative and the use of the CIDOC-CRM is clearly described, but the application is not available on the web. In addition, a similar example of content-based search in the field of cultural heritage is seen in the website of the Hermitage Museum (http://www.hermitagemuseum.org/). As [SGL*05] pointed out, since the assistance of a CRM expert was required to complete and validate the mappings, some problems rely on the validity of mappings.

Norway seems to be one of the most active countries in the use of the CIDOC-CRM and the Semantic Web. [JHOO04] tackled a task to map unstructured data into a CIDOC-CRM compliant model semi-automatically. The case study used old reports, acquisition catalogues and grey documents from different types of museums in Norway. The project used XML and DTD as a mark-up language and schema to encode unstructured running texts. An event-based approach was adopted and experimented in order to validate the potential of the CIDOC-CRM.

The use of unstructured data in relation to the CIDOC-CRM is interesting, compared to structured databases which are relatively easy to map. Arising issues—if not problems—here are intensive labour force and selection for digitization. All encoding works to extract the meaning of the information have been done manually. Although [JHOO04] stressed that manual mark-up is an unavoidable process, even if automation is worth trying, the intensity of human involvement is subject to the users needs for such unstructured information. Similarly this issue is applied for the ideas of how to create a digital summary of contents for newly published books, in order to make a content-based search of modern publications. Basically the task is unsolved. For example, the BOOK Database developed by several Japanese publishers has 720,000 entries of tables of contents, yet all were input manually [Sug06b]. From those examples, it is evident that the selection for digitization is an important aspect.

On the other hand, MuseSuomi archived a type of semantic web portal in conjunction with the National Museum, Espoo City Museum, and Lahti City Museum [HJK*04]. A search engine, Ontogator, enables users to execute a view-based multi-facet search. The nine views of facets system are underlaid by seven ontologies including artifacts, materials, actors, locations, times etc. Some of them are the subset of widely used cultural thesauri in Finish museums. This search interface is an easy way to navigate the whole complicated database. In addition, a semantic recommendation system allows users to explore hyperlinks of both explicit and implicit knowledge of a collection they choose. RDF triples and collection domain ontologies realized a powerful knowledge base. Moreover, a prototype implementation was made for the use of MuseSuomi in WAP 2.0 compatible mobile phones. It is planned in the future to accomplish the functions of accessing to objects related to the users' current geographical location. It has to be noted that the CIDOC-CRM seems not to be used for the ontology of this model, but this is one of just a few applications of Semantic Web in cultural heritage actually working on-line. Despite the absence of the CIDOC-CRM, MuseSuomi is an excellent showcase to understand how powerful an ontological approach is in the

cultural domain. The on-line documentation/publications of the project are also extremely helpful for those who would like to develop a similar system. It is a pity that the project is one-country driven, without much consideration to international standards and thesauri of cultural heritage.

So far museum-oriented projects have been discussed as they are the primary concerns of the CIDOC-CRM, but the Centre for Archaeology (CfA) in English Heritage aimed to reveal the basic structure of archaeological data and projects [CGF*04]. This is one of the rare examples of the CIDOC-CRM applications for field archaeology which should require the extension of the CIDOC-CRM. Therefore, the author would like to mention rather some specific points about its application.

In the model, "context" is a focal point for the webs of archaeological services. Archaeological context is very important since it contains the nitty-gritty information about excavation. The concept of time and all semantic relationships among finds and features are structurally formed by contextual records. However, maybe because of the focus upon museums in the CIDOC-CRM, there are not so many properties concerning the geographical position of physical thing (context). For Physical Object entity, properties such as P46, P58, and P59, and for Place entity, P5, P88, P89, P121, and P122 are available. Apparently, this is not enough to conceptualize all relations of the different layers of archaeological data. Thus, it is not easy for archaeologists to map the data of archaeological stratigraphy into the CIDOC-CRM straightforwardly, and there seem to be big discussions about how to map such complicated data. Similarly, this complexity should apply for buildings and monuments that have three dimensional data in geographical space. The CfA project team tackled to solve this problem by the use of temporal properties known as Allen's operators (CIDOC-CRM Properties from P114 to P120). These temporal properties make it possible to describe the semantics of archaeological context. For instance, if X is stratigraphically above Y, archaeologists actually imply that X occurred some time after Y. Expanding this transformation of spatial information into temporal information, it is possible to encode all of the semantics of an archaeological matrix [CGF*04].

However, as [CGF*04] pointed out that the unfriendly CIDOC-CRM terminology is a barrier for domain experts to communicate with information experts, thus the transformation of archaeological contextual information would be a risk for the use of the CIDOC-CRM. Some sort of automatic toolkit would be required for the practical use of future applications. This project certainly succeeded in providing a knowledge representation of practical operations of an archaeological organization.

A new inter-European project has been launched for the use of the CIDOC-CRM in various stages of archaeological operations (from field recording to museum documentation). The AMA (Archive Mapper for Archaeology) project attempts to create a semi-automatic toolkit for the mappings of different archaeological resources including structured and unstructured data to the CIDOC-CRM [EPO]. Such collaboration work may solve some of the problems of the use of CIDOC-CRM in a wide range of archaeological documentations.

[ERV05] have developed a system for virtual exhibition using XML data processing. This framework of museum systems fosters the administration and management of virtual exhibitions, so that this can be regarded as the development of a museum framework by expanding the idea of the CIDOC-CRM. An object-oriented methodology provides an integrated system for museum management, exhibition management, web service and user management. UML (Unified Modelling Language) was mentioned to use for the robust design model. This is a good example of designing museum data-flow particularly from user's point of view (e.g. visitors and curators). When cultural information is incorporated, it is easy to assume that the information management will fall both within and outside the scope of the CIDOC-CRM. In fact, the role of the CIDOC-CRM is not well described in this paper, simply because this system especially deals with a framework of museum exhibition management rather than the contextual contents of museum collections. In this kind of management-level system, control and security issues will be increasingly important. By far, there have been few debates on copyright and security for the semantic net of cultural heritage information. More attention should be also paid to an authorization system which facilitates data quality control.

3. Thesauri

Some forms of domain specific dictionaries such as taxonomy, thesaurus, controlled vocabulary, and terminology are essential elements for the development of the CIDOC-CRM applications. There are different views on the distinction of those terms, however the common idea is to control the use of data in order to improve performance of matching different data in a standardized way. In this paper, a word, thesaurus, will be used for a representation of this general concept, to its convenience. As a review, several examples of thesauri with regards to archaeology will be discussed.

The Paul Getty Trust has played a leading role for art history. It has developed three famous thesauri called the Art & Architecture Thesaurus (AAT) and the Union List of Artist Names (ULAN), and the Thesaurus of Geographic Names (TGN). Without doubt, these are extremely useful for some areas of cultural heritage. In terms of archaeology, TGN (and maybe AAT) is the most relevant thesaurus. In spite of a wide range of and a great amount of thesauri found on the web, archaeology-specialized thesauri are not competitive. England would be the best place to look at. There are Archaeological Object Thesaurus by former MDA (Museum Documentation Association), Monument Type, Object Type, Material, Warfare, Maritime, and Aircraft Thesauri by the

National Monuments Record in England and English Heritage. The British Museum has also created Object Name and Material Thesaurus. Obviously these thesauri are heavily dependent on English archaeology, so that it cannot be generalized in world archaeology. However they are disseminated through websites and they seem to be good guides for practice. It is assumed that there are a large number of archaeology specific thesauri, but a lot of them are often not widely available and are developed and used in-house. It is also said that site specific vocabularies have been developed in archaeology, so that it seems extremely difficult to incorporate such various thesauri. Consequently, a survey for archaeological thesauri is needed to understand the distribution and the diversity of the domain thesauri. In the meanwhile, an interesting work has been done by [DKS05]. They provide a formal methodology for the creation of multilingual thesaurus of historical periods. Based on the CIDOC-CRM model, the combination of the ontological and terminological approach tries to clarify the concept of periods.

Multilingualism is another topic to be considered. MINERVA has recently published a report on multilingualism in European heritage [Min06]. It carried out a survey for multilingual websites and thesauri, targeting libraries, archives, museums, and other cultural sites. According to the survey, it seems local and national-level thesauri have been developed and international thesauri are used in some members of the EU countries, however they vary in size and purpose and multilingual thesauri are still not popular and not widely used. The trilingual UNESCO thesaurus aims to provide a controlled and structured list of terms used in the area such as education, science, and culture. The HEREIN (European Heritage Network) thesaurus specializes in national policies, architectural and archaeological heritage, and offers a help in obtaining various national reports. A multilingual vocabulary has been built by the NARCISSE (Network of Art Research Computer Image SystemS) project, describing works of art, technical data of photographic archives, restoration and study reports. It is now available in eleven languages [Min06] [LAS*]. ICONCLASS is a famous classification system for iconographic description, currently available only in English, but the translation into French and other languages is underway.

By having a careful look at those thesauri, it is envisaged that geographical and temporal terms have to be created in the first place. Even though there are various discussions about the definition of terms in cultural heritage, it should be much more straightforward to create these thesauri than the thesauri of classification of archaeological potteries. Regardless to say, geographical and temporal terms are foundation stones of a huge area of the heritage sector, therefore, the construction of those two thesauri exemplifies very basic human perceptions of the world, time and space, which is unavoidable when creating a common understanding of cultural semantics. It is, however, better not to build a complete version of the thesauri, because a perfect thesaurus is not possible and it can be modified later if necessary. Whilst the TGN could be one of the strongest candidates for the geographical standard, a chronological thesaurus needs to be developed sooner or later. Although [DKS05]'s new methodology opened a new possibility of thesaurus, problems rely on the complexity of the creation and the use of such model. Unlike the CIDOC-CRM, which leaves the issues of domain-specific knowledge, the development of terminology/thesaurus is time-consuming and will cause a considerable controversy. The potential candidates for a chronological version also exist inside history textbooks. If the chronology of world history can be merged into one framework, the thesaurus will be created. At this stage, the problem is not a cultural but a political. Historians in different countries (and politicians and citizens) may have to agree with one single thesaurus. But the TGN should also confront the problems of territorial conflicts in the political world. In conclusion, it seems better for cultural experts to develop a chronological thesaurus for their own needs of information exchange without any problematic political discussions. As soon as two thesauri are constructed, only one question will be left: Who controls the thesauri? It is obviously not possible to answer this question.

Maybe building up international-level thesauri is not the only way forward. For example, software like the IKEM toolkit (http://www.vartec.be) might be a good starting point. This software allows users to construct and manage their own thesauri based on the ISO 2788 and 5964 standards (monolingual and multilingual thesauri). The thesaurus management software supports to merge personal/local thesauri to generate corporate thesauri, and the function of web-based group-discussion enables users to exchange ideas of thesaurus terms over the internet. This is an extremely useful feature of the software to develop and maintain thesauri through web collaboration. The IKEM seems to offer a bottom-up approach for the creation of thesauri with more interactivity and flexibility. This approach seems a bit slow, but considering the future development of automatic assemblages of information by highly intelligent computer robots, this approach could be quicker in the long run.

4. Summary and conclusions

In this conclusion, the author would like to highlight several problems with some suggestions of solutions.

1 Conceptual difference (Different mapping model)
Many cultural professionals now try to conceptualize their own data in different ways. As there was a discussion in the CfA to map archaeological contextual data into the most appropriate CIDOC-CRM entities and properties, even the same data could be mapped differently by different people. But it is not known how to solve the problem of such conceptual differences. In addition, it seems that nobody knows if a consensus for the best way of mapping should be made in the same domain. These problems may be caused by the

implicitness of the definition of the CIDOC-CRM. In the CIDOC-CRM, there are definitions of entities and properties with scope notes and examples. However examples are sometimes very few and either too specific or too general. Probably the definitions are quite clear for the inventors of the ontology, but, to some extent, they are not explicitly described and explained badly. In order to avoid misunderstanding, better manuals, possibly in several languages should be published.

2 Lack of thesaurus and standard

Thesauri and domain standards are indispensable elements for the development of the CIDOC-CRM. However the reality seems rather chaotic. There are no established thesauri which could serve across the different documentations in different archaeological communities. A survey for archaeological thesauri is needed. For instance, [Sug06a] executed the Digital Data Survey for Japanese Archaeology (JAD2) in order to figure out the current situation of archaeological data and its use and archaeologists' expectations, taking into account the needs of the CIDOC-CRM. This kind of perspective is vital as a further step to standardization.

Practically speaking, the incorporation of existing thesauri, particularly temporal and spatial ones, would be a solution. In terms of archaeology, the successful creation of an archaeological dictionary at a national level should result in the integration of such dictionaries at an international level, since most of countries have some sort of governmental control over the protection of cultural properties. This is an ideal approach particularly because this form of information management can be related to national laws and regulations of cultural heritage. The plan for national thesauri is also underpinned by the fact that international co-operation for the illicit trade of cultural items is crucial. On the other hand, locally-specific dictionaries cannot be underestimated. The value of local identity—which has to be central to the idea of the CIDOC-CRM—should be preserved well. These local vocabularies could be assembled automatically by the use of software like IKEM, then the expanded vocabulary will be more practical because it is based on actual data used, not on a top-down creation of vocabulary from scratch. It is very difficult to say which approach would be suitable for the future, but it seems significant to maintain both approaches considering the diversity of cultural vocabularies. Although the CIDOC-CRM is translated into several languages, multilingualism is also essential in terms of thesaurus. The lack of proper multilingual thesauri may cause problems of the international use of the CIDOC-CRM. It is also not too much to say that the validation and implementations of the CIDOC-CRM have been mostly confined within Western cultural communities. The collaboration with Asia, Oceania, Africa, and the Americas will become more necessary.

3 Utopia: Encyclopedia of archaeology

The ultimate goal of the CIDOC-CRM would be to construct the semantic structure (encyclopedia) of all subjects in cultural domain, however, there is no clearly-defined concept of archaeology as an academic subject. Obviously archaeological theories exist, but nobody has ever described the semantic framework of archaeological data, services and systems. This is, apparently, not only the case in archaeology but also in other disciplines. It may be a good occasion for every domain expert to discuss all of the theories and practices, but it seems a long way to archive such a huge encyclopaedia. The question then becomes whether the CIDOC-CRM will last until everything is clarified semantically.

4 Lack of experiment and dissemination

The experimentation of the CIDOC-CRM is still not sufficient. Although there are many projects related to the CIDOC-CRM, it is hard to find practical examples of its application on the web. In addition, in contrast to the acceptance of the CIDOC-CRM within international museum community, many cultural experts still do not know of its existence. For instance, the JAD2 survey shows the most of Japanese field archaeologists are unaware of the CIDOC-CRM [Sug06a]. Therefore, it is uncertain whether there could be some opposition to this more-or-less ISO standard ontology.

It also appears that many applications remain at the theoretical level, and the implementations are also conducted only in-house. The problem is that the results of such applications are not well disseminated. If a goal of the CIDOC-CRM is information exchange at the detailed level that cultural specialists request, it is vital to show the results in a proper way. However there still seems to be hesitation among cultural professionals to open their ideas and resources to a wider audience. What is missing is a widely available publication on the details of the applications. Web-accessible contents of the applications are also fundamental. Cultural experts should discard old fashioned ideas like "My data, my idea and my application" which are completely opposite to the intention of the CIDOC-CRM, and try to follow the idea of "Open Source" developed in the information domain.

5 Too broad scope

The definition of "domain ontology" is quite uncertain, as is the definition of cultural heritage [CDG03]. Museums are its initial targets, but libraries and archives are also included in the Intended Scope. Formal mappings have also been made for various fields of cultural heritage. In reality, the boundaries of the domain are only defined by the exclusions of administrative and management works such as personnel, accounting and visitor statistics. Having said this, as far as entities and properties are concerned, the range of the domain is museum collection oriented. All of this implies that the CIDOC-CRM is, in fact, not a domain ontology but a core ontology of curatorial knowledge in cultural heritage. Therefore, a series of agreed extensions of the CIDOC-CRM could lead to different domain ontologies such as ethnological ontology and library ontology. Similarly [Doe00] stated that the CIDOC-CRM could inspire a good metadata, which is a knowledge representation of a specific domain. At the

G. Sugimoto / the CIDOC-CRM Applications and Thesauri in Archaeology

same time it is also possible to consider the "core ontology" which merges existing ontologies developed in different disciplines. [CGF*04] and [JHOO04] mentioned that one of the strengths of the CIDOC-CRM is its event- based approach, and the core entities for this approach are E5 Event, E39 Actor, E52 Time-span, E53 Places, and E77 Persistent Item (or E70 Things). These event-centred relationships could serve as general purposes. In fact, some effort has been made by [Hun03]. She proposed the ABC model to improve semantic interoperability among different genres of domains by means of multimedia. This top-level ontology is also based on an event aware model, attempting to facilitate the harmonization of different ontologies of MPEG-7 and MPEG-21, CIDOC-CRM, and ON9.3.

In order for the CIDOC-CRM to be widely used in practice, it seems better to attempt to archive a de-facto standard first, rather than an ISO standard, since top-down approaches are sometimes to be avoided. Having said this, it is also interesting to see what the ISO standard means to cultural experts. There seems to be very few ISO standards in this domain, thus this top-down method might be a good opportunity to conquer the problems of bottom-up standardization methods we have tackled for many years.
As the CIDOC-CRM becomes the ISO standard, cultural professionals seek perfection, but it is a compromised format of expressing cultural data that most of them agree to use in order to integrate fruitful cultural data as much as possible. The extensible function of the CIDOC-CRM allows all cultural experts to be involved in one framework. The elegance of the CIDOC-CRM is that it is a conceptual model leaving complicated issues such as domain vocabularies and technologies behind. However, precisely because of this conceptual elegance, the practical level of implementation poses numerous questions as discussed above. Is the CIDOC-CRM the beauty or the beast? The answer is in your hands.

References

[CDG03] Crofts N., Doerr M., Gill T.: The CIDOC-CRM Conceptual Reference Model: A standard for communicating cultural contents. *Cultivate Interactive 9* (Feb. 2003). http://www.cultivate-int.org/issue9/chios/.

[CGF*04] Cripps P., Greenhalgh A., Fellows D., May K., Robinson D.: Ontological modelling of the work of the Centre for Archaeology. (2004) http://cidoc.ics.forth.gr/technical_papers.html.

[Cid06] The CIDOC-CRM. (2006) http://cidoc.ics.forth.gr/.

[DKS05] Doerr M., Kritsotaki A., Stead S.: Thesauri of historical periods -A proposal for standardization. (CIDOC'05 Conference, Zagreb) http://www.ics.forth.gr/isl/publications/paperlink/CIDOCpaper1_Doerr.pdf.

[Doe00] Doerr M.: Mapping of the Dublin Core Metadata Element set to the CIDOC-CRM. (2000) http://cidoc.ics.forth.gr/technical_papers.html.

[EPO] EPOCH: European Research Network on Excellence in Processing Open Cultural Heritage: AMA -Archive Mapper for Archaeology. (No Date) http://www.epoch-net.org/index.php?option=com_content&task=view&id=74&Itemid=120.

[ERV05] Elbekai A. S., Rossiter N., Vassilev V. T.: Virtual exhibitions framework: Utilisation of XML data processing for sharing museum content over the web. (CIDOC'05 Conference, Zagreb) http://computing.unn.ac.uk/staff/CGNR1/.

[HJK*04] Hyvönen E., Junnila M., Kettula S., Mäkelä E., Saarela S., Salminen M., Syreeni A., Valo A., Viljanen K.: Finnish museum on the semantic web: The user's perspective on museum Finland. (2004) http://www.archimuse.com/mw2004/papers/hyvonen/hyvonen.html.

[Hun03] Hunter J.: Enhancing the semantic interoperability of multimedia through core ontology. (2003) http://www.itee.uq.edu.au/~eresearch/papers/2003/hunter-core-ontology/paper.html.

[JHOO04] Jordal E., Holmen J., Olsen S. A., Ore C.-E.: From XML-tagged acquisition catalogues to an event-based relational database. (2004) http://www.muspro.uio.no/Nettsider2004/Artikler/jordal_caa2004.htm.

[LAS*] Lahanier C., Aitken G., Shindo J., Pillay R., Martinez K., Lewis P.: EROS: An open source multilingual research system for image content retrieval dedicated to conservation-restoration exchange between cultural institutions. (No Date) http://www.c2rmf.fr/documents/c2r_eros.pdf.

[Min06] Minerva Plus Project: Multilingual access to the European cultural heritage multilingual websites and thesauri. (2006) http://www.minervaeurope.org/structure/workinggroups/inventor/multilingua/documents/Multiligualism_v1_printed.pdf.

[SGL*05] Sinclair P., Goodall S., Lewis P. H., Martinez K., Addis M. J.: Concept browsing for multimedia retrieval in the SCULPTEUR project. (2005) http://www.acemedia.org/ESWC2005_MSW/papers/ESWC_2005_MMSW_Sinclair_SCULPTEUR.pdf.

[Sug06a] Sugimoto G.: A digital data survey for Japanese archaeology. (2006) http://www.chiron-training.org/go_sugimoto/digital_survey/.

[Sug06b] Sugimoto G.: Eyes of art: Archaeological information and digital archiving from the viewpoint of art. *Journal of Computer Archaeology 11*, 2 (2006), 48–62.

Surveying Monuments by Who's Standards

K. Tokmakidis[1]

[1]Aristotle University of Thessaloniki, Greece

Abstract

During the last decades many monuments have been surveyed in Greece for several reasons, all those works have been carried out under different standards and circumstances. Surveying methods varies from classical ones up to photogrammetric, 3D laser scanning, architectonic and all the combinations of the above. Even though there are so many methods there are no standards at all for doing all those works. There have been some efforts for setting standards for monument surveys but none of them has ever been accepted. The author, having a multiyear on site surveying experience, is trying to propose some specifications for the survey of monuments, concerning all methods in use. At least a minimum of standards for such works is pointed out.

1. Introduction

Last years we have seen many monuments, all over the world, which have been destroyed from several reasons. Therefore, and also because of the great interest of all people nowadays for the cultural heritage, we need detailed plans and registration for every monument if possible. As a result of the above many scientists are involved in surveying monuments. Their specialization varies widely and a common language is needed but more over is needed their close collaboration. So the archaeologist, the architect, the conservatist, the engineer, the phogrammetrist, the surveyor, and others are requested to work together as a team. And generally, I believe that, we are leaded in a new century of teamwork, because of the excess and very fast development of technology.

Registration for a monument is needed each time we want to deal with it. For example whenever we have to study, or to repair, or to reconstruct, or to conserve a monument its plan is necessary. There is no possibility to do anything on a monument or archaeological site without drawing its present accurate situation on a plan. Also in some cases we have to survey the monuments just for registration purposes only, because there are monuments which are invaluable and we own to register them at least in detailed archives. This becomes more obvious for all classical ancient monuments all over the world.

As well obvious is the necessity of surveying the monuments and the archaeological sites. As a matter of fact scientists with a variety of specialization are involved in that field and all of them are trying to develop better methods for surveying. According to the above mentioned the classic method of surveying applied by architects is modernized and automated with less people and time needed for similar or sometimes better results. New techniques are developed that give various methods for the survey and editing of the final plans. Even more when we need detail surveys in large scale we need better accuracy in measuring thus we apply special surveying methods.

Whenever a detailed plan is needed in great scales we have to apply different methods in surveying. If we choose the photogrammetric one, we need better accuracy in control points. Another factor we have to face is that we need very high resolution in shots; therefore we use large format cameras. Usually we use control points for the survey which are permanent marked on its surface in a way that they can easily be used for further densification of the details in future surveys. In this way we succeed to have higher accuracy and connectivity of the measurements between different measuring epochs. Last years emphasis has been given in detail surveys as a major tool for studying the monuments. Also detailed plans are used for 3D reconstruction in a computer graphic environment that is valuable for restoring the monuments.

On the other hand the cost that concerns both time and money has been eliminated in the modern methods of surveying. This is because of the automatism in many steps in both field and office work. Even though the cost of the initial instrumentation is higher it is worthy because you have the payback much more soon. Many new techniques have been developed for surveying monuments during the last years. There are at least four reasons, which cause this fact:

a. The development of instrumentation in surveying
b. The development of computers which automated most of the work
c. The development of photogrammetric instrumentation from analogue plotters to the digital plotters
d. The remarkable acceptance of archaeologists for the new technology

The new techniques depended upon the size of the monument, the scale of surveying and the required accuracy. Most of the new techniques are based on

photogrammetry, even though surveyors have yet the responsibility for target control point establishment. Photogrammetric surveys are depended on the accuracy of control points, which are observed with classic surveying methods using total stations or GPS. The density of control points depends upon the scale. The accuracy of the control points depends on the method of their determination and the accuracy of measuring instruments. Another applied classification deals with the type of the used camera, which could be metric, semi-metric or non-metric and also digital camera. The number of required control points depends also on the type of the camera and the method of solution for extracting the final results.

Apart from all of the above we use many types of platforms to take the proper shots, such as kites, balloons, grains, model helicopters etc. in order to carry the camera at the appropriate distance from the object we want to survey [Miy96]. After that we have the choice to manipulate the images in many different ways with several programs in order to obtain the final results. The conclusion is that more easily with fewer hours and less people we can have valuable results, which have much accurate information.

2. Surveying monuments

It was in 1978 when many monuments in Thessaloniki were damaged from an earthquake and there was an urgent need for supporting and restoring them. At that time there were no plans at all for those monuments because they had passed several centuries since they had been built. Facing that challenge some engineers from the city started to survey those monuments and draw their basic plans. At that period it was obvious that every engineer was doing his own best work to answer all the needs of all the specialists who were involved in the restoration process.

In 1982 when Prof. Manolis Andronikos discovered the theatre at Vergina, he asked me to make the plans of the excavation. At that time, it has been used a Di3S by Wild for distance measurements combined with an optical theodolite for measuring the angles, while data were registered manually. It took about three hours in the field and a few days in the office to draw the plans of the site. When the plans delivered to him, he informed me that when his professor discovered the palace of Vergina in 1965 at that time some surveyor was measuring for 15 days to survey the site, so he was surprised from the speed, the accuracy and the low cost. Since that time, even though it is not so far ago, the development of instrumentation for surveying purposes has been changed dramatically.

Apart from those efforts many other surveys have been carried out in several monuments but none has ever oriented in establishing standards for such works. This fact results works that most of the times are incompatible. On the other hand during all these years an excess development has happened in surveying methods due to new instruments. Nevertheless, in my opinion, it is necessary to establish specifications for the monuments surveys in order to have a common reference for all engineers and specialists they deal with the monuments.

The real problem of non existing specifications we faced occurs when we start to measure the monument and finally we have to create a plan on which we present the current situation of it. At this point everybody is free to follow his own thoughts concerning the methods, the instruments of surveying and the presentation techniques. This causes a variety of results that have no uniformity or compatibility. Another fact is the development of 3D surveys the last decade which gives many advantages for the final result, such as rendering, texturing, visualizations, 3D representations and virtual applications.

As we have been engaged all these years in surveying monuments we observed the needs of the users in scales, details, information etc. For example in the survey of Tholos in Delphi (Fig. 1) they wanted an accuracy of 2mm and we succeed it. In another case the architect wanted the section of the church of Saint Andrea in Mount Athos in order to prepare his restoration study and we did it (Fig.2). In a third case the Municipality of Thessaloniki wanted to survey for registration purpose the Gallery of the town and we did it (Fig.4). While the list goes on the experience gained from all those surveys lead us in specification quest.
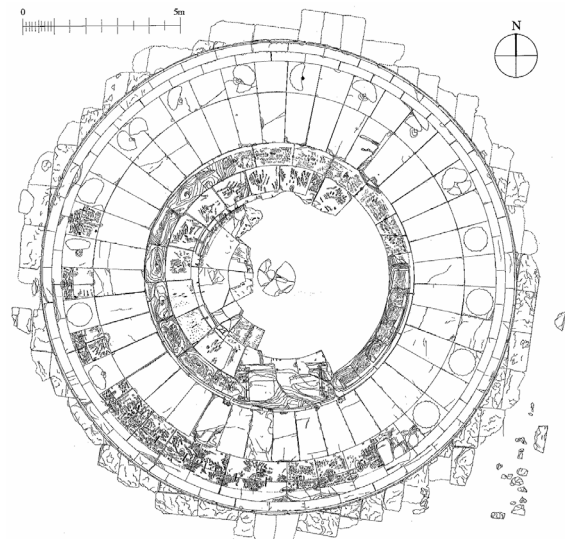

Figure 1: *Plan of Tholos in Delphi*

Figure 2: *W-E section of St Andrea's church in Athos*

3. Surveying methods

The development of the methodology has been changed a lot since the first surveys in the '70s. During the last two decades we passed from the optical theodolites to the electronic ones and after that to the total stations. Then data collectors have been developed which made easier the fieldwork. From simple total stations with external data collectors we have passed in less than 10 years in total stations with built in memory for data registration. And more over now we have motorized total stations that can be used by one man only. And also the last achievement of technology is the reflectorless total stations, which can measure without a reflector.

Figure 3: *Measuring in the Acropolis of Athens*

Now with such a total station (Fig.3) is possible to survey easily inaccessible points situated on ceilings, roofs and on high buildings. The methodology in surveying had changed because several years ago there was a cost per detail point, which was based on the method of surveying the point. If it was inaccessible the cost in time and money was very hight. But today with such instrumentation the cost for some more detail points is meaningless. We have just to sight the point and press the measuring button. The instrument has also a built in laser pointer so we can easily view the target point.

The techniques and the methods in surveying have changed due to this development in the technology of surveying instruments. Surveying has become easier in the field in action and mistakes do not occur very often as in the past. The instruments are computerized and this causes the rapidly development in their technology. The next step will be to have the ability for printing the plan in the field, which is coming very soon. It is possible today with a laptop connected to the total station and via special software that you can manage the measurements from the mouse of the laptop directly in CAD environment. Then the operator must sight to the target and just click the mouse so the instrument will measure and the new point will be plotted on the screen. By this way we can connect the laptop on a plotter and have the drawing of the day in the end of the measurements.

Now concerning photogrammetry in addition to the powerful CAD programs we had the development of the stereo plotters which lead photogranmmetry into the "digital darkroom" [Pat91]. Today both hardware and software in this section are developed and is subject of changing very often towards better solutions. Using CAD programs we can easily produce 3D plans of the buildings and findings in the excavation as mentioned for city plans [Gru98]. This is a powerful tool for architects when they wand to visualize the site [ITM98]. Such 3D drawings can have several applications. But accordingly to the huge development of technology in all areas there has observed a difficulty in following and learning all the changes. Hardware and software is changing and developing every day. This will lead to new young people who have a better efficiency in the modern technology and a greater level of understanding it.

As mentioned above the development of computers caused in a way the development in surveying instruments. But moreover this caused the ability of designing and drawing plans in the computer environment. The CAD programs are of a major help for all specialists dealing with the cultural heritage. Those programs have been renewed and their abilities became extremely helpful for the surveyor. For example several years ago there was not possible to define a volume between two not similar surfaces, now this is possible due to the CAD programs development. That fact was causing the impossibility to create sections of the surface automatically.

Recently it has been easily succeeded to draw 3D models of the monuments and sites because of the H/W and S/W development. A 3D model of one site is useful for four reasons:

- Better viewing of the site as it was
- Understanding of the site and its functionality
- Studying the shapes of the site
- Plan out the reconstruction

It is obvious the fact that the 3D model gives us the ability to recognize the typical basic building blocks of the monument and their location in the site; in a way to predict their original connection with the monument. Having this information architects face a much easier problem than it was in the past. Towards this direction lead also the 3D laser scanning instruments even though the programs for manipulating the point clouds are yet in the very beginning.

4. Specifications for surveying monuments

In the past there have been some propositions for standards but none has been accepted and applied yet. The best effort of establishing standards is the one by English Heritage under the title Metric Survey Specifications for English Heritage in 2000. A copy of this was given to me by Paul Bryan for which I thank him. Then our effort has been developed by the author and it concerns surveys in scales from 1:50 up to 1:10. It concerns also topographic, photogrammetric and architectonic methods. According to the standards all measurements should be referred in a common reference network. Such networks composed from control points for horizontal and vertical control. Also control points for the densification of the information and the photogrammetric surveys.

Concerning photogrammetry the standards give details about cameras, films, scanners and all the consequence work. They give details also about orthophotos and digital cameras. They give specifications also about DTM extracting from photogrammetric surveys, about rectified images and digitization of old surveys. They give details concerning the product plans for its content, types of lines, layers, details and the structure of CAD files.

Concerning architectural surveys the standards give all the details about what to do, how to do and what to present. They give details for scales, plans, sections, façade plans etc. They give details what to survey, utilities surveys, dimensions, heights, areas and volumes. They give details for the accuracy of the plans and the digital drawings. They describe the contents of the plans, lines, layers etc. They propose a uniform codification for the layers and the plans. They describe the format of the plans concerning editing and contents.

Another fact that the standards propose is the final control of the plans that have been produced concerning their accuracy, their completeness and their exactness. All those controls take place in the field by partial control of the plans before the final acceptance of the whole survey. For the time the only problem is that all those specifications are available only in Greek language at http://web.auth.gr/e-topo

5. Conclusions

We can observe today a trend for standardization in every work. This fact leads towards uniformity and a common perspective for every work. After so many years been engaged in surveying monuments we reach the necessity of establishing standards in this field in order to have a better result in the team work around the monuments. At least we can establish specifications for the final plans of the survey and in the "how to do" some of the work because many specialists insist that every monument is something different and special and so we can not apply standards on the work with them.

References

Architectural Measurements of the Sanctuary of Athena Pronaia in Delphi 1994-1996, Preliminary Report, Architectural Mission to Delphi, Kumamoto University 1997

Dallas R. W. A., Architectural and Archaeological Photogrammetry, Close Range Photogrammetry and Machine Vision, Atkinson Whittles Publishing, pp: 283-302, Scotland 1996

[Gru98] Gruen A., TOBAGO-a Semi Automated Approach for the Generation of 3-D Building Models, *ISPRS Journal* 53/1998

[ITM98] Ito J., Tokmakidis K., Mamoto E., Visualization of Classical Sites by 3D Computer Graphics, ISPRS Hakodate 1998

Metric Survey Specifications for English Heritage, English Heritage, York and Swindon, July 2000

[Miy96] Miyatsuka Y., Archaeological Real-time Photogrammetric System using Digital Still Camera, ISPRS Vienna 1996

[Pat91] Patias P., Architectural Photogrammetry Goes to the Digital Darkroom, ISPRS Delphi 1991

Theodoridou S., Tokmakidis K., Skarlatos D., Use of Radio-Controlled Model Helicopters in archaeology Surveying and in Building Construction Industry, ISPRS Amsterdam 2000

Tokmakidis K., Ito J., Mamoto E., Mori F., Detail Surveys with Close-Range Photogrammetry in Archaeological Sites, ISPRS Hakodate 1998

Tokmakidis K., Ito J., Inada K., Applied Surveys in Archaeological Sites, ISPRS Thessaloniki 1999

Tokmakidis K., Ito J., Inada K., Surveys in Archaeological Sites for 3D Modelling, ISPRS Amsterdam 2000

Tokmakidis K., Skarlatos D., Mapping Excavations and Archaeological Sites Using close range photos, ISPRS Corfu 2002
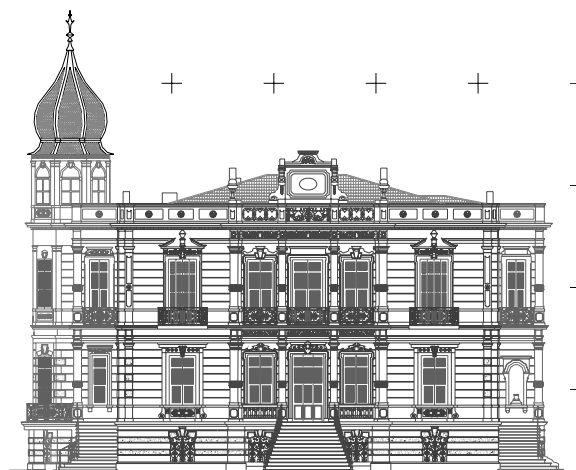

Figure 4: *Facade of the Gallery in Thessaloniki*

Realtime intrasite documentation from above: the case of balloon-mounted wireless photography

Kari Uotila[1], Isto Huvila[2], Hannele Lehtonen[3] and Jan-Erik Wahlberg[4]

[1] Archaeology, University of Turku, Finland
[2] Information Studies, Åbo Akademi University, Finland
[3] Muuritutkimus, Finland
[4] Vigilia Omni, Finland

Abstract

During an excavation the archaeologists need to document the excavation area in multiple instances during the entire duration of the investigation, to add necessary notes and remarks and to do that quickly. Digital technology offers several possibilities for instant documentation and real time reuse and elaboration of the documents. The present contribution reports of an experiment carried out to apply balloon mounted intrasite scale remote controlled aerial digital photography to the process of acquiring real time photographs of the excavation work for annotation and archival. The emphasis of the approach was on the usability of the configuration by a non-technological expert, its unintrusiveness and low cost. The experiments revealed problems related to the image quality and the sensibility to the wind experienced with the present configuration. The usability of the concept is, however, promising and the benefits of the real time photographing became apparent.

Categories and Subject Descriptors (according to ACM CCS):
B.8 [Hardware]: Performance and reliability; J.5 [Computer Applications]: Arts and humanities; I.4.1 [Computing Methodologies]: Image Processing and Computer Vision, Digitization and Image Capture

1. Introduction

An archaeological excavation might be described as a paradoxical function of limited time and expected comprehensiveness. The development of field methods is important in order to cope with this unsatisfactory yet unavoidable state of affairs. Both techniques and technology may help to speed up processes and release staff from manual labour to the more profitable intellectual work. The present contribution discusses the itself already established technique of balloon-mounted aerial intrasite documentation with the novel prospects opened by wireless networks and digital photographic technologies. The focus of the discussion is in the capabilities of the new technologies to speed up the cycle of taking photographs and using them real-time in cartographic documentation. A further emphasis is placed on the aspect of packaging the technology in a form, which may be used by a technologically untrained archaeology professionals. The observations and conclusions are based on field trials conducted during the spring and summer 2006 on several sites located in southwestern Finland.

2. Background

One of the central features of the documentation of archaeological excavations is a need to record repeatedly individual objects and physical locations in their different states of visibility during the project. This means that an archaeologist needs to record information on a daily basis, or sometimes even several times during one day, on a single unit, feature or structure.

Another typical feature, which relates to the currently prevalent paradigm of conducting excavations is that an average excavation site is seldom in an especially photogenic state in any moment during or after the excavation. The strive for efficiency especially in the case of rescue excavations makes it very difficult to acquire clear compositional images. The pacing of the excavation of the different units in a

manner, which would keep the excavation surface relatively flat, would significantly slow down the excavation process. The requirement of efficiency together with the unit based stratigraphical excavation method leads to the removal of the layers and structures one by one, instead of an orderly maintaining regular surfaces, distinct layers and levels. A complete picture of the site, analytical layers and levels come about often first in the post-excavation analysis after the digitally acquired cartographic material has been compiled and revised for publication and archival.

The postponement of the completion of the picture of the investigation site is not entirely problem-free. At the present, the units and structures are typically measured by using a total station. The measurements result in a level drawing containing relative altitudes of the various layers and structures as a key element of the document. The individual measurements reside in a three dimensional space, but the resulting aggregate of the lines and points is basically two dimensional map unless the measurements are interpolated to form truly three dimensional objects. Measuring with a total station is very accurate, in fact, to an extent where the need for such a precision becomes debatable. In practise, it might be more essential to consider the relations and interpretations of the units than to strive for a microscopic precision. In any event, an overly accurate measurement increases needlessly the amount of the measuring work.

The challenge of producing rapid, precise and analytically informative information has been met in the field work by using digital image overlays alongside with the measurements. The aim of the using the digital images is to superpose the total station data with a series of a photographs of the actual layers and thereby combine on location the measured data and images with a verbal report, clarifying remarks and sketches in a single document.

The main problem with the approach is that it is rarely possible to position the photographer straight above the object of interest in order to document the units and structures from a direction, which corresponds with the vertical angle of the aggregate of the total station measurements. Angled views are also helpful as complementary documentation, but significantly more difficult to combine with the measurements in real time even with the current georectification packages. The angled views do also leave often significantly large blind spots in the rugged and irregular excavation surfaces. In trials, we have found out that the precision of these photographs is far less an issue than the accurate angle of the images and the straightforwardness of the process, which both contribute to the easy orientation and focussing on the analysis instead of technical details.

3. Documentation from above

Photographic documentation of the investigation area has been a cornerstone of the field documentation almost throughout the entire history of archaeology [Ree36] [RB96, 78] [Bew03]. The tradition can be separated in two practises: documentation from a scaffold or tower and documentation from higher in the air. These two practises differ in the way that photographing from a scaffold is used for documenting details (units and structures in the contemporary terminology), whereas the aerial photography has been used primarily to document large areas, special features and images for publication [RB96, 78-80]. Examples of intrasite aerial photography have been published on several sites (e.g. [Mye78]), but they are in minority compared to the surveys and large scale documentation [Cam03, 76-77]. Close range aerial photography has been used also in related disciplines, such as in the documentation of vegetation patterns [MYN*04],

Erecting a scaffold or tower above or adjacent to an excavation and the efficient use of one has at least in Finland been set aside as a result of changes in excavation documentation techniques since the 1990s. The inauguration of digital imagery has first replaced the colour film images used for note purposes and gradually also the archive-grade B/W film images (cmp. [Tak98]). Digital images as part of field documentation have increasingly been used for various photogrammetric imagings, but seldom in excavating archaeological layers. Digital imaging and photogrammetry are more common in documenting vertical objects and profiles.

4. Developing the tools

The issue of developing new functioning means for from above documentation was taken into a consideration in early 2006. The pondering started with an idea of constructing a modern photographing tower for positioning a digital camera above an excavation. The basic requirements were the repeatability of the documentation work flow and, within reason, the possibility for all-weather shooting. Motivation for the premises were the practical needs: an average excavation can not wait. Things need to be done in schedule. The basic requisite was to be able to take images from the air in the same conditions it is on the ground. Few archaeologists take pictures in extreme weather and lighting conditions. Rain smudges and deforms the excavation site to an extent, which reduces the usability of the photographs. Similarly the limitations of the photographic technology limit the quality of the images. In Finland, the darkness of the autumn is yet another a challenge for the field work. Therefore the aim was set to be able to work in normal Finnish archipelagial conditions during the summer: within the +10 to + 30 centigrade temperature range and in less than 5 m/s light wind. It was also considered that the research areas are mostly free of additional problems, such as strong, turbulent or divergent winds.

Another prerequisite was the ability to have the acquired images very rapidly available, preferably in real time, in digital form. As discussed earlier, the objective was to combine

the images during the field documentation with the measured data and unit forms. For the practical reasons in order to be able to work real time, it became evident that the photographer needed to have a real-time viewfinder for panning, zooming and cropping the image. These prerequisites led to the applying of wireless local area network (WLAN) between the camera and the ground station laptop operated by the photographer.

Considering the aims of documenting the excavation process, feasible scale of the photographs was established to a few excavation squares, which means that the area covered by the photographs area should be approximately 2 X 5 metres or larger. In Finland the highest free flight altitude is 30 m above ground level (AGL). The preliminary plan was to stay below that level to avoid the need of special permissions for scaffolds or flying devices.

The technical usability of the system was compared to that of a regular scaffold:

- Any archaeologist should be capable of using it after 1-2 hrs of practical training.
- All of the equipment should also be manageable by only one person and two people should be able to master the task to perfection.
- The system may under no conditions present any danger neither to its personnel nor the environment, and should not require any special permits or skills to operate, but be easy to use for every archaeologist.
- The system needs to be usable in typical weather and wind conditions (+10 - +30 centigrade, < 5 m/s wind).
- The vegetation, foliage and man made structures often limit the open air around the excavation site. Therefore the system should require as little horizontal space as possible.
- It was acknowledged that the system should also be as quiet and unintrusive as possible, given the fact that excavations often take place in locations of sensitive ecology and in areas, where the current everyday functions need to be taken into account. This applies to a variety sites of from tourist attractions to the graveyards and sites of heavy traffic.

The traditional photography scaffold or tower with its height of 5 to 6 metres was considered to be too low and rigid. The established criteria ruled out also dirigible planes and helicopters, kites as well as hot air balloons (cmp. e.g. [STG04]). The most promising device seemed to be a large refillable helium-filled balloon (ref. [MPK03]). It is light, relatively small, simple, inexpensive and unintrusive (ref. used to survey sensitive wetland areas [MYN*04]). The balloon was decided to be equipped with a high-quality surveillance camera for the remote pan, zoom and crop capabilities.
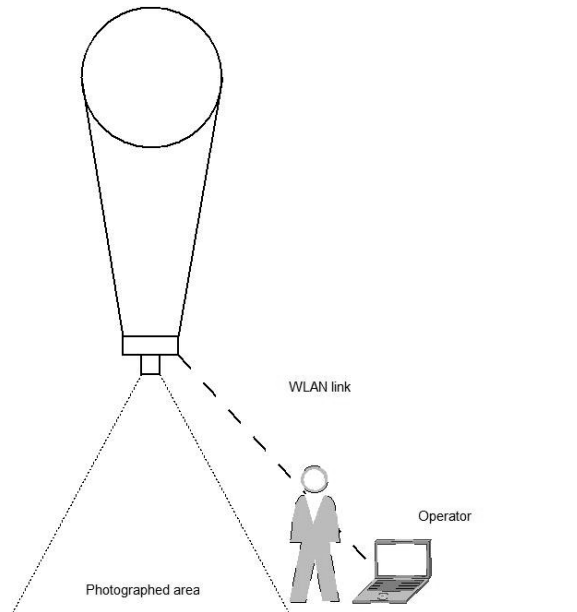

Figure 2: *SkyCam 2006 system*

5. Development results: SkyCam2006

The SkyCam 2006 aerial documentation system (shown in action in Figure 1 on page 4) was developed jointly by the workgroup in order to create an easy-to-use, ecologically sound system for aerial photography at a reasonable cost. Existing balloon carried systems were considered to be prone to technical errors and not suitable for real time documenting.

The solution was to rig a high-performance computerised surveillance camera (presently a Sony SNC-RZ25N dome-camera) attached with a WLAN-card to a 3 m diameter (appr. 10 feet) polyurethane, helium-filled balloon (see). The balloon, filled with helium, is strapped to the ground by four tethers (present length max. 75 m / tether, or 246ft), which ideally leaves the lines outside the area under viewing. In order to keep the balloon in place even in heavier than moderate winds, counterweights were made by pouring cement in plastic pails (weight/pail appr. 15 kg or 33 lbs.). The tethers are fastened to these weights to ensure the stability of the construct. The currently used balloon is an advertising balloon made of polyurethane. A 3 metre diameter balloon requires 15 m3 or 525 cbft. of helium gas.

The balloon mounted camera is installed with a software allowing real time remote viewing, and controlling of the device. The camera is powered by a 10-piece set of 12 V DC rechargeable batteries, which currently gives approximately 5 hours of operating time. The Sony dome-camera has a 30 FPS frame rate giving good flexibility to the remote viewfinding and an additional possibility to shoot video

Figure 1: *SkyCam 2006 aerial photographic system in use at the Kuusisto Castle in Southwestern Finland*

if necessary. The device requires only 0,7 lx illumination, which enables viewing and shooting in poor lighting conditions. The lens provides the user with 18 x optical zoom, which is assisted by a 12 x digital zoom. Panning and tilting the head provides limitless angles to view any research area. The possibilities of using IR or UV filters is under research.

The camera and power source are fitted securely to a stainless steel plate, which in turn is fastened to the supporting device, in this case the balloon, at each corner. A weatherproof IP-box with built-in fan and protective lens cover was also designed to enable viewing in poor weather. The SkyCam is not, however, safe to use if there is a danger of lightning. A suitable viewing height for the average excavation can be anything from 10 to 30 metres above ground level, depending on the documentational needs.

Pictures are transmitted by a built-in SNCA-CFW1 wireless LAN interface (802.11b) to a laptop on the ground, where the operator can pan, tilt and zoom the viewing area at will. The images are named and stored immediately in

JPEG-format. The principal benefits of using a WLAN based connection instead of e.g. a video connection (as e.g. in [KO98] [ACKT04]) anticipated before the project and confirmed by the trials are the

- Flexibility of the connection and data transfer. The photographs may be edited, used and archived as a part of the excavation documentation instantaneously using the same workstation, which is used to control the camera and to take the pictures (cf. [KMM*99]). The operator can use an ordinary image editing tool or a specialised documentation system to add labels, notes and draw on the images.
- Wireless connection. The lack of wires simplifies the construction and frees the operator to work at the best possible spot on the site, even inside a building if necessary (cf. e.g. [ACKT04]). Moreover the wires do not interfere with the angle of view (cf. Fig. 2 in [ACKT04]).
- Seemless integration to the general network infrastructure used at an excavation and to the internet. The images may be shared on an excavation wide WLAN network between all workstations and used simultaneously by several ar-

chaeologists in a variety of documentation and annotation tasks. The pictures may also be transmitted directly to remote users for e.g. consultation by email or using an FTP-server, if available.

- Use of standard technology. The WLAN capable cameras and workstations are relatively inexpensive (in comparison to proprietary systems) and easily interchangeable (e.g. in case of a technical failure or in need of a higher resolution camera, video capabilities, etc.).

The total cost of the complete system is about EUR 2300-3300 without a computer. The helium balloon costs between EUR 700-1000, the helium gas 600-700 EUR per season, the SNCA-CFW1 camera EUR 1000-1500 and a WLAN base station EUR 50-100.

6. Discussion of the first test results

So far the experiences show that one complete fill and later complementing fills are sufficient for one summer of activities. This means savings in gas costs and very little ecological traces. Leakage problems reported in earlier experiments conducted with hydrogen filled rubberised silk balloons could also be avoided [Mye78]. The balloon and its accessories are transported to each site on a trailer.

Both the balloon and the attached camera have been subjected to rigorous tests in the archaeological investigations at the ruins of the medieval Kuusisto Castle near Turku, in southwestern Finland during the passing summer. After some training, the balloon and its accessories have been set up ready to use from the transportation package in 15-20 minutes. The system is manageable by one person with a reasonable physique. The pull of the balloon is quite strong although quite manageable in moderate weather conditions. The longest distance for the WLAN between the ground station and the camera measured to work properly, seems to be about 150 metres with the present configuration.

Some tentative issues were recorded. The balloon has a slight problem with its sensitivity for wind. Stationed over an excavation it can only stand for winds in the range of 1-2 m / s. Besides the general sensitivity to the wind, the low altitudes at about tree-top level seemed to be especially problematic due to the strength of turbulence. The balloon attached with a camera has obviously a mass, which moves around very rapidly and rather compellingly in sudden winds. The balloon is capable of moving even the 15-20 kg counterweights on the ground. Further, the estimated lift of the balloon was not sufficient to make it possible to apply a completely weatherproof harnessing.

The greatest challenge proved, however, to be the resolution of the camera and especially the JPEG compression of the current software version. The 640x480 px resolution with a high compression rate renders images in calm weather conditions, which are suitable for a limited use in popular

Figure 3: *A detail of the ruins of Kuusisto castle, southwestern Finland. Foto: Kari Uotila.*

Figure 4: *An undated, Bronze Age grave mound in Parainen, southwestern Finland. Foto: Kari Uotila.*

presentation and on the Internet. Even a very subtle swinging of the balloon and camera have, however, a deteriorating effect on the image quality, which renders them useless for research purposes. The image in figure 4 is taken in nearly ideal conditions (only slight breeze), although the low sun height causes some problems in form of shadows. The figure 3 on the other hand, illustrates the low resolution of the present camera and the deterioration of the image quality in somewhat heavier winds. It is expected, however, that the stability and image quality issues may be solved by adjusting the balloon configuration and by using a different, higher resolution camera.

7. Conclusions

A few months of testing has shown, that a helium balloon, WLAN and digital camera offers a relatively easy and technically feasible method to take real time aerial images of archaeological sites. The current configuration is cheap, easy to use, unintrusive, allows suitable angles for photographing and permits working sessions of up to 5 hours. Therefore the balloon needs to be taken down only once in a middle of a day for the change of batteries. The objectives of real time stratigraphical documentation and notetaking may be met with ease.

The present technical problems relate to the relatively poor image quality of the surveillance camera technology used in the current configuration. The problem is easily solved by finding and installing a more accurate camera.

The sensitivity to the wind, which is a special problem with the round balloons, may be worked out if a cigar shaped 'airship' or kite balloon is used instead. The currently known issues with the approach relate primarily to the increased size, weaker lift and higher cost of the cigar shaped balloons compared to the round ones. Also, the earlier reported problem of the relatively narrow window of suitable winds for the kite shaped balloons has to be taken into consideration [Mye78]. Another possibility would be to use of two or more balloons (as in [MYN*04]), even though that would definitely decrease the controllability and the ease of handling. In spite of the reported successes, the need of additional training and equipment decreases also the feasibility using a combination of kite (in moderate winds) and balloon (in low winds and windless conditions) (cf. [Ahm04]).

8. Future prospects

The work will continue with the issues of image quality and the sensitivity to the inoptimal weather conditions. The quality of the images is under research and several new camera models with WLAN connection are being tested including both the surveillance cameras and the relevant consumer products. A further issue under consideration, is the sensitivity to wind related to the round balloons. Possible solutions, including the changes in the shape and size of the balloons are tested to reach an optimal configuration.

References

[ACKT04]　ALTAN M., CELIKOYAN T., KEMPER G., TOZ G.: Balloon photogrammetry for cultural heritage. In *Geo-Imagery Bridging Continents, Proceedings of the XXth ISPRS Congress, 12-23 July 2004 Istanbul, Turkey* (2004), Altan O., (Ed.), ISPRS.

[Ahm04]　AHMET K.: The western Papaguería from the air: Digital imagery using kite and balloon aerial photography. In *Enter the Past, The E-way into the Four Dimensions of Cultural Heritage. CAA 2003 Computer Applications and Quantitative Methods in Archaeology, Proceedings of the 31st Conference, Vienna, Austria, April 2003* (2004), der Stadt Wien Referat Kulturelles Erbe Stadtarchäologie Wien M., (Ed.), vol. 1227 of *BAR International Series*, Archaeopress, pp. 46–49.

[Bew03]　BEWLEY R. H.: Aerial survey for archaeology. *The Photogrammetric Record 18*, 104 (2003), 273–292.

[Cam03]　CAMBI F.: *Archeologia dei paesaggi antichi: fonti e diagnostica*. Carocci, Roma, 2003.

[KMM*99]　KARRAS G. E., MAVROMATI D., MADANI M., MAVRELIS G., LYMPEROPOULOS E., KAMBOURAKIS A., GESAFIDIS S.: Digital orthophotography in archaeology with low-altitude non-metric images. In *International Archives of Photogrammetry & Remote Sensing* (1999), vol. 32, pp. 8–11.

[KO98]　KAMADA M., OKABE T.: Vegetation mapping with the aid of low-altitude aerial photography. *Applied Vegetation Science 1*, 2 (December 1998), 211–218.

[MPK03]　MAVROMATI D., PETSA E., KARRAS G. E.: Experiences in photogrammetric archaeological recording. In *Proceedings of the XIX CIPA International Symposium, Antalya, Turkey, 30 September - 4 October 2003* (2003), CIPA, pp. 666–669.

[Mye78]　MYERS J. W.: Balloon survey field season, 1977. *Journal of Field Archaeology 5*, 2 (Summer 1978), 145–159.

[MYN*04]　MIYAMOTO M., YOSHINO K., NAGANO T., ISHIDA T., SATO Y.: Use of balloon aerial photography for classification of Kushiro wetland begetation, Northeastern Japan. *Wetlands 24*, 3 (September 2004), 701–710.

[RB96]　RENFREW C., BAHN P.: *Archaeology: Theories, Methods and Practise*, 2nd edition ed. Thames and Hudson, 1996.

[Ree36]　REEVES D. M.: Aerial photography and archaeology. *American Antiquity 2*, 2 (October 1936), 102–107.

[STG04]　SKARLATOS D., THEODORIDOU S., GLABENAS D.: Archaeological surveys in greece using radio-controlled helicopter. In *FIG Working Week 2004: The Olympic Spirit in Surveying 22-27 May, Athens Greece. Workshop - Archaeological Surveys WSA1 Recording Methods* (Athens, 2004).

[Tak98]　TAKALA H.: *Arkeologian maastotöiden perusteet*. Helsinki University Press, Helsinki, 1998.

Integrated methodologies for data elaboration and real time: Villa of Livia (Via Flaminia project)

L. Vico[1], A. Moro[1], F. Galeazzi[1], M. Di Ioia[1], N. Dell'Unto[2]

[1]CNR-ITABC, Istituto per le Tecnologie Applicate ai Beni Culturali, VHLab, Montelibretti, Roma, Italy

[2] IMT Insititute of Advanced Studies, Lucca, Italy

Abstract

The CNR ITABC (Institute for the Technologies Applied to the Cultural Heritage), through the Virtual Heritage Lab, develops integrated methodologies for data elaboration and visualization and for the creation of virtual archaeological landscape.

The Via Flaminia's territory (Rome, Italy) is a composite setup of buildings, terrain and vegetation. Its virtual reconstitution requires the acquisition of architectural and topographic data and the development of a methodology to consolidate all data into a unique real time modelling framework.

Gathering data about the current status of the various elements of the territory requires to draw on a broad spectrum of instruments and techniques. Each technique should indeed be adapted to the morphology and scale of the entity that is surveyed. The instruments used to acquire data are: laser scanners, photogrammetry, computer vision, Total Station and differential GPS.

Using an advanced technology such as the laser scanner (for example in the case of the Villa of Livia) we obtained three-dimensional sets of points. The level of resolution is 6mm, or about 30,000 points by square meter. A total of 7,000 square meters were surveyed. Points were then triangulated (using Rapidform) and a first model produced decimated.

The preparation of a real time model requires such raw and bulky models to be optimised, and especially to reduce the number of polygons and ease the texture management. Two approaches were tested in this respect.

The optimized models are finally integrated in the virtual reality system, together with other models, prepared using different technologies, such as photomodelling (applied to regular geometries) that produces low-poly models with textures. Through the 3d reconstruction of the architectural heritage and its real time display, we obtained an accurate and communicative interpretation that both suits research purposes and can transmit the importance of conservation to the general public. It is perceived as an effective way to divulgate and publicise an information that is often only accessed by the scientific community.

I.3.6 [Computer Graphics]: Methodology and Techniques

1. Introduction

Processing information from the archaeological fieldwork to the communication medium is complex and requires assumptions and interpretations to be made at various stages. In addition, surveyed data has to be selected and simplified in order to lighten information files and provide a clear representation of reality. There is thus a risk of displaying distorted and incomplete information and thereby inducing bias in interpretation and research. Against this background, the Virtual Heritage Lab (VHLab) based at the CNR ITABC (Institute of Technologies Applied to Cultural Heritage), develops since 1999 an integrated methodology to acquire, elaborate and visualize archaeological landscape, through virtual reality systems.

In autumn 2005, CNR-ITABC signed a research agreement with ARCUS (Art & Culture Society), in collaboration with the Archaeological Superintendence of Rome and the participation of the UPM (University polytechnic of Catalunya), for the "reconstruction of the archaeological landscape of the ancient Flaminia with virtual reality systems", building a digital ecosystem that individualizes two levels of perception: the first one represents an holistic vision of the road from Rome to Rimini, based on historical maps, information on the archaeological excavation, technical cartography and aerial and satellite photos able to support the realization of a web gis; the second one, which dips into a micro-space vision that focuses the attention on four sites represent and contextualize the local entities within the "ancient landscape" entity.

In this paper, we introduce how we developed a specific approach for data gathering, incorporation in unified models and optimization protocol oriented towards real time desktop DirectX 9.0 applications, in order to reconstruct an archaeological landscape based on surveyed scientific data.

2. The study area

The ancient via Flaminia represented in the ancient times the road axis of fundamental importance for the connections between Rome and northern Italy and towards Centre-oriental Europe, joining Rome and the Umbria with the Latin colony of Ariminum (268 a.C.). The road followed the ancient transhumance ways and has been used during the Romanisation of the area. In II sec. a.C., Sempronio Gracco was restored, and it is supposed that the Interamna-Spoletium-Trebiae-Forum Flaminii section was renovated in the same time, following a pre-existing Umbra's road (important for the connection with the colony of Spoletium, 241 a.C.).

The road and bridges were renovated under Augusto. One of the main objectives of the road was the conquest of the Padania Valley and the Gallia Cisalpina. Along the road were found numerous burial sites and some important urban centres. Nowadays, the ancient Via Flaminia is still visible in few zones and important archaeological rests are conserved, scattered in a modern peri-urban context. The transformation of landscape and degradation of vestige make them hardly visible and appreciable.

The topographical knowledge of the Via Flaminia is disjointed and therefore the first problem in the virtual restitution is the contextualization of the sites able to be relieved and reconstructed in a unique VR frame.

Gathering data about the current status of the various sites of the territory requires to draw on a broad spectrum of instruments and techniques. Each technique should indeed be adapted to the morphology and scale of the entity that is surveyed. The sites that interest the project are very dissimilar, the necropolis of Grottarossa; the bridge Ponte Milvio, on Tevere river; the ancient arch of Malborghetto become nowadays museum, and the Villa of Livia at Prima Porta. The cognition of the actual state of the sites is based on the possibility of using advanced technologies for the data acquisition that is intimately connected to the typology and the particularities of the entities to examine. The instruments used to acquire data are: laser scanners (Villa of Livia), photogrammetry and computer vision (Grottarossa), photomodelling, Total Station and differential GPS (Malborghetto and Ponte Milvio). Nowadays the project is still in progress and if the relief of Villa of Livia and Malborghetto are already finished, for the other sites the work is started in this days.

2. 1. The villa of Livia

The Villa of Livia is the most important and complex component of our project (fig.1). The great archaeological complex is situated in the IX mile of the Via Flaminia, traditionally identified with the villa of Livia Drusilla, wife of Ottaviano Augusto, The villa was built between the 30 and 25 a.C., using the rests of a previous republican construction, and was occupied until severian age, when important restoration works were made, especially in the thermal area. Four construction's phases are identified, the last one in the III century B.C. The Villa was discovered in 1863. Unfortunately, the villa was bombed and damaged during the last world war. Damages are still visible in the room 15 and in the thermal area.

The villa is designed in a terraced structure, supported by opus reticulatum's structural walls. It has two visible floors, with an underground floor for services, and probably a second floor in many areas of the Villa. On the main central terrace of m. 160 x 80, the residential rooms were opened towards south, placed around a small porticus with a garden of republican age; towards the North, a complex of rooms and gardens was developed with an atrium tetrastilo with impluvium with private access from the Via Flaminia.
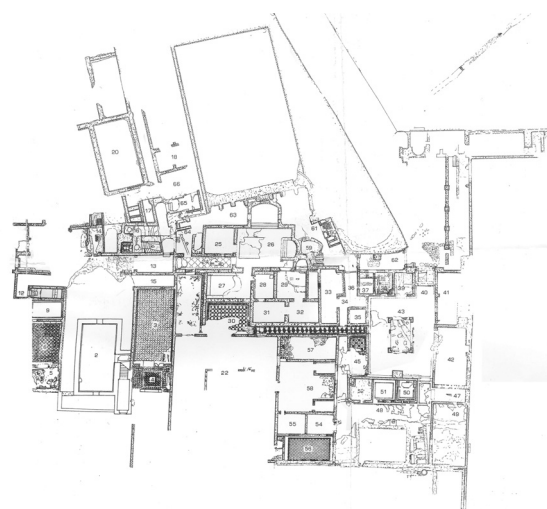

Figure 1: *plan of Villa of Livia*

North-west of the atrium, the present thermal zone corresponds to severian age but the original structure is datable between age Claudius-neronian and domitian. In the South-West sector of the villa there was the representative zone, perhaps used for receptions, and various dependences of service, of augustea age modified until severian age. Under these rooms, there is the underground triclinio with the famous frescoes of the garden, now kept in the national Roman museum.

3. Methods and results

A completed digital 3D processing of acquisition and representation will be the best basis of knowledge according to an integrated approach in order to minimized the risk to lose scientific data (Forte, 2003). We interpreted what we perceived, a VR system is able to show all the phases of the digital processing in a 3D domain. The dynamical interaction in a VR system can multiply the faculty of interpreting archaeological data, monitoring the digital ontologies of all the process of research.

To start the relief of the Villa we found out different problems: First, a fixed shed built in 1986 completely covers the site (fig.2), preventing any overall vision of the building and thus precluding the site survey from any zenithal point of view (e.g. aerial photographs). The

second problem relates to the complexity and great dimensions of the Villa, and thus to the need for methods that compromise surveying time and accuracy. Moreover, another question was how we could manage the big 3D model file of the entire villa for the real time.

Figure 2: *view of the Villa of Livia*

The design of a reliable and verifiable reconstruction begins with collection of quality and comprehensive data, both by a thorough survey of the vestiges ("bottom up") and the collection of texts drawings and other archives (in close collaboration with the Superintendence of Cultural Heritage), relative to actual places and on study cases morphologically and temporarily comparable ("top down").

The importance of starting from objective and accessible data, in the case of the Villa of Livia has turned out even more necessary, due to the complexity of the architectonic system and the insufficient and partial credibility of the planimetry in public archives and of scarce information caused by incomplete excavations.

For the great archaeological complex of Villa of Livia, we had selected two different surveying techniques. The first is based on the laser scanner and targets for the "representation zone" rich of important traces of painting in fresco and for the thermal area. With this technique we acquire high resolution and accurate data on volumes, at the expense of intensive surveying time The raw data collected with this technique is also too bulky for real time system. The second techniques is photomodelling, used for "the private" areas. In these simpler areas, photomodelling allows to rapidly acquire low polygon resolution with an high metrical accuracy data easily used in the 3D model.

The laser scanner technology represents a substantial technical step towards the availability of publishable, up-to-date, accurate data. In addition data is georeferenced, which is fundamental for an archaeological contextualization of the buildings in their territory. The acquisition of 3D data with the laser scanner generates a high resolution point cloud able to support the development of 3d models with a resolution of 6mm or

about 30,000 points by square meter (Cyclon by Cyrax Technology). Because of the heavy files generated by the scanner, the relief Villa was made room by room, delaying the problem of merging all the files in a unique model. The second step of the point cloud elaboration relies on the RapidForm software developed by Inus Technology, which functions and algorithms for the construction of the mesh seem to be still more powerful in this moment. The result is a 3D model based on exact data, with generated and interpolated faces. The same technique is used to detect both the architectonic compound of the Villa of Livia and the hill on which it exists. In fact, to contextualise the villa we used the scanner laser to survey the hill. This produced 4.379.590 points cloud that was process with the software RapidForm to produce a mesh. The processing of the cloud was complicated by the high level of noises and could not reach a satisfactory result. GRASS was thus used as an alternative software, importing the dxf file of the point cloud from Cyclon, and a geo-referenced model of the hill could be generated, using also some reference points measured with the Total station. (Fig.3).
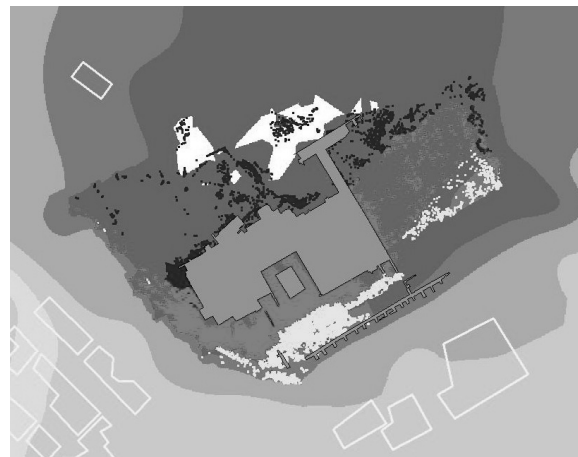

Figure 3: *Digital Elevation Model reconstructed through the interpolation of GPS data and the laser scanner point cloud of the Villa of Livia*

This approach allows both the creation of complex archives and the use of these data to reconstruct archaeological landscape in virtual reality applications for DirectX 9.0 environment.

The preparation of a real time model requires such raw and bulky models to be optimised, and especially to reduce the number of polygons and ease the texture management. Two approaches were tested in this respect. (Rapidform and 3dsMax software).

The first consist in mapping the surfaces using a specific algorithm dedicated to generate textures. This fast, but accurate method produces images composed of series of triangles that could not be edited with photographic software. Moreover, the algorithm of rapid form

introduced a monochrome background to the unused zones (fig.4), thus causing an annoying puzzle effect to the meshes (fig.5). More importantly, this method does not allow to apply the "multires" modifier, which is the most important tool we have used to obtain a low polygon 3D model .This first method was thus abandoned.
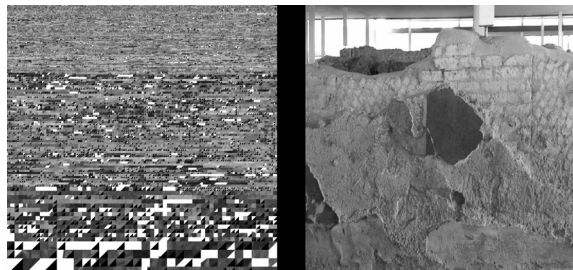

Figure 4: *Texture applied to the mesh in RapidForm, detail of the puzzle-effect*

The second method is based on 3dsMax software. A special mapping tool was used ("unwrap"), that allows to directly apply the image on the mesh.

This technique allows to roto-translate the projection plane to the same position as acquired with the digital camera. The possibility to manipulate the textures after the processing allows to fine-tune every single image of the total scene (e.g. brightness, colour, contrast), conferring realism and quality to the model. The ulterior optimization of the mesh is made using the modifier "multires" of 3dsMax, which, unlike the modifier "optimize" (previously used), allows to have a great control on the reduction of the number of polygons without modifying the perception of the model (fig.6). This second method thus reached a satisfactory compromise between the level of detail and the fluidity of the model.
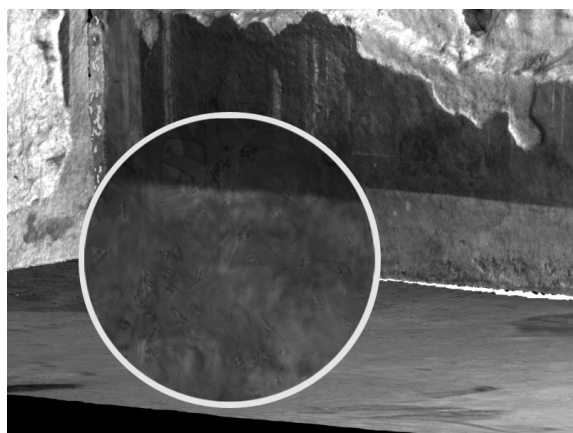
Figure 5: *Texture by rapidForm*

Rooms were then modelled and texture added to the mesh. Merging the models of each of the single room within the general model was finally done using the 2D

Autocad relief in DXF format obtained from the Total Station and imported subsequently in 3dsMax (Fig.6). In order to obtain a unique realistic model, it was necessary to equalize colours, contrast and brightness of the textures of the single rooms, using Photoshop.
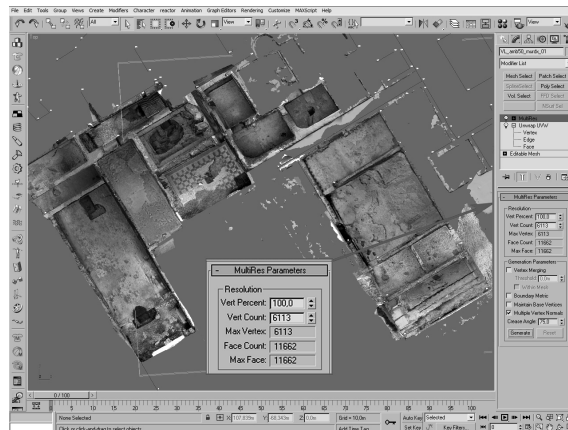
Figure 6: *Merged rooms with 3dsMax*

Photomodelling was first applied to three of the private rooms of the Villa. This easy, but not so fast, technique generates a very low poly model, readily textured. Comparing the two different way: (1) laser scanner with RapidForm and 3d Max (2) Photomodeller, it is evident that the first method is more accurately and detailed than second. Because the time needed to prepare the two optimized 3d model was more or less identical, we decided to drop the photomodelling technique and survey the whole villa with the Scanner, in order to achieve a uniformly accurate and detailed mode.

Figure 7: *Room 52 with photomodelling*

In fact, to realize the 3d model of the room N°52, for example, (fig.7) with the Photomodelling takes one mission of one person on site to make the pictures and four to five person-days to (1) realize first the 3d model with the software Photomodeler 4.0, (2) import the vrml or dxf

format files in 3d Studio Max and (3) correct geometry (checking with 2d cad layout), (4) create "mappe in bump", and (5) lights and rendering to texture.

For the same room, instead, it takes one mission of three persons with Laser scanner to realize n°19 ScanWorld. One person day is the required to process data with the software Cyclone by Cirax Tecnology and realize a point cloud composed of 965.017 points that cover an area of 378 sqm (where the room in object is just 35 sqm). The post processing with RapidForm (to construct the mesh and make a first optimization) and 3d Studio Max (for texturing with "unwrap" and optimize with "multires" tool the model) takes then three days of one person (fig.8). For the whole Villa, the Laser scanner was used to survey of total 7,000 square meters in about forty person-months.

Figure 9: *Rooms modelled with RapidForm and textured with 3ds Max*

The method can also generate low polygon resolution version of the meshes without modifying the perception of the model, keeping the frame rate of the application higher than 25 frame/sec. With this modelling approach, we obtain a fluid navigation through the mesh. The reconstruction of the virtual site is later realized trough an application in Virtools Dev 3.5, which allows to obtain a final version. This last version is not editable but the previous version is editable and could be upgraded at every moment if required. Through the 3D reconstruction of the architectonic heritage supported by real time applications, we approach an accurate and suggestive interpretation (using also the avatars reproducing historical and non-historical characters) that involves the public and transmits the importance of cultural heritage and thus of its conservation. Such models allow to disseminate data and information that often belong to the scientific ambit and that are not accessible or comprehensible to the majority of the unspecialized public. The interpretation increases the experience and vice versa: the possibility to interact with the cultural heritage increases the respect and the understanding of the public, transmitting the importance of the conservation, knowledge and the sharing and exchange of data and contents.

Figure 8: *Room 52 with 3ds Max*

Photomodelling was still a useful technique to survey the Malborghetto, an area of 204,68 sqm with very simple volumes. Together with the acquisition of reference points using the total station and the GPS, it supported the reconstitution of the site and its landscape.

4. Conclusion

The Via Flaminia project is still in progress but the work done up to now already allows to draw methodological conclusions for the creation of a virtual reality system based on a unique model (example of integration of spatial data, different technologies and methodologies) with high accuracy and detailed data (fig.9).

The cultural wealth at our disposal and the application of advanced but freely shared technologies give the possibility to make the common heritage accessible to everyone, in its historical, artistic and scientific dimensions.

5. Acknowledgements

6. References

BARCELO J., FORTE M., SANDERS D.: *Virtual reality in archaeology*, Oxford, ArcheoPress (BAR International Series S 843, 2000), 247-263.

BURROUGH P. A., MCDONNELL R.A.: *Principles of geographical information systems*, Oxford University Press 1998.

FORTE M., GOMEZ L., PESCARIN S., PIETRONI E., VICO L.: *Integrating Technologies: The Appia Antica Project*, 2st Italy-United States Workshop, Rome, Italy, November 3-4, 2003, BAR International Series, Oxford.

GOODRICK G., GILLINGS M.: *Constructs, simulations and hyperreal worlds: the role of Virtual Reality (VR) in archaeological research*, Lock, G. and Brown, K. (eds.), On the Theory and Practice of Archaeological Computing, Oxford, Oxbow Books 2000.

GRANELLI A., TRACLÒ F.: *Innovazione e cultura*, Milano, Il sole 24 ore, 2006.

MESSINEO G., CALCI C.: *La villa di Livia a Prima Porta*, Roma, De Luca, 1984.

MESSINEO G.et alii.: *Ad Gallinas Albas: villa di Livia*, Roma, l'Erma di Bretschneider, 2001.

MESSINEO G.: *La via Flaminia (da Porta del Popolo a Malborghetto)*, Roma, Istituto poligrafico e Zecca dello Stato, 1993.

MESSINEO G., SCOPPOLA F.: *Scoperte nei nuovi insediamenti militari della via Cassia e della via Flaminia*, QUAEI, ArchLaz IX, 1988

PERKINS J.B.W.: *Architettura romana*, Milano Electa Stampa, 1974.

QUILICI L.: *Le strade: Viabilità tra Roma e Lazio*, Roma Quasar, 1990.

WHEATLEY D., GILLINGS M.: *Spatial Technology and Archaeology. The archaeological applications of GIS*, London, Taylor and Francis, 2002.

WILSON JONES M. 2000, *Principles of roman architecture*. Yale University Press.

VR Modeling in Research, Instruction, Presentation and Cultural Heritage Management: the Case of Karanis (Egypt)

W.Z. Wendrich,[1] J.E.M.F. Bos,[2] K.M. Pansire[1, 3]

[1]Department of Near Eastern Languages and Cultures, University of California, Los Angeles, USA
[2]Past 2 Present-ArcheoLogic, The Netherlands
[3]The authors would like acknowledge contributions by Terry Wilfong (Kelsey Museum of Archaeology, University of Michigan), Lisa Snyder (Experiential Technology Center, UCLA), Zoe Borovsky (UCLA Digital Humanities Incubator Group), and Zahi Hawass, secretary general of the Egyptian Supreme Council of Antiquities.

Abstract
Since Fall 2005, a team at the Experiential Technology Center of the University of California, Los Angeles (UCLA), and archaeologists from the UCLA and the Rijksuniversiteit Groningen (RUG) expedition to Fayum have been creating a Virtual Reality model of the ancient town of Karanis. The model has multiple purposes, perhaps the most innovative being its future use as a management tool for the archaeological site. The model will aide in monitoring the decay of the town since the early 20th century, and in reconstructing the buildings, but it will also be used to study aspects of routing and the use of space, as well as a way of explaining architecture, principles of stratigraphy, and life in the ancient town to students. These seemingly disparate aspects of the VR model all aid the compilation of a site management plan for Karanis. This short paper presents a work in progress, envisioning the full potential that 3D technology implies.

Categories and Subject Descriptors (according to ACM CCS): J.3 [Arts and Humanities]: Architecture

1. Introduction

In the late 19th century three British scholars, Grenfell, Hunt and Hogarth visited the Fayum oasis in search of scholarly treasure (Figure 1). They were after Greek papyri, which were found in great quantities by the so-called *sebakhin*, farmers who were excavating ancient settlements to use the mud brick on their fields as fertilizer. The papyri and other antiquities were a lucrative by-product of these activities, and became a focus of the antiquities trade. The three British gentlemen had no interest in architecture, or archaeology, although they did remark on the exceptional preservation of wooden objects at the Fayum sites, in particular at Karanis. After two thousand years agricultural tools, doors, windows, roofs, textiles and baskets were still found intact and in amazingly good condition, but their focus was the papyri [GHH00]. The architecture was left to be cut away by the *sebakhin*. In 1924 the University of Michigan started excavations in Karanis, after a complicated battle with the *sebakhin*, who by that time were well organized and had a little rail line running from the center of the ancient town towards the edge, so that the mud brick was harvested on an industrial scale. The maps and elevations of the Michigan expedition show at least six major occupational phases, but also a large area, encompassing the entire center of the town, marked ominously "Area Entirely Destroyed By Sebakhin".

From 1924 to 1935 the University of Michigan excavated a large part of Karanis, concentrating on the town's central quarter. The excavations revealed a large mud brick town, with two stone temples, multiple storied houses, granaries, dovecots and ample evidence of grain and olive processing [Boa33; BBP31; Hus79]. The excavations were a race against time, with the purpose to save and document as much of the town remains as possible in the little time they had, before the *sebakhin* would excavate all. Before the Michigan excavations finished, the destructive work of the *sebakhin* was brought to a halt, by urgent claims that the site represented an important historical monument. The excavations cleared a wide area, to enable an in-phase overview of the different strata. Late Roman layers (dated to the third to fourth centuries CE) were removed to understand the earlier periods of occupation. After excavation was finished, in 1935, the mud brick monuments were mostly left open to the elements.

2. Present situation of Karanis

The town of Karanis was probably founded in the third century BCE, during the efforts under Ptolemy II Philadelphus to bring the Fayum under cultivation. These earliest (Ptolemaic) levels were not reached by the Michigan excavations. A recent re-interpretation of the archaeological remains puts the end of Karanis to the sixth or seventh century CE [Pol98]. These nine
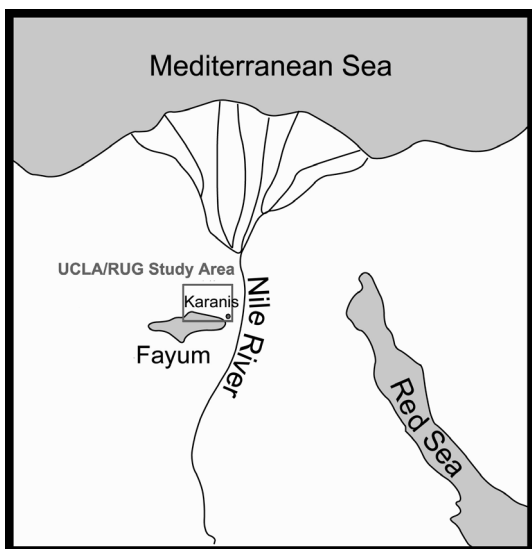
Figure 1: *Location of the Fayum, the study area of the UCLA/RUG excavation project and the ancient town of Karanis.*

centuries of occupation have created a depth of deposit which in some places is over ten meters. The large area excavated by the Michigan team, and the part destroyed by the *sebakhin* still cover no more that 25% of the entire site. On satellite photographs it is clear that the unexcavated parts of the town extend to the north, south and west, and continue at the west side of the main road from Cairo to the Fayum (Figure 2).

The site east of the road is open to the public and offers tourists an open air exhibit (the excavated part of the site, Figure 3), and a small museum which boasts antiquities from all periods of Egyptian history, from pottery dated to the Predynastic (3000 BCE) to the porcelain of Egypt's last King Farouk (1950's CE). The museum does not focus specifically on the Fayum, although several objects on display have been excavated in the Eastern part of the Fayum (Hawara). The museum was established in the 1960's as part of a philosophy to give all Egyptians the opportunity to find a broad overview of their national history in locally accessible museums.

At present, the open air museum at Karanis is a bewildering experience for the visitor. Sand-filled pathways lead through the excavated areas, and in many places run over underlying structures, exposing older, vulnerable mud brick walls. To the uninformed eye, an enormous deep vacant space in the center of town, flanked by two stone temples, seems to represent a curious type of inversed agora. Without knowing the history of exploitation of the site, the town's fabric is incomprehensible.

The mud brick buildings, excavated by the Michigan expedition, show evidence of rapid decay:

Figure 2: *Google Earth photograph of the ancient site of Karanis, with the approximate boundaries of the ancient remains, the cemetery west of the Cairo-Fayum desert road, and the destroyed central part of the site between the North and South Temples.*

Figure 3: *Center of Karanis looking south west towards the South Temple. The low lying area between the mud brick building and the stone temple is the "area entirely destroyed by sebakhin" (see also Figures 2 and 4).*

severe undercutting by wind erosion, dissolving of the plaster and bricks by rare but occasional precipitation. Conservation efforts of the Supreme Council of Antiquities and a French team in the 1970's have concentrated on a few buildings: the North and South Temple and a bath house in the west part of town.

3. Environmental archaeology in the Fayum area

In 2003 an excavation team of the University of California, Los Angeles (UCLA) and the Rijksuniversiteit Groningen (RUG), started a landscape project in the northwestern region of the Fayum. The project focuses on land and water use in the development of agriculture, from prehistory to present. The project's concession area includes extensive Prehistoric remains and three Greco-Roman settlements: Qaret Rusas, el Qarah el-Hamra (discovered in 2002), and Kom Aushim / Karanis.

The Prehistoric remains provide information on the earliest agriculture in Egypt, the cultivation and storage of wheat and barley. A study of Karanis is undertaken to augment information provided by the Michigan excavations. Many of the botanical remains have been shipped to Michigan and are now in the Kelsey Museum in Ann Arbor. Another portion of the Karanis finds (botanical remains, but also agricultural implements) are on display in the Agricultural Museum in Cairo. The botanical research, headed by the co-director of the Fayum project Dr. René Cappers, studies these finds, but also tests rigorous sampling methods in new excavations, to determine how representative the present Karanis botanical collections are.

Archaeology has seen a development in recent years, from purely research based projects, to an approach that takes much more responsibility for site preservation and presentation, as well as information to the general public. It is in this context that the UCLA/RUG Fayum project, directed by Willeke Wendrich and René Cappers, started to collaborate with Jolanda Bos, from the Dutch archaeological company Past2Present-ArcheoLogic, to investigate the possibilities of site management. The project has received support from the Antiquities Endowment Fund, administered by the American Research Center in Egypt for the first phase of the work: the initial evaluating phase of the management to be summarized in a position paper.

4. Karanis site management plan

The remains of the ancient town of Karanis were not adequately protected, through backfilling after excavation was finalized. Since the excavation of the University of Michigan, the mud brick town has been exposed to the elements. A rough estimate of the decay in the last century leaves the impression that more than 50% of the exposed remains have eroded in the past seventy years. For the UCLA/RUG expedition it was apparent that the monuments needed to be dealt with in some way. Excavation is not the main focus of the team, which feels a responsibility to aid the preservation of the remains of Karanis for future generations. As became clear from an initial survey, complete conservation of the site would be an impossible undertaking, both technically and financially. Difficult choices need to be made regarding the conservation of this vast area. To provide well founded grounds for these decisions, the site needed to have a management document. A team, headed by Jolanda Bos, is developing a site management plan to safeguard the preservation of the remains, at the same time enabling well substantiated decisions regarding access, information, conservation and future research. For this purpose the determination of the value of the Karanis monuments and the site as a whole will be assisted by developing several management assessment tools. These will also provide a toolkit for the archaeologists working at the site, in relation to site and heritage management in Fayum. Instruments, needed to determine the direction of the archaeological heritage management, will be developed in a bottom-up approach. At the core will be the archaeological remains and the interests of the different stakeholders, in contrast with an approach in which 'best practice' is implemented without a thorough analysis of a site's potential.

One of the main assessment tools for (future) archaeologists and heritage managers of Karanis is a survey of the state of conservation and rate of decay of the mud brick buildings. Important elements in the study are the publications, maps, excavation notes and other documentation of the previous archaeological expeditions. During our initial year at the site, it became apparent that one of the sources to assess these issues are the photographs taken over seventy years ago by the Michigan expedition. Comparing these with documentation of the modern state of preservation should facilitate answering questions such as: How fast does the mud brick deteriorate? What has disappeared during the past seventy years after exposure of the buildings? What are the processes that are causing this? To aid us with the assessment, and to enlarge the impact of our findings, we decided to make use of the results of a parallel project, the creation of a virtual reality model of Karanis for use in the class room at UCLA.

5. Virtual Reality model of Karanis

In Fall 2005 a start was made to create a real time Virtual Reality model of the town of Karanis (Figure 4). With funding from the Office of Instructional Development at UCLA, three graduate students of the Department of Near Eastern Languages and Cultures at UCLA, Kandace Pansire, Eric Wells, and Carry Zarnoch are rendering the plans and elevations of the Michigan publications into a three-dimensional model of the town. The work is done in the laboratory of UCLA's Experiential Technology Center, and greatly assisted by the center's Associate Director, Lisa Snyder. The rendering program used is Multi-Gen, which enables the creation of a real time model, which is generated on the fly. The model is created in such a way, that it serves multiple purposes, five of which are highlighted below.

Figure 4: *First stage of the Karanis VR model (in development), based on published maps from the University of Michigan publication. In the forefront the map indicates the "area entirely destroyed by sebakhin".*

5.1. The Karanis VR model as an instructional tool

The values of VR modeling in archaeology is generally recognized [Bar00]. Students of architecture or archaeology learn how to read maps, plans and elevation drawings. Students of history, art history, or ancient languages often do not have this background and show great reluctance to study information in a non-linear or non-narrative way. Understanding an ancient city, the activities of its inhabitants, the role of neighborhoods, location of industrial quarters, routing, social gathering spaces and all other aspects that are part of a town's fabric, requires a spatial approach to the subject. By creating the VR model, the plans and elevations are translated into a three dimensional representation, familiar to a generation accustomed to computer games. Perhaps the most important aspect of the instructional model is the display of phasing of the site. Rather than painstakingly studying a series of eight large fold-out maps, the student can toggle between phases. This enables an understanding of urban development, re-use of buildings, re-definition of city quarters, and concepts of growth, decline and abandonment.

5.2. The Karanis VR model as a research tool

The potential of the Karanis VR model as a research resource is as enormous as that of the teaching tool. Complex phasing of individual buildings or even segments of buildings, can be integrated in the phasing of the site as a whole. The model can be used to summarize and integrate micro-analysis into an overall stratigraphic overview. Secondly, the virtual reconstruction of buildings or entire sections of the town will enable testing of hypotheses ranging from building methods, to inside light levels, temperature control, storage capacity and lines of vision. Architectural reconstructions have an important heuristic function, because decisions on, for instance, wall height, roof lines, and stair wells require decisions on very specific structural details. Each choice has consequences which are difficult to foresee when made on paper, while the virtual reconstruction translates each alternative into a very specific set of delimiting conditions. A third example is a research project starting in Fall 2006 in which the model will be used to represent the spatial distribution of grinding stones and olive presses. The site of Karanis is littered with large round limestone milling stones, smaller granite hand mills, heavy half-rounded press weights and large stone press foundations. Although not all of these are in situ, a study of the distribution is expected to result in the identification of centers of activity of grain processing and olive oil production. In combination with a detailed study of each grinding or mill stone and the wear marks on these, reconstructions of the different production types will be made. By connecting the VR model to a GIS, full use can be made of the three dimensional spatial analytical functionality.

5.3. The Karanis VR model as threat monitor

During the Fall 2005 field season, Bastiaan Seldenthuis, the photographer of the project systematically recorded the wall faces marked on the old University of Michigan Karanis site plans. This time consuming project, which will be finalized in the Fall 2006 field season, enables us to correctly project the wall faces on the Karanis VR model. By underlying the 2005/2006 photographs with those made in 1924-1935, the VR model will enable us to visualize the wall decay during the past seventy years. Similar photographic recording of all, or part of the standing walls on site in future years will provide one method of documenting the state of preservation and an instrument to monitor further deterioration.

5.4. The Karanis VR model as presentation tool

The VR model will be part of an exhibit that will elucidate the function, appearance and history of the town. Similar functionality used to teach the ancient urban fabric to students, will be used to guide tourists through the virtual town as preparation of a visit to the actual remains. Stills from the model will present reconstructions of particular quarters on site, so that the extant remains can be compared to the recreated model.

Such on-site information panels also aid the visitors in understanding how the bewildering mud brick landscape ahead represents different phases in town use, partly dug away by excavators and looters. The use of VR models has been applied with success for this purpose at for instance the sites of Ename and Luang Prabang [PCK*00; Let99].

One of the aspects underdeveloped in archaeological information allocation to the general public is the methods archaeologists use. Popular on-site presentation of archaeology often still focuses on artifacts, rather than the archaeological context. The public is, therefore, often not aware of the potential information to be gained from an archaeological site, and the modern excavation and scientific methods used to do so. In addition to explaining the history and development of the town, the VR model can be programmed to show the visitor a glimpse behind the scene: it will present the research potential of Karanis as an archaeological site, the vulnerability of the remains, the efforts to preserve the site, and the importance of public awareness and participation. The model will, therefore have a prominent role in the Karanis site information center.

5.5. The Karanis VR model as an assessment and management tool

At several stages the VR model for the site will serve in the management of the ancient town. Its function as threat monitor and explanatory aid were outlined above. In addition to the educational aspects, the model will be used to design the routing for visitors. At present tourists are allowed to roam freely on site, while there is no discouragement to climb on buildings. Assessment of areas under immediate threat can be monitored closely, and the results conveyed to the public version of the model, to be used as a vivid illustration why the vulnerable mud brick should not be touched. Based on the detrimental stress, selected visiting highlights and routing, a selection will be made of areas which require immediate backfill, or other consolidating interventions.

Not all remains of the town of Karanis were excavated by former expeditions. In fact a considerable part of the site still lies hidden in its protective matrix of sand. These unexcavated areas which are not under direct threat of deterioration by natural or human factors, should be preserved *in situ*, rather than endure *ex situ* conservation. The results of surveys with non-destructive techniques, such as a magnetic survey to be done in Fall 2006, will be added to the VR model to extend the town to its full former size. At that stage, the model can be used to implement a site zoning as a management tool for the different potential usages. Areas that are completely off-limits, public areas restricted to tourist routing, increased access for guided specialized trips, and research areas are some of the potential zones to be defined.

6. Conclusion

Originally designed as an instructional and research tool, we are just now exploring the full potential of VR modeling technology by making it accessible to all the stakeholders of a multi-faceted project such as the Karanis site. The model's instructional value can be utilized as a wake-up call for policy makers when threats and decay are made shockingly visible by overlaying photographs from different periods; visitors, when confronted with this evidence, may comply more willingly with limited access if they understand that the rules are designed to preserve what previously was invisible to them. Research results feed into public information as well as management decisions. Assessment of the current situation, aided by a three-dimensional spatial representation can go hand in hand with a representation of the foreseen improved state of affairs after specific interventions. The VR model can be used as a record, a representation, a prediction, and a test of previous, current and future situations. The potential of VR in cultural heritage resource management is vast, but it is our task to envision the new capabilities it gives us, i.e., its potential to enable research to proceed, while preserving the site itself. Most importantly we must avoid designing our projects and predicting our results based on existing technologies rather than taking into account the full potential that this new 3D technology implies. The Karanis VR model, with its easy accessibility, may become the center of focus for students, archaeologists, visitors, local population, government oversight officials and policy makers. It will bring together the important stakeholders of the Fayum heritage and cover the multiple angles of the Karanis heritage management.

References

[Bar00] Barceló, J.A., Visualizing what might be, an introduction to virtual reality in archaeology, *Virtual reality in Archaeology*, Barceló, J.A., Forte, M., Sanders D. (Eds.), 2000, 9-36.

[Boa33] BOAK, A. E. R. (ED.) *Karanis, the Temples, Coin Hoards, Botanical and Zoological Reports Seasons 1924-31.* Ann Arbor: University of Michigan Press, (1933).

[BP31] Boak, A. E. R. and Peterson, E. E. (Eds.) *Karanis, Topographical and Architectural Report of the Excavations During the Seasons 1924-28.* Ann Arbor: University of Michigan Press, 1931.

[GHH00] Grenfell, B. P., Hunt, A. S. and Hogarth, D. G. *Fayûm towns and their papyri.* London: Egypt Exploration Fund, 1900.

[Hus79] Husselman, E. M. *Karanis, Topography and Architecture.* Ann Arbor: The University of Michigan Press, 1979.

[Let99] Letellier, R., Virtual Reality? A new tool for sustainable tourism and cultural heritage sites management. *Proceedings CIPA Symposium* (1999).

[PCK*00] Pletinckx, D., Callebaut, D., Killebrew, A.E., Silberman, N.A. Virtual-reality heritage presentation at Ename, *Multimedia, IEEE* (2000), 45-48.

[Pol98] Pollard, N. (1998) The Chronology and Economic Condition of Late Roman Karanis. An Archaeological reassessment. *Journal of the American Research Center in Egypt* 35 (1998), 147-162.

Photogrammetry   in Architectural Study: A message from architect to surveyor

Ryuichi Yoshitake*, Juko Ito**, Hiroto Watanabe*** and Nobuo Kochi***

*Aristotle University of Thessaloniki, **Kumamoto University, ***Topcon Corporation

Abstract

Photogrammetry is nowadays one of a prime technology for architectural drawing. This paper aims to report an architectural survey by using photogrammetry. The authors discuss not up-dated technique of photogrammetry but what is the problem when the architect makes drawing by photogrammetry. The authors had an opportunity to participate in the fieldwork of the architectural remains of Ancient Messene and a Byzantine church in Messenia, Greece. We used photogrammetry to make drawing and visualize the Classical monuments and the Byzantine church. In this paper, we make it clear the problems of photogrammetry as a visualization tool for architectural survey.

1. Introduction

Photogrammetric techniques with digital camera are quite proceeding in these years. These techniques are suspected to simplify the fieldworks in the archaeological sites. The method of photogrammetirc techniques with digital camera has advantage in its conveniences: the surveyors just take pictures on sites, and analysis them by laptop computers.

It is very important to record the data for the architectural research or archaeological survey, because the excavation aims to protect the cultural heritage, not to destroy the ruins. For architectural studies, especially, drawings and measuring data are quite important. Thus, architects and archaeologist has to make drawing and to take photographs in order to record the data and to analyze them. Most of the historical monuments have complicated shape, such as sculptures or architectural members with decorations. It is suspected the photogrammetry make easier these architectural field works. In addition, 3D modeling data will be useful for presentation sources, virtual museum and making replicas, etc.

The authors had an opportunity to use photogrammetric techniques in Ancient Messene in Peloponnesus, Greece (the excavator is Prof. P. Themelis, Society of Messenian Archaeological Studies), and a Byzantine Church near Messene in 2004. This project conducted by Architectural Mission to Messene of Kumamoto University (leader: Prof. J. Ito), collaborated with Topcon Corporation. EOS Kiss Digital (Canon, 630 M pixels) and software PI-3000 were used for this photogrammetric survey.

2. Systems

Topcon PI-3000 is application software for 3D measuring, 3D modeling and 2D pictures, so this system also enables us to make Digital-Ortho-photo (image of orthogonal projection). It is possible to analyze various kinds of target with various sizes, from few cm to 100 meters. Moreover, this system is useable in laptop computer so that we could analyze data on the sites. The principle of PI-3000 system is based on stereo method: combination of more than two pictures from different viewpoints (see Fig. 1).
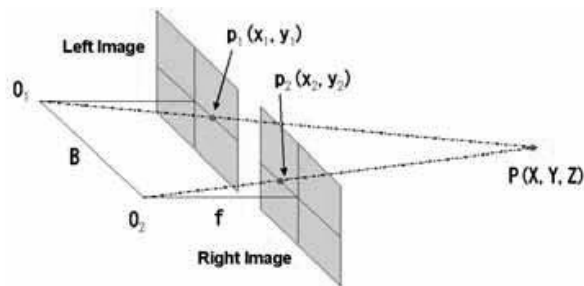
Fig. 1 *Basic Principle*

Measuring work is as follows (Fig. 2):

1) To calibrate your digital camera, before taking photos (you may can calibrate it after taking photos). It is necessary for camera calibration by selected lens and digital camera and obtains the interior orientation parameters (focal length, principal point, lens distortion).

2) Put picture data in your laptop and open it in the PI-3000 software.

3) Make orientation. Orientation is to calculate the photographing position of cameras, based on the image coordinates of the corresponding points on the left and right images. More than six corresponding points should be correlated.

4) Determine the common measuring area of two pictures within one model. We determine this common area on the stereo-images, rectified to become visible in 3D from the required parameter by the orientation. We can also determine easily on the two images displayed
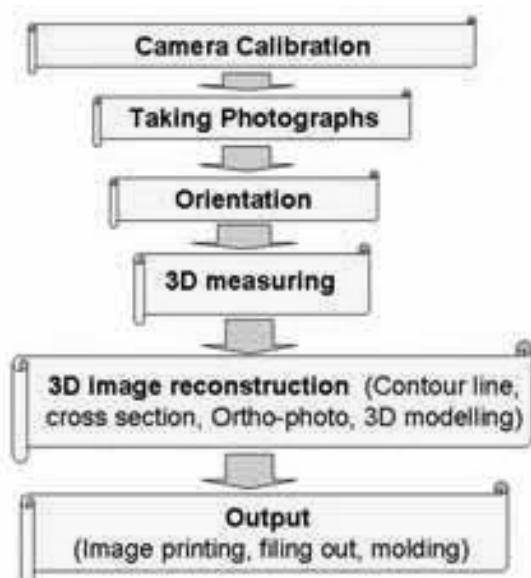
Fig. 2 *Flow chart*

simultaneously at right and left on the same PC display.

5) Once the common area is determined, we make automatic measuring (stereo-matching). Through this automatic measuring, we can process thousands of points altogether at a time and obtain the 3D coordinates.

6) After the work of 3D measuring, you can make 3D model in automatic and manual. It is also possible make rendering image, texture mapping image as well as contour line image by making a wire-frame out of the 3D point clouds.

7) Finally, we output the data of reconstructed. Since this can be output as DXF, PDF, CSV and VRML data, so we input them into CAD to make drawings or bonding other data, etc.

3. Examples of 3D measuring and modeling

3.1 Ancient Messene

The ancient city of Messene, one of the most important classical sites in Greece, is located around 20 km north of Kalamata, Peloponnesos (Fig. 3, 4). Messene, an ancient city in Peloponnesos, Greece, was founded by Epaminondas, the Theban hero, in 369 BC. The Sanctuary of Asklepios (or the Asklepieion) was the main sanctuary of the town and located in the center beside the Agora. The sanctuary was excavated by A. K. Orlandos during the years from 1950s to 1970s. However, he passed away after that, leaving the research uncompleted. The investigated the Stoa of the Asklepieion, the Grave Monuments of Gymnasium, and the Byzantium Church, which is about 5 km south form ancient site of Messene.

3.2 Corinthian Capitals

The Corinthian Capital is an architectural member of the column, which support the upper roof structure of the colonnade of the Asklepieion. It shapes bell-like with spirals with acanthus leaves around its (Fig. 4). The Corinthian capitals are used in stoas (colonnade) of the Asklepieion. The Corinthian Capital, which we measured, was about 70 cm (in length), 50 cm (in height), 70 cm (in width). Firstly, we put seven target seals on the Corinthian capitals to measure 3D coordinates by electric total station (Topcon TS), and then took photo by the digital camera (EOS Kiss Digital, Canon). The environment of taking pictures are; object distance was
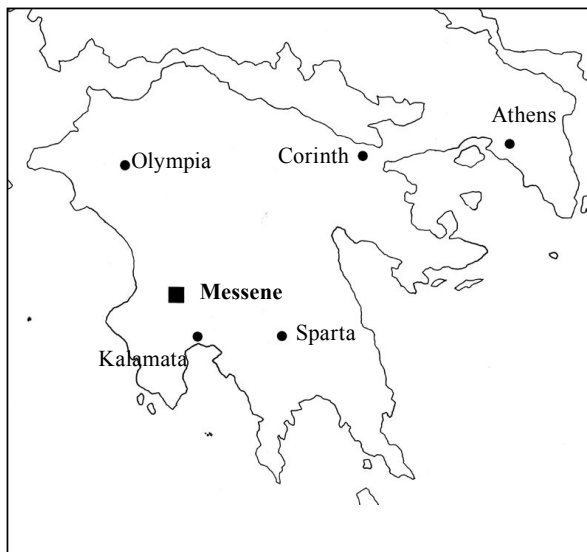
Fig. 3 *Map of Peloponnesos, Greece*

Fig. 4 *Aerial view of the Asklepieion (below) and the Stadium (above) from Acropolis*

around 65 to 70cm, distance between viewpoints was around 0.3 m, focal length was 18 mm, and 11 photos were used. In this environment, one pixel is equal to about 0.3 mm in horizontal direction, about one mm in vertical direction. As a result, we got texture-matching picture with contour lines (Fig. 5, 6). The contour lines will be helpful for measure vertical height and make architectural drawings. It took 10 minutes for taking photos and one day for making 3D mode.

3.3 Architrave-Frieze Blocks

The Architrave-Frieze block is timber block putted on the columns and support the roof of colonnades. The block was consisted with two parts of the Order; architrave and frieze. There are decorations three steps of facia (horizontal bands) in architrave part, and buclanie (bull-heads) and phialae

Fig.5 *Corinthian Capital, Messene*

Fig.6 *3D model of Corinthian Capital with texture maching*

(sacred dish for worship) combined with festoon in frieze part (Fig. 7). The targets were 3 Architrave-Frieze blocks, which was about 7.3 m (in length), 0.75 m (in height) and 0.35 m (in width). For taking photos, same as Corinthian capital, put 22 target seals on the blocks to measure 3D coordinates by electric total station (Topcon TS), and then took photo by digital camera. The environment of taking pictures are; object distance was around 1.1 m, distance between viewpoints was around 0.4 to 0.75 m, focal length was 18 mm, and 16 photos were used. In this environment, one pixel is equal to about 0.4 mm in horizontal direction, about 1 mm in vertical direction. Working hours was 30 minutes for taking photos and 5 day for making 3D model. As a result, the authors succeed to make 3D model with clear texture mapping: the 3D model with texture is so enough clear to see three steps of facia, bull-head and phialae decorations that the architect will be able to use for basic sketch or layer to make final drawings.

The authors made comparison of Digital-Ortho-photo from

Fig. 7 *Architectural drawing of Architrave-frieze Block with relief of buculanii and phialae*
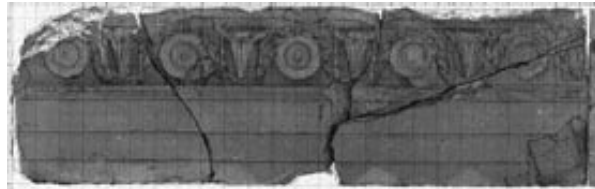
Fig. 8 *Digital-Ortho-Photo of Architrave-frieze Block*

3D model and architectural sketch by hand measuring (Fig. 8). Fig. 7 shows architectural sketch one of the Architrave-Frieze blocks (the length of which is about 2.4 m) in original scale 1 to10. It took seven days for the architectural sketch by hands; two days to detailed measuring (because the block is too heavy to rotate by human power), three days for general sketch and two days for decoration part. Fig. 8 shows comparative pictures the Digital-Ortho-photo and the hand made sketch of the same block of PI-3000. The hand made sketch are digitalized by scanner and adjusted to have same pixel per inch as the Digital-Ortho-photo. With comparison, there is 1 mm difference between these two pictures in the edge and clacks of the block. The cause of this might be from the difference of definition of facade of the block, that is, there is difference of viewpoint. It is also suspected that scan machine and camera lens make distortions. Secondly, the shape of difference between these two pictures of frieze decoration. It might be caused from using template when we make drawings by hand, not because of distortion of camera lens. As an evaluation, the Digital-Ortho-photo is enough collect (under 0.5 mm in generally) as an architectural sketch or basic layer for final architectural drawings. In addition, photogrammetry can make decoration drawings quicker than hand drawing.

3.4 Lion Statue

The lion statue was founded from Grave Monument K1 in Gymnasium complex buildings and now you can see in the Archaeological Museum of Messene. The lion is hunting a deer from its behind (Fig. 9). This lion statue is considered
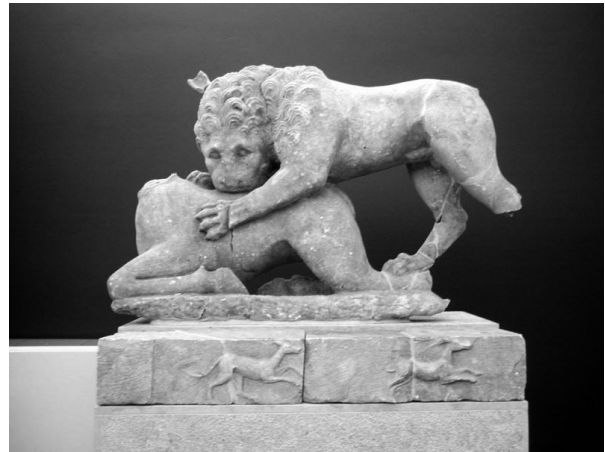
Fig. 9 *Lion Statue from Grave Monument I, Archaeological Museum of Ancient Messene*

Fig. 10 *3D model of Lion Statue with texture mapping*
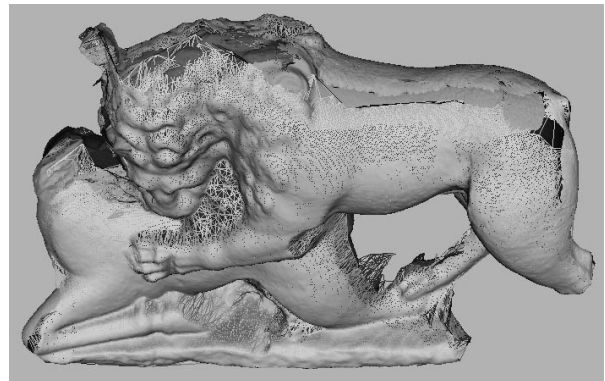
Fig. 11 *Rendering Model of Lion Statue*

that it was on top of the Grave Monument roof. The authors succeed to make 3D model of whole of the statue. More than 20 photos were used to make 3D model. Unfortunately, the brightness of each photo is different because we could not change the lighting in museum. It took half of a day for taking pictures but 10 days for analysis. For archaeological research, in generally, it is required only the facade part drawing of the statue, so we will be able to shorten working

hours for the drawing.

3.5 The Church of Agia Samarina

The Byzantine church of Agia Samarina is located 5 km south of Ancient Messene (Fig. 12). This church renovated from ancient building (probably a kind of temple) to Byzantium church, so big limestone blocks were used in the lower part of the church. In generally, it is necessary one week at least to make architectural drawing for such a big building. We tried to use photogrammetry, and it took a half of one day for taking photos, five days for making 3D model. The environment of taking photo was: object distance was about 11 m, distance between viewpoints was av. 4 m and 34 photos were used to make 3D model. In this situation, one pixel equal about 4.5 mm in horizontal direction and about 15 mm in vertical direction. Fig. 13 shows 3D wire flame model with texture mapping, and Fig. 14 show Digital-Ortho-photo of 3D model.

As you see in these pictures, the authors successes to make Digital-Ortho-photo s of the elevation of this church (unfortunately, we could not measure the roof). In this time, the author made just 3D model, but it will be possible to make simplifies of site working, if we have more detailed photos and measuring data.

4. Summaries

In summing up, the authors succeed to make 3D measuring and modeling by use of market on digital camera and software (Topcon PI-3000). This system can measure various kind of object from small to big: a small object such as lion sculpture in the museum, and big object like Byzantium church. This system need not big instrument or electric sources in the site, so it is easy to use in the site. In addition, the authors could make Digital-Ortho-Photos with well correctness to use as architectural drawing, or basic sketch for the final drawing. Although, the authors, as architects, could not satisfy enough of the result: the architectural member of Classical period made high accuracy less than few millimeter, so at this moment, we will not able to use the Ortho-Photos for architectural drawings directly. In Byzantine Church, there is a distance error in the length of wall more than more than 20cm; this irregular is unacceptable as architectural drawings. In this case, the

Fig. 12 *Byzantium Church of Agia Samarina, Mssenia*
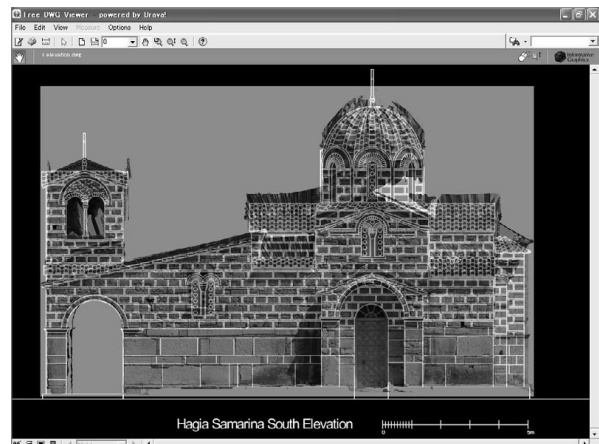

Fig. 13 *3D model of Churuch of Agia Samarina*

Fig. 14 *Comparision of ortho picture and hand drawing elevation, south elevation of Agia Samarina*

Ortho-Photo is only useable for layers on the part of upper small stones of the facade of church. The laser scanner will have advantage for such a round material, like the Corinthian capital, but we have to carry up such heavy stones, which is more than 150 kg. We have to take care the required accuracy is depending on the kind and size of the object. Additionally, this system requires well-trained operator

who have not only operating skills but also architectural or archaeological experience, because the final purpose of the architectural survey is to make drawings with collect measurements. In our case, the working hours for making sketch by photogrammetry are approximately same with it by hand. Thus, if the photogrammetry has enough accuracy for architectural requirement, there is big possibility to make the filed work simply and easily. For example in measuring work in the church facade, it will be not necessary to put up scaffolding for measuring the roof of church. It is possible to solve this problem by using Picture TS (Topcon GPT-7000i), which can measure the points without reflector, and can take photos with each point. It is also more safety for surveyor and proper for sensitive object like sculptures.

References

[1] T. Yoshizawa, "Introduction of Image Measurement Topics," O plus E, December 2004, Vol. 26, No. 12, pp. 1428-1429. (In Japanese)

[2] N. Kochi, H. Watanabe, M. Yamada, T. Ito and H.Otani, "3Dimensional Measurement Modeling System with Digital Camera," O plus E, December 2004, Vol. 26, No. 12, pp. 1430-1435. (In Japanese)

[3] N. Kochi, T. Ito, H. Watanabe, H. Otani, R. Kadobayashi and J. Ito, "PC-Based 3D Image Measuring System with Digital Camera and It's Application,"10th Symposium on Sensing via Image Information, 2004, pp. 323-328.

[4] T. Noma, T. Ito, H. Otani, M. Yamada and N. Kochi, "Development of Digital Camera Calibration Software Using Camera's Zoom Functions," 9th Symposium on Sensing via Image Information, 2003, pp. 35-40.

[5] P. G. Themelis, Ancient Messene, Site and Monuments, Athens, 2001.

[6] N. Kochi, H. Otani, T. Ito and T. Nagashima, "Hazard Survey with Digital Camera," Journal of the Japan Society of Photogrammetry and Remote Sensing, 2005, Vol. 45, No. 2, pp. 26-29.

[7] N. Kochi, M. Yamada, H. Watanabe, and H. Aoki, 3D-Measurring-Modering-System based on Digital Camera and PC to be applied to the wide area of Industrial Measurement, SPIE, August 2005, pp.

[8] J. Ito, Reconstruction of Ancient Monuments in 3D CG: Baalbek and Messene, 4th International Image Sensing Seminar on 3D Measurement, Modeling and Visualization by New Digital Sensors, ETH Hoenggerberg (HIL D52) Zurich, Switzerland Association for Real-time Imaging and Dynamic Analysis (ARIDA) Institute of Geodesy and Photogrammetry, August 2005.

[9] J. Ito, Photogrammetry and Study of Architectural History: From architect to surveyor, 3rd International Image Sensing Seminar on New Development in Digital Photogrammetry, pp. 24-27 September 2001, Gifu, Japan, CD-ROM edition.

[10] J. Ito, K. Tokmakidis, and K. Shimada, Reconstruction of the Stadion Area of Ancient Messene using 3D Computer Graphics and Analysis of Its Townscape, ISPRS XXXIII, B5/1 V, Amsterdam, The Netherlands, July 2000, pp. 395-400.

[11] R. Yoshitake, Y. Hayashida and J. Ito, A Survey of the Stoas of the Asklepieion in Messene, Journal of Architecture, Planning and Environmental Engineering No. 576, 2004, pp. 207-214.

Author Index