CLOSE-RANGE PHOTOGRAMMETRY, VIRTUAL REALITY AND THEIR INTEGRATION IN ARCHAEOLOGY

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ABSTRACT

The paper describes an experience of integration of different topographic and photogrammetric surveying methods, together with photographic virtual reality techniques, in the area of the ancient town of Bakchias (Fayyum, Egypt). The surveys were conducted with the aim of recording metrical, and non metrical information, in a common reference system, allowing to support GIS based multimedia realisations. The capabilities and advantages of the application of digital techniques in archaeology and Cultural Heritage are shown by some examples, related to surveying of structures and small objects.
One main objective of the work is to assess the potentiality of virtual reality technologies as core of a system permitting a site to be studied from remote locations using Internet; the use of these technologies are today mainly devoted to qualitative purposes (visualisation and interactive exploration), but the interface with simple surveying software applications, based on digital photogrammetry, could bring new powerful instruments also for metrical investigation.

1 INTRODUCTION

In 1993, a topographical activity for the archaeological expeditions of Bologna and Lecce Universities at the site of the ancient town of Bakchias (Fayyum, Egypt) began (Pernigotti and Capasso, 1994). The town (figure 1), dating back to the Graeco-Roman period, is located among desert sand dunes that partially cover a very large number of mud-brick buildings.
Topographical surveying in this site has currently two main aims, namely:
- providing an accurate metric description to support excavation activities and to make a record of the current state of the ancient town;
- setting up the most appropriate representation techniques for remote archaeological study and analysis.

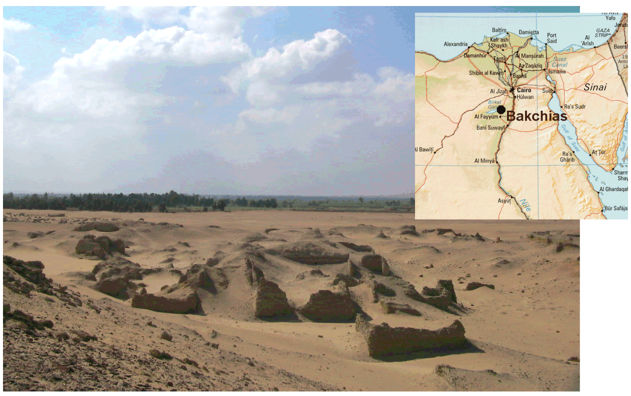


Figure 1. The archaeological site of Bakchias

The characteristics of the site require the integration of different surveying methods following different approaches at different scales with the aim of mapping the area, defining a common reference system for all the surveying activities and experimenting with the latest methods. In fact, the availability of new surveying tools and techniques, integrated with modern digital data management, have created new and interesting possibilities in the metric surveying of

archaeological sites. In order to provide an up-to-date description of the area at regional level, remote sensing and spatial imagery products were examined. Classical and satellite based surveys (using GPS, Global Positioning System) were extensively carried-out to survey the site and the excavations; selected examples and results are described in (Bitelli et al., 1997). Close-range photogrammetric techniques were applied, during excavations, to survey structures, walls and objects in order to achieve good accuracy with high productivity for different situations.
The use of virtual reality was considered and widely applied inside the ancient town and excavation sites, to permit virtual navigation of the archaeological site, three-dimensional visualisation of objects, and to furnish a visual support during data collection.

2 TOPOGRAPHICAL SURVEYS

During the 1994 Excavation Campaign no national planimetric vertices were available in the vicinity of Bakchias. A local reference frame was therefore created using a topographical network consisting of six points (Bitelli et al., 1995). The network was surveyed using a high precision total station (Wild TC2000). Redundant angular and distance measurements were collected in order to allow a least square adjustment of the network. Using the same total station, more than 3000 points were surveyed from the network vertices, providing the data for the generation of a DTM (Digital Terrain Model) for the area, by using Kriging interpolator. A detailed survey and a corresponding map, scale 1:100, was produced for the buildings belonging to the current excavations.
During the 1996 campaign, this local system was connected to the WGS84 Geodetic System by means of very long GPS sessions to reference stations (Malindi, Ankara, Matera) belonging to the IGS (Int. Geodetic Service) network, and from this to the national geodetic datum; finally, coordinates in the national cartographic system were determined by using published parameters. The known elevation value of a benchmark at the access bridge to the nearest village was used for the vertical datum.
The determination of a reliable reference system, connected to the national one, can permit not only to support the mapping activities, but also to georeference each survey carried out on the site with different aims (classical topographical measurements, kinematic GPS, close-range photogrammetry, photographic virtual reality imagery). This is the prerequisite for a correct implementation of a GIS for management of all the data coming from the campaigns.

3 CLOSE-RANGE PHOTOGRAMMETRIC SURVEYS

Close-range photogrammetric techniques were applied, during excavations, to survey structures, walls and objects. Digital photogrammetry, in particular, was widely applied in order to optimise the quality, the productivity and the cost both of the instruments and data processing tools used to obtain the end products. Different approaches were adopted, ranging from rectification processing to automatic DEM extraction and orthophoto production. Some examples are shown below.

3.1 Digital image rectification

Rectification is a quite simple method for surveying flat surfaces, common in archaeological and architectural works. Digital techniques are very suitable for this kind of applications because they enable to work with computer systems, without having to use optical-mechanical rectifiers, and they permit friendly interaction for direct measurements on the rectified images or simple production of vector interpretation using these metrical scaled images as a backdrop. Moreover, we are very interested in integration of these data with other data sets and textual information.
Many digital photogrammetric rectifications were performed on internal and external walls of the excavated buildings. The wide use of rectified images is justified by the necessity of obtaining representations with a metrical content and moreover giving a detailed and realistic information to comprehensively record the current conditions of the buildings. The example in figure 2 is related to a portion of a large wall in the north-east part of the Major Temple, dedicated to Soknobkonneus God, surveyed during the 1999 campaign using a semi-metric Leica R5 35mm camera. The images were converted to digital format using the Kodak Photo-CD scanning process, and stored on Compact Disc in high resolution (2048 x 3072 pixels). The surface of the wall was roughly plane, so it was possible to proceed to rectification, performed in digital environment (Rollei MSR software). The figure, that is the result of the rectification of 3 original images and of their subsequent mosaic, clearly shows that the course of bricks is slanting.

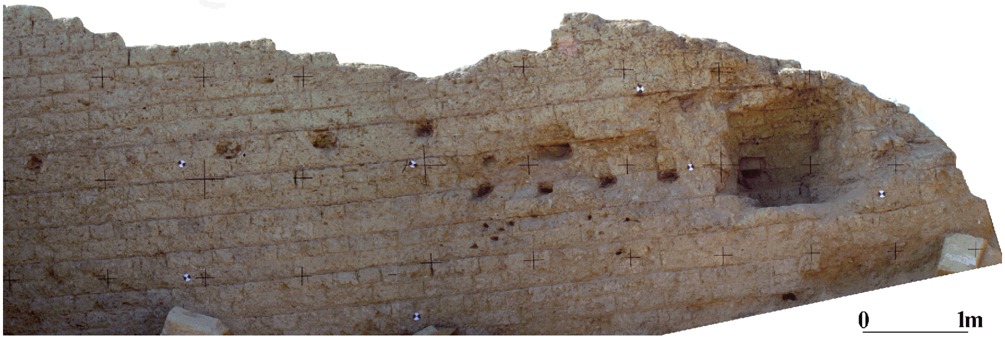
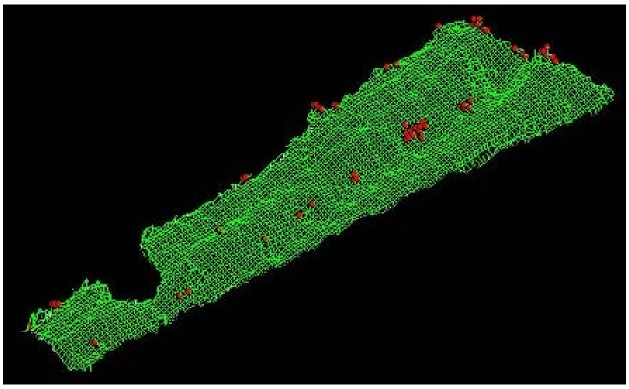


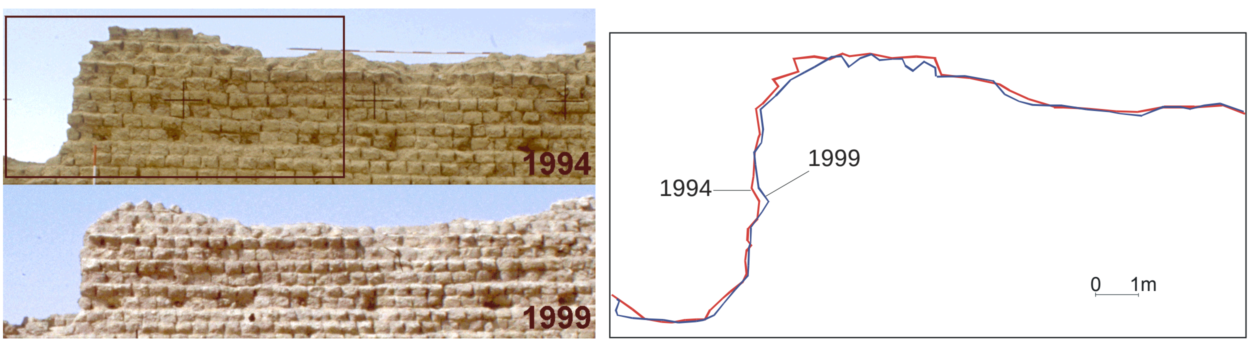
Figure 2. Mosaic of rectified images for a portion of a wall in the north-east part of the Major Temple

3.2 Survey of structures, automatic extraction of object's surface model and orthophoto production.

Photogrammetric surveying of non plane objects requires the use of two or more images and stereoscopic or monoscopic systems, or in alternative differential rectification. All these approaches are today provided by digital photogrammetric workstations, and have been adopted for the study case presented, where however monoscopic techniques are very difficult to be applied due to the nature of the structures materials.
The example in figure 3 is related to the east wall of the so called Minor Temple, where two photogrammetric surveys were performed during the 1994 and 1999 excavations by using semi-metric cameras and successive high resolution image digitisation. An experiment was realised to assess the erosion caused on the mud-bricks structures by weathering. A first information for this analysis can be derived from the digital surface models of the façade: to obtain this kind of product, image matching techniques were adopted, using low cost software for personal computer (e.g. Menci StereoView, Siscam Ada.). Figure 3a shows a 3D view of the digital model, made by area based correlation method, derived from the 1999 photogrammetric survey.
Another useful data for the evaluation of changes has been obtained using a digital photogrammetric workstation by the plotting of the top of the wall, derived from the two surveys, referred to a unique reference system: the figure 3b shows the differences found in this way for a portion of the wall.



(a)



(b)

Figure 3. a) digital surface model for the east wall of the Minor Temple; b) differences found at the top of the wall.

For the same structure an orthophoto was previously produced by analytical instrument and the result is shown in figure 4, with the superimposition, in a digital environment, of the contour lines derived from the digital surface model of the wall. The generation of orthophotos by a process completely carried out in digital form must be further investigated for different archaeological applications. If this kind of product shows interesting properties and advantages in respect to conventional stereoplotting in some situations, the automatic production of the surface model by matching procedures with low cost systems needs for an accurate control and validation by the user: an editing process of the model is in general required, and the overall procedure must be carried out by experienced operators.

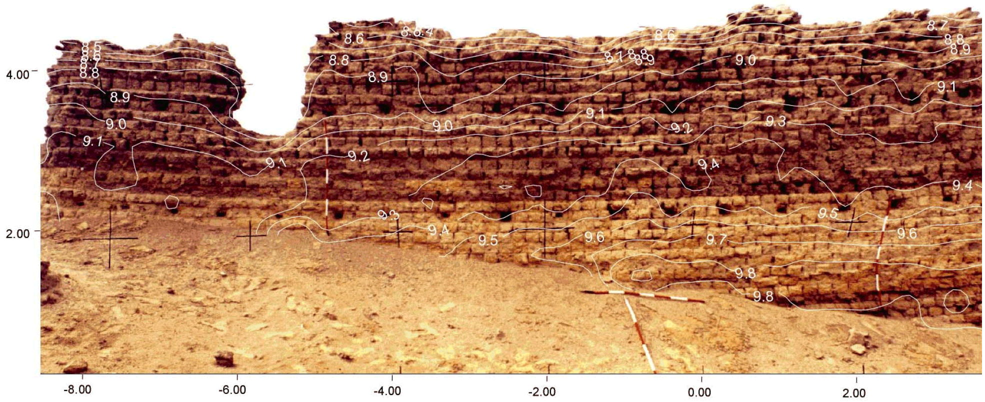


Figure 4. Othophoto of the wall, with superimposition of the contour lines.

3.3 Surveying of small objects

During excavation work, a three-dimensional frame was used to quickly establish the external reference system for stereo-pair orientation in surveying of small objects. The high number of control points supplied by the frame also permits calibration of non metrical, classical and digital, cameras. Figure 5 shows two images taken by the digital camera Canon Powershot Pro 70.

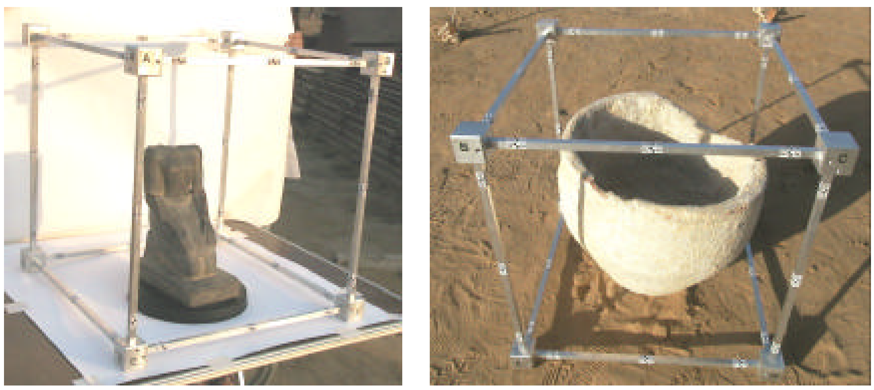


Figure 5. Images of discovered objects inside the 3D reference frame, taken by a digital camera.

4 PHOTOGRAPHIC VIRTUAL REALITY

4.1 Aims

During the excavation activity on the Bakchias site, the need of a comprehensive and detailed representation of the town became evident for two main reasons:
- the mud-brick structures brought to the surface by excavations are exposed to the weather and deteriorate very rapidly as a result. So it is necessary to keep a record of the town as it appears today;
- archaeologists have very little time to work on and study the buildings and other finds on site. It is therefore very important for them to be able to collect as much information as possible as quickly as possible on the objects of major interest.

Consequently, starting from 1996 we experimented photographic virtual reality (PhotoVR) techniques in order to create realistic renderings which can be analysed from remote locations. Virtual reality scenes are important because they can provide as much information as colour photographs: types of materials used and their combinations, colour compositions and differences, wall texture, decorative patterns and so on. Compared to simple photographs, however, virtual reality includes additional information which defines the representation of the site in three dimensions: for example, the shape and proportions of the objects, their location in space, their dimensions and relative positions.

4.2 Method

Normally, virtual reality scenes are generated by building three-dimensional models starting from fictitious metric information or real data, acquired by various surveying methods. Then, once the position of the observer has been defined, "textures" are applied to the model in order to produce a realistic representation of the object ("Model-based rendering").

A new approach known as "Image-based rendering" (Xang, 1998) is currently being developed. This technique is based on the interpolation of digital photographic images following geometrical constraints and pixel reprojection to create images from new virtual points of view. The virtual scene is therefore created without having to create explicit 3D images of the objects themselves. This latter category of rendering includes the construction of cylindrical panoramas, that we used to build the virtual scenes of the Bakchias site.

In this technique, series of pictures taken with a linear wide-angle lens at 360° and stitched together to form panoramic images are used as source data. Images are captured by positioning the camera on a tripod with vertical axis and turning it around the nodal point of the lens, in steps set at a certain angle (depending on the focal distance used), until all 360° of the panorama have been covered. The images obtained are deformed with algorithms to pass from the central projection on the photographic plane to the projection on the cylinder. Finally, the overlapping zones between adjacent images are processed to eliminate radiometric and geometric inconsistencies.

In order to perform these operations, we used QuickTime Authoring Studio (Apple, 1997) because the QTVR technology allows images to be captured and processed very quickly using simple tools and methods.

The same technology was also used to construct the so-called virtual objects (QTVR Objects). A QTVR object lets you view a 3D object from a variety of angles: you can interactively rotate the object and zoom in on parts of the image for a closer look. Images are captured by positioning the camera on a stationary support and the object on a turntable or other support that can be rotated. After taking a shot, the object is rotated by a certain number of degrees to the next position, and the next shot is taken. This step is repeated until the object has been turned through a full circle.

Each panorama and object can represent a node of a complex scene where the nodes are connected together by creating hot-spots on the images. Multimedia techniques are available for linking to different URLs. The final movie (QTVR scene) can be made available over Internet and can be viewed using one of the appropriate plug-in modules widely available.

4.3 Applications of virtual reality on the Bakchias site

The first two experiments with photographic VR were made on the Bakchias site during the 1996 excavations (Bitelli and Vittuari, 1997). The objects of analysis using this technique were the city's Major Temple and the House VIII.

The scene of the Major Temple was created using 17 nodes constructed by means of photographic images scanned at high resolution. The nodes were chosen and positioned in such a way as to be mutually visible and so as to make navigation around the site easy.

A second scene was created for the building VIII, located at the northern end of the city. The survey in this case was conducted right around the exterior of the building and inside it using nodes in all the rooms (figure 6). The positions of nodes on the exterior were determined by GPS technique, in order to insert the panoramas in a GIS realisation. The images were taken using a Sony Hi8 video camera with a wide-angle lens, and then digitised using the 24-bit frame grabber of a Power Macintosh 7600 system.

Instead, during the 1999 excavations, tests were carried out to apply the QTVR technique to objects. For this purpose, we captured images of several archaeological objects found at the Bakchias site (figure 7). We took photos with a 35 mm camera and a digital camera, with a rotation step of a maximum of 20 degrees in order to obtain a good smoothness and make navigation around the final object realistic. The negative films were converted in digital format using the Kodak Photo-CD scanning process. The images were then processed with Adobe Photoshop 5.0 to smooth light differences between adjacent images and to fill the background with a solid colour. Finally, we created QTVR objects by using a minimum of 18 digital images per object, with high resolution (2048 x 3072 pixels); a smaller resolution is of course required to make available the scene over Internet.

Figure 6. Navigation through a QTVR scene: House VIII, Bakchias.

Figure 7. Different angles of view in the interactive visualisation of a QTVR object (erotic cruet).

5 DATA INTEGRATION AND REMOTE ANALYSIS USING INTERNET

In addition to the information provided by the QTVR products, the Photo VR technique could become a powerful tool for integrating and organising information of different kinds relating to the study of a site. URL addresses can be added to scenes to provide links to different types of data. Panoramas, objects and virtual reality scenes can therefore constitute the basis for an information system that travels over Internet.

In order to investigate further into this new application of QTVR, we experimented different methods of associating to virtual reality scenes the information normally used by archaeologists to study objects. We therefore inserted links to text, information sheets and video clips in the virtual scene of building VIII. The result is a multimedia database in which you can explore the building as if you were actually walking from one room to another and stopping to read information of interest about it: for example, information sheets regarding the objects found, details on materials and construction diagrams illustrating the walls (figure 8).

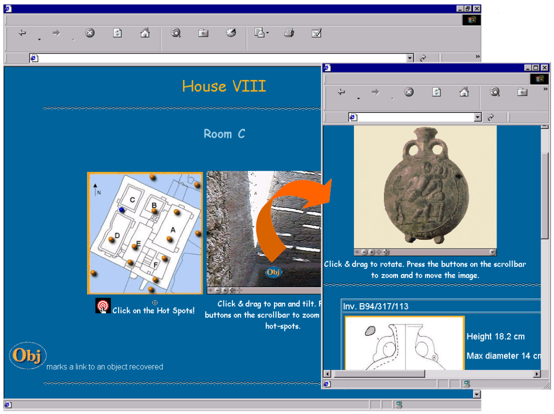


Figure 8. Multimedia database from virtual reality environment: links between different data sets.

In particular, we are experimenting the possibility of using Internet to provide access, from within the VR product, to metrical information obtained with the photogrammetric techniques described above. In a first simple example this is accomplished by inserting a link to a Web page where a rectified image is displayed. With a Java applet and a simple procedure, it becomes possible to measure the distance between points or the area of closed polygons selected with the mouse. Thanks to the universality of Java language, this type of application can be used on any platform and any user of the Internet site, exploring the virtual scene, can perform metrical analyses on the objects using only the resources of the web browser (figure 9).

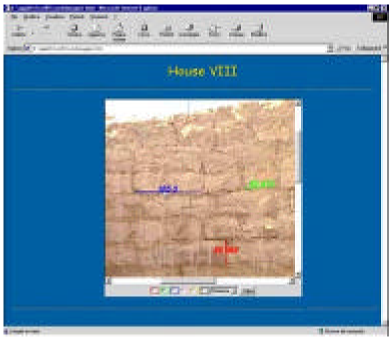


Figure 9. A Java Applet allows measurements to be taken on a metrical image from a Web browser.

5 CONCLUSION

The case study describes accurate and fast surveying approaches in Archaeology; the methods exploited can provide immediate support to excavation activities without interfering with work in progress.
The ancient city studied was built mainly of mud bricks. Topographical surveying thus plays an important role in storing information relating to the geometry and description of those objects that are subject to gradual, inevitable deterioration. Regarding the use of photogrammetry, the products of major interest, beside conventional stereoscopic techniques, are digital rectification and orthophoto generation. Experimenting with image matching for automatic Digital Surface Model generation may permit new forms of metrical analysis of objects and their development in time, based on grids with a high density of points.
The other technique adopted was photographic virtual reality, as an instrument for a highly realistic representation and immersive exploration of objects not directly accessible.
The information collected, whether descriptive or metrical, can be used by specialist researchers but also by the public at large. Especially for researchers, the correct archiving and management of data must provide a working tool that can be shared and updated by the entire research team. For this purpose, we are investigating the possibilities offered by the PhotoVR technique, not only as an advanced rendering tool but also as a vehicle for communication processes between different operators and for the integration of the results obtained with different surveying methods. The virtual reality model could become the core of a multimedia database making it possible to pass from a single scene to information of different kinds kept constantly up to date and able to be consulted using Internet. One of the most interesting features of this environment is that it would provide researchers with tools for the metrical analysis of the data displayed in the form of images and three-dimensional models.

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