

DOCUMENTATION OF ARCHAEOLOGICAL RUINS AND STANDING MONUMENTS USING PHOTO-RECTIFICATION AND 3D MODELLING.

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ABSTRACT:

Photo-rectification and 3D modelling offer a wide range of methods for the study and presentation, to a variety of audiences, of both urban features and standing monuments at archaeological sites. Ever more powerful software and hardware are continually pushing forward the limits of performance while electronic publication, on CD-Rom and through the World Wide Web, allows quick and easy dissemination of results. This paper presents a study at the METU Faculty of Architecture, made possible by a METU research grant (AFP2000), in which staff and students worked on different techniques for recording and surveying urban and architectural elements and reconstituting them in a virtual environment. The studies include examples from Kerkenes, a large Iron Age city in Central Anatolia, where well-preserved elements of defensive stone structures together with extensive stone paving were revealed, a portion of the standing Byzantine to Ottoman walls at Ankara Kale and, finally, multi-period remains of Napoleonic to WWII defences located on a small islet off the south-east coast of Mauritius. Software employed are (i) AERIAL, a simple rectification program designed for non-experts working on desktop computers, (ii) PhotoModeler and (iii) GIS (Geographical Information System) software, including ArcView and ERDAS Imaging. These studies have made considerable and significant progress towards demonstrating the potential of IT (Information Technology) and GIS tools in the study of architectural and urban elements within both the historical and the present environment. The methods and techniques could equally well be used to make visual projections of active and intrusive architectural conservation and restoration programs.

1. INTRODUCTION

New software and improvement in hardware continually push forward the limits of performance in the application of photo-rectification and 3D modelling. Electronic publication of results, on CD-Rom and through the World Wide Web, allows for rapid and easy dissemination of results. The aim of these studies, conducted on a wide variety of projects, was the development of techniques in photo-rectification and 3D modelling that would have a broad range of applications in both urban and architectural studies. The Kerkenes Project team has pioneered employment and collation of several different methods for surveying, recording and analysing urban elements. Recent results show that Information Technology provides numerous, continually developing, tools which the city planner and the architect can use in studies of the built environment, be it historical or contemporary. Examples have been taken from several ongoing projects concerned with archaeological, urban, architectural and environmental studies. The project has focussed on:

1. The use of various techniques for recording and surveying urban and architectural elements, both historical and contemporary;
2. The representation of data and results in a virtual environment;
3. Virtual reconstitution of urban and architectural elements within the areas of study;
4. Traditional and electronic publication of the results.

2. SURVEY AND RECORDING TECHNIQUES

2.1 Plans and Elevations of Stone Walls

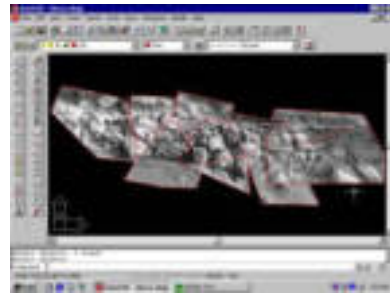


Figure 1. Rectified photographs are imported into AutoCad and cropped to form a photo-mosaic of the wall elevation.

Stone walls are tedious to record when accurate scale drawings that show each stone are required. Digital photography and rectification can greatly reduce time expended on detailed recording in the field. One example chosen for this study was a stretch of walling (Fig. 1) revealed by a machine dug trench at the bottom of the Kerkenes Dağ to tap water to the village of Şahmuratlı. This feature, perhaps of historical value, was exposed only for a short time and working conditions were difficult. Rectification with AERIAL 5.3 involves creating over the wall surface a net of control points marked with chalk, paper or in some other suitable way. Strings can also be used to mark the triangles formed within the net. In cases where the surface comprises a combination of different planes it is

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necessary to process each one separately. It is preferable to create these nets before photographs are taken, although it is possible to take printed versions of the digital photographs back to the field and measure marked distances. Once rectified in AERIAL 5.3, each of the individual photographs were imported into AutoCAD, the control points and lines matched to the drawing and each image cropped as necessary to form a photo mosaic (Fig. 1). The wall elevation thus produced can be digitised on screen or inked by hand over a scaled printout in the comfort of the office. The number of individual photos depends on the level of detail required, the size of the wall, and the space available for taking the photo (in this case restricted by the narrowness of the trench).

Photogrammetric recording and some photography of the Iron Age cyclopean granite masonry used for the Cappadocia Gate at Kerkenes was done in 1999 and 2000 and reported at CIPA 2001 (Baturayoğlu 2001 and Baturayoğlu et al. 2001). In 2002, as excavation of the gate passage continued, the side walls to the entrance were recorded in the way just described, using a quality digital camera (photos of 2032 x 1536 pixels) once control points had been chalk-marked and measured (Fig. 2).

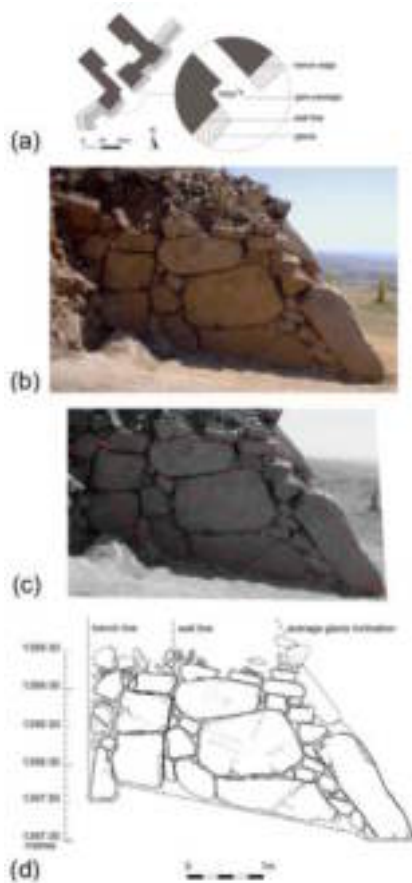


Figure 2. (a) The location of the section across the passage of the Cappadocia Gate at Kerkenes Dağ; (b) Excavation revealed the addition of the glaucis to the front of the north-east passage; (c) Accurately measured control points and lines are used for photo-rectification; (d) The drawing, by Gülnur Uçar, was inked over the scaled printout of the rectified photograph.

3D modelling of the part of the stone glaucis, using PhotoModeler, also produced encouraging results. It was concluded that, as had been anticipated, the results obtained from a digital camera with a good resolution were preferable to scans made from prints or colour slides (Fig. 3).

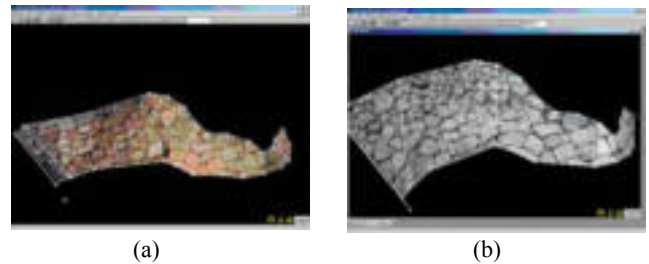


Figure 3. A model of part of the glaucis at the Cappadocia Gate produced in PhotoModeler from (a) digital photos and (b) scans of black and white photos. These 3D models, generated in PhotoModeler by Refik Toksöz, can be viewed from different angles.

2.2 Planning Stone Pavements

This same technique was particularly successful when used to record an extensive area of excavated stone pavement at Kerkenes in July 2002 (Fig. 4). Traditional recording techniques involve the tedious and time-consuming task of making pencil drawings, with the help of a planning frame (usually 1m x 1m), showing each stone in plan at a scale of 1:20. The technique that was developed uses digital photographs of each 1m by 1m square of pavement together with grid points surveyed with a Total Station. The slope of the pavement was sufficiently gentle for the rectification of photos over a plan view using the (x,y) coordinates obtained with a Total Station. Photographs were taken from the top of a stepladder in order to have sufficient coverage for use of only the central portion of each photo, which has minimal distortion. Chalk marks on the stones or nails with white and/or red tags were used as control points placed at the corner of each grid square. AERIAL 5.3 produces grayscale images (Fig. 4b and c) which were aligned over a grid in AutoCAD to complete the mosaic. The mosaic can be printed at scale and a hand drawing made (Fig. 4c).

Other techniques used more sophisticated GIS software (Arc View and ERDAS Imaging) to produce photo-realistic colour 2D images and 3D models. Ground control points are either measured with a Total Station, using a local coordinate system, or plotted by a GPS in UTM (Universal Transverse Mercator) or similar system. To create a colour photo mosaic of the entire pavement area, ERDAS Imaging was selected (Fig. 4d). The polynomial transformation can translate the photo to any coordinate system, rescale, rotate and skew. A 1st order transformation or rubber sheeting method requires a minimum of three control points on the photo although four points are preferred. When all control points are generated within the same coordinate system, different images can be combined with ease into a photo mosaic generated in 3D or, if desired, in 2D as a plan. Points and vector drawings can be opened simultaneously in different windows and control points matched on screen or using a table. A photo realistic plan of the stone pavement exposed at Kerkenes by the Palace Complex glaucis was thus generated (Fig. 4d).

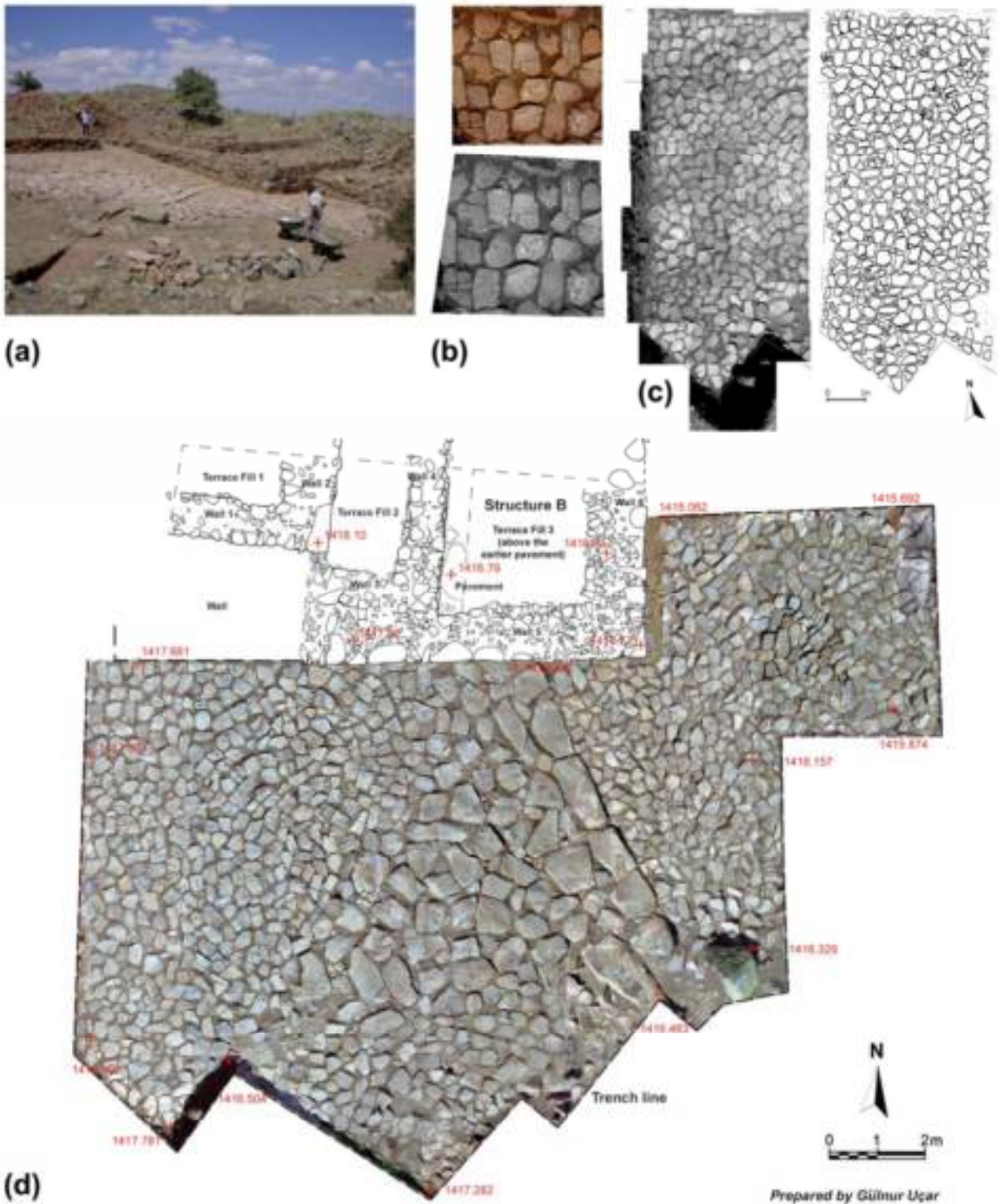


Figure 4.
 (a) The large stone paved area by the Palace Complex entrance at Kerkenes;
 (b) Digital photo and grayscale rectified photo of a 1m x 1m square of the pavement;
 (c) An inked plan produced from the AutoCAD photo mosaic printed to scale;
 (d) Each 1m x 1m square grid of the pavement was individually photographed and the pictures were combined into a single ortho-image using ERDAS Imaging. The extensive stone pavement was laid in at least two phases.

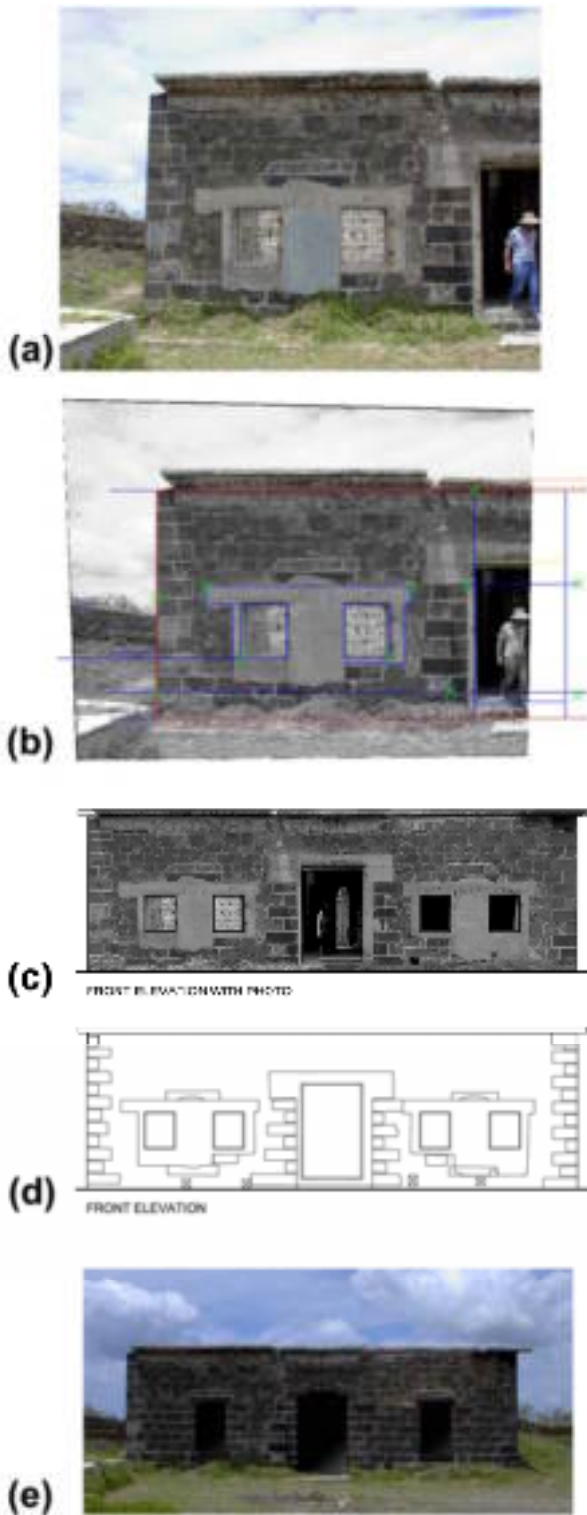


Figure 5.
 (a) Digital photograph of part of the front façade of the Storehouse on Ile de la Passe, Mauritius;
 (b) Rectified grayscale image aligned to control points in AutoCAD.
 (c) Front elevation of the Storehouse with rectified photo.
 (d) Front elevation of the Storehouse with details digitised from the rectified photo.
 (e) The Storehouse façade reconstructed in Photoshop to present its earlier appearance when built by the French.

2.3 Architectural Survey of Standing Buildings

The use of programs, such as AERIAL 5.3, for 2D photo-rectification and PhotoModeler for 3D modelling, has shown how detailed documentation, such as plans, sections and elevations of buildings, can be produced from digital photographs using only a limited number of measurements (Figs 5a to d). The results of such surveys can be presented graphically in considerable detail even when time and resources in the field are limited. Data can be collected during a short period of recording on site but subsequent processing in the office is necessary and it must be remembered that this can be time consuming.

The methodology is similar to that used for the archaeological remains described above, but emphasis is put on precise recording of the architectural features and details. The rectification program used, AERIAL 5.3, processes a grayscale photograph from a minimum of four known points, gives excellent results and is not too demanding on computing facilities or expertise. These photos are then imported into an AutoCAD drawing where a simple profile can be drawn from only a few key measurements (Fig. 5b). In most cases the aim is to produce AutoCAD ortho drawings (Fig. 5c and d). Digital capabilities can be extended to the representation of earlier phases of a building as seen for the Storehouse (Fig. 5e) or indeed to put forward restoration schemes when desired. Finally, elevations that record individual stones or details are, if desired, hand drawn from the rectified imagery (Fig. 6).

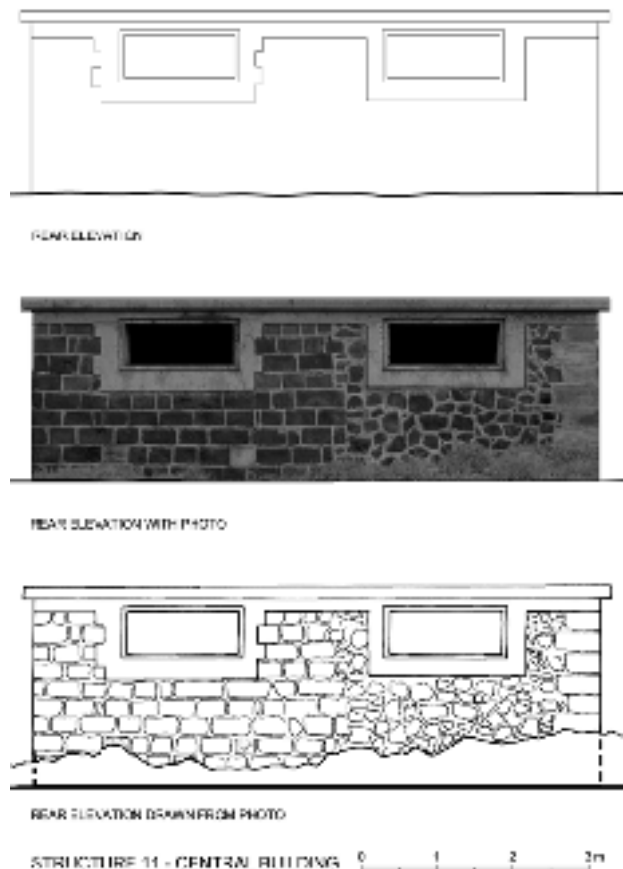


Figure 6. Rear Elevation of the Central Building on Ile de la Passe, Mauritius.

These techniques were used for the architectural survey of standing structures at Ile de la Passe, Mauritius. The fieldwork for this research was conducted by Geoffrey and Françoise Summers in January 2002. Post-fieldwork processing was done at METU with the help of postgraduate students. The islet guards the entrance through the coral reef into Grand Port and played a critical part in the last Napoleonic naval victory against the British. Standing monuments include defences and military structures built during the eighteenth century French colonial period and the following British occupation from 1810 to World War II. The archaeological and architectural survey was initiated by the Mauritius National Heritage Trust to document remains and standing structures and permit the implementation of appropriate approaches to cultural heritage issues, including preservation and conservation. A proper understanding of what survives is essential before a programme of cultural assets enhancement for presentation to contemporary and future generations of Mauritians and tourists can be proposed.

With very limited time and resources in the field, full documentation of all structures was successfully completed. All standing buildings were photographed and basic measurements

taken. Width, length, heights and a sufficient number of control points, either distinctive features or chalk-marked crosses, were measured. One example illustrated here (Fig. 6) is the rear elevation of the Central Building clearly built in two phases. Simple sketches to record key measurements were drawn in the field and the AutoCAD ortho drawings produced in the office during the post fieldwork study. The digital photos were rectified and aligned in AutoCAD to the selected control points, details were then digitised onto the elevation drawing and it was further possible to produce a stone for stone inked drawing from a scaled printout (Fig. 6).

Two more examples, from Ile de la Passe, illustrate the documentation of structures. The hot shot furnace (Fig. 7), built during the French occupation period, was presented as elevations with aligned photos giving the desired detailed information without the necessity for the time consuming production of a stone for stone drawing. Finally the photo realistic 3D model of the small stepped structure (Fig. 8) demonstrates the use of PhotoModeler to match photos to their respective surface on a 3D model drawn in AutoCAD with given measurements.

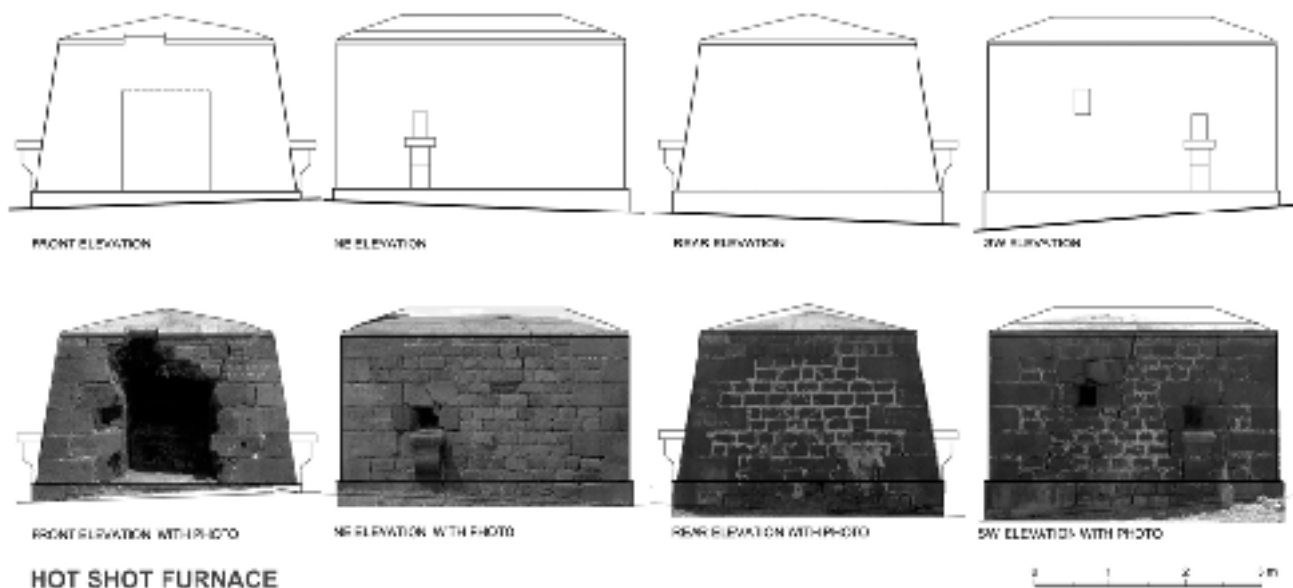


Figure 7. Rectified photo and elevation drawings of the hot shot furnace on Ile de la Passe, Mauritius.



Figure 8. The small stepped structure, probably a flag pole emplacement, on Ile de la Passe, Mauritius, was reproduced as a 3D model in PhotoModeler by Çağatay Kariptaş. The cropped portion of photograph used for each flat plane was matched to the corresponding surface of the model.

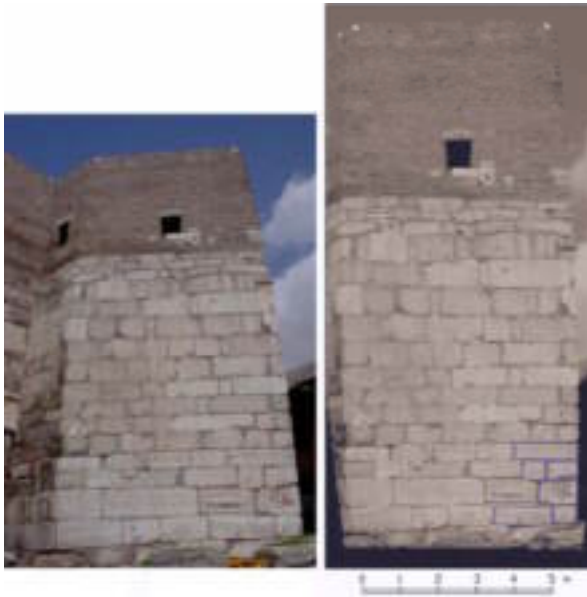


Figure 9. Digital photo of Tower 5 at Ankara Kale before and after rectification. A rectified greyscale image is inserted to the AutoCAD file to match the control points and an outline drawing of the individual stones can be produced by digitisation. The image can also be printed to scale and stone outlines traced by hand, preferably on acetate.

The final example chosen to illustrate rectification and 3D modelling techniques is a study of the Byzantine-Ottoman castle walls of Ankara. The research is undertaken by Sinan Sülüner as part of his PhD thesis, supervised by Prof. Dr. Ömür Bakırer. The study focused on the towers at the Ankara Kalesi Zindankapı where recent restoration work has been carried out under the auspices of the Turkish Ministry of Culture. The aim was to produce a 3D model of the towers and rectified photographs of wall faces from which scaled elevations could be drawn. The graphics and drawings assist in the analysis and the statistical study of the building materials that were used and reused during construction in the Byzantine and later periods.

To collect the necessary data, a GPS survey was conducted over seven days using a Trimble 4600 LS rented from the British Institute of Archaeology at Ankara. This GPS system utilises a base station and a roving antenna to provide highly accurate measurements. Approximately 10,500 readings were taken. A static survey, lasting two days, provided the UTM WGS 84 coordinates for a selection of fixed points located during the restoration work. Data processing was done with the GPSurvey program. Points needed for the rectification were also collected using the static survey technique while a kinematic survey provided data for a 3D surface model constructed using the GIS software Arcview 3.2 and Arcview 8.2.

Where it was not possible to measure points with the GPS, either because of the inaccessibility of the point or because the GPS signals were masked, a theodolite was used. Kemal Gülçen, from the METU Photogrammetry Laboratory, carried out the theodolite survey, measuring (x,y,z) coordinates for all necessary points. AERIAL 5 was used to rectify the digital photographs (Fig. 9) from which tracings of individual stones were done.

3. CONCLUSIONS

There are, perhaps, three largely separate but overlapping areas in which these techniques can be used and developed:

1. Rapid, efficient, accurate and detailed recording, or documentation, of archaeological and architectural features. Applications include the recording of standing structures, such as built defences, and of excavated remains. It is possible, and indeed desirable, to use these techniques in emergency situations as well as in routine, day-to-day, recording.
2. The 3D models permit realistic rendering and multi-perspective views of monuments in their present condition and situation. Modelling will also allow projection of the effects of active restoration and conservation schemes.
3. The graphic displays of heritage sites and monuments, as they are at the moment and as they may once have been, permits world-wide dissemination to a variety of audiences. This can be achieved by means of the World Wide Web, publication on CD-Rom or DVD, or in printed form.

The methods and techniques used for the different studies were selected so as to provide a comparative study of different approaches. The potential of Information Technology and GIS tools in the study of architectural and urban elements of the historical and the present environment has been demonstrated. They could equally well be used to make visual projections of the results of active and intrusive conservation and restoration programs. It must however be noted that the increasingly sophisticated software and hardware are continually stretching both human and financial resources, and the need to upgrade the hardware or to acquire new software is difficult to meet.

4. REFERENCES

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For further information on the Kerkenes Project, see:

<http://www.metu.edu.tr/home/wwwkerk/index.html>

5. ACKNOWLEDGEMENTS

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