RECORDING, MODELING, VISUALISATION AND GIS APPLICATIONS DEVELOPMENT FOR THE ACROPOLIS OF ATHENS

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ABSTRACT:

This paper presents the project *"Development of Geographic Information Systems at the Acropolis of Athens"*, financed by the European Union and the Government of Greece. The Acropolis of Athens is one of the major archaeological sites world-wide included in the UNESCO World Heritage list. The project started in June 2007 and will finish at the end of 2008. The paper presents the motivation for the project and its aims, giving a description of the deliverables and the specifications, as well as the project difficulties. Furthermore, we present the techniques used, both photogrammetric and geodetic, for data acquisition and processing. The project is divided into three basic tasks: the geodetic one, involving field measurements for the generation of a polygonometric network and terrestrial laser scanning of the walls and Acropolis rock and also the Erechtheion monument, the photogrammetric one involving image acquisition, orientation, DSM generation and orthorectification, and finally the development of a GIS database and applications. This contribution underlines particularly the potential of combining different technologies (especially digital imaging and laser scanning) for an accurate 3D modeling of cultural heritage sites. Preliminary results are reported.

1. INTRODUCTION

This work is part of the project "Development of Geographic Information Systems at the Acropolis of Athens" (Moullou and Mavromati, 2007). One of the primary aims of the project was the recording and documenting of the Acropolis circuit walls. The walls are very valuable because of the great quantity of material from various Acropolis structures built into them; a fact that makes the lack both of adequate measurements and of plans all the more noticeable. Having secured in 2005 funding from the European Union and the Greek State, the Acropolis Restoration Service initiated a project and prepared a detailed plan of implementation developed by:
1. Analyzing the existing data,
2. Recording the problems,
3. Defining the needs,
4. Establishing project goals,
5. Determining steps needed to achieve these goals,
6. Determining a realistic time-frame for the project,
7. Determining costs and,
8. Evaluating whether the project is worth doing given projected time and cost.

Currently, the project is well in process after starting in June 2007 and its completion is estimated by the end of 2008.

The project has two main goals. Firstly, the production of the scientific infrastructure needed for current or future restoration planning, with the emphasis laid on the Acropolis circuit walls. The project will cater for the investigation of the various interventions the walls have sustained across time, for the location and study of the poros limestone and marble blocks reused in them and for the examination of their static sufficiency. Secondly, the exposure of all information gathered over the years about the interventions and the new historical, archaeological, architectural evidence that has been forthcoming from recording the monuments, inventorying and identifying scattered architectural members and dismantling the buildings.

Expected final products

The steps to achieve the above mentioned goals are the following:
• Establishment of four new trigonometric points (combined with the three old ones) covering in visibility the whole monument
• Establishment of a new polygonometric network.

• Production of true-orthophoto mosaic at a scale of 1:50 (pixel size 5mm) of the north, west, and east circuit wall façades.
• Production of true-orthophoto mosaic at a scale of 1:25 (pixel size 2mm) of the wall areas where built-in significant architectural members exist (areas of special interest).
• Production of true-orthophoto mosaic at a scale of 1:100 (pixel size 10mm) of the top view of the hill.
• Production of full 3D surface models (and photo-textured surface models) of the rock, the walls and Erechtheion derived from 3D laser scanning at a resolution of 1cm for the areas of special interest, 5 cm for the rest of the walls, including its interior façades and 0.5 cm (or even better where it is needed) for the Erechtheion.
• Development of a GIS based on the above mentioned orthomosaics and the existing architectural plans, aiming at constituting a valuable documentation and restoration management tool.
• Connection of the GIS with the upgraded documentation database and publication on the Internet.

Major problems and difficulties

Currently, the archaeological site of Acropolis (see Figure 1) is both an enormous worksite and the main tourist attraction of Athens. Several problems exist for this project, which can be summarized as follows:
1. The outstanding importance of the site, which determines the high level of accuracy required and the platforms of image acquisition to be used. It is worth mentioning that all flights over Acropolis monument should be performed above 5000 feet for propeller aircraft or helicopter, prohibiting their use for the specifications of this project, and also that no UAV, or any other remotely-controlled platform is allowed. Thus, the only accepted platforms were balloons and/or cranes.
2. The fact that most of the days are extremely windy on the hill can cause serious problems in handling of the balloon platform but also the tripods for laser scanning and geodetic measurements.
3. The constant presence of hundreds of visitors.
4. The large object size and the difficult morphology.
5. The abrupt changes in relief and the monument height, compared to the short data acquisition distance.
6. The obstructions caused by vegetation, scaffoldings, cranes, and scattered architectural members, pose severe problems to automated tie point measurement in aerial triangulation, matching for DSM generation, true orthoimaging and laser scanning.

Therefore, it is evident that the supervision, the organizing, management and provision of efficient, functional and realistic solutions is a challenge for the researchers involved.

More detailed investigations of this project are reported in Tsingas et al. (2008), El-Hakim et al. (2008) and Remondino et al. (2008). The Acropolis of Athens has been an object of many studies. Within the context of the previously mentioned detailed investigations, other related studies are mentioned in Blomerus and Lesk (2007), Debevec (2005), Lundgren (2004) and Stumpfel et al. (2003).

2. DATA ACQUISITION AND PROCESSING

The major included technologies involved were:
- Digital imaging using different medium format digital cameras and different lenses and sensor platforms, incl. a balloon.
- Geodetic instrumentation and GPS for the various geodetic tasks and establishing the various networks and measuring control and check points.
- Various laser scanning technologies including Time-Of-Flight (TOF) and phase-shift with three laser scanners of varying specifications regarding minimum and maximum range, object size, point density and accuracy.

The balloon and the associated platform with GPS, WEB camera, Bluetooth for wireless data transmission and camera are shown in Figure 2. The camera was a Mamiya ZD (22 MPixels). Two Canon 5D (12 MPixels) were used for texturing Erechtheion and its image-based modeling, while Mamiya was also used for imaging some selected sites of the Erechtheion for scientific purposes. A Canon 400D was used together with the terrestrial laser scanner Trimble GX for scanning of the walls and the rock. Two more scanners were used for the Erechtheion, the Surphaser 25HSX phase-shift based laser scanner and the Leica HDS 3000 TOF scanner. The latter was used to scan the higher parts of Erechtheion but also for scientific investigations, involving penetration of laser beams into marble by comparing these point clouds of these two laser scanners but also to digital surface models derived from digital images by matching (see El-Hakim et al. 2008; Remondino et al., 2008).

The data processing has been performed both with commercial software packages and own developed software, the latter being critical for critical processing steps and higher performance.

Figure 1. The hill of Acropolis (aerial photo). In the center the Parthenon, left the Propylaia, at the top Erechtheion, on the right the old Acropolis museum (Tsingas et al., 2008).
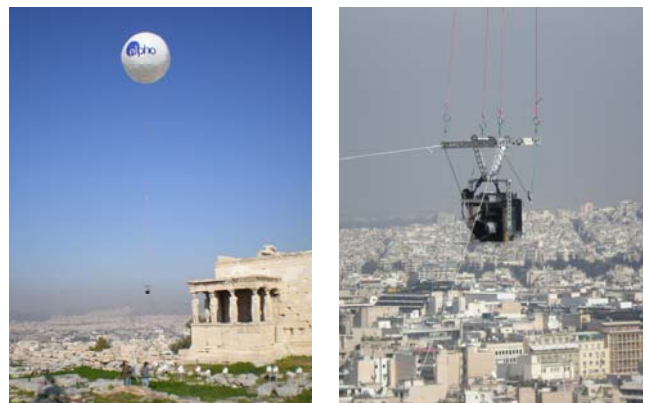

Figure 2. The balloon system (left) and the base with GPS, WEB camera, Bluetooth and the Mamiya camera (right) (Tsingas et al., 2008).

Figure 3. Terrestrial laser scanning of Erechtheion, showing some of the difficulties (El-Hakim et al., 2008).

3. PRELIMINARY RESULTS

As mentioned above, the project is still on-going. Preliminary results are reported in more details in Tsingas et al. (2008), El-Hakim et al. (2008) and Remondino et al. (2008).

A few thousand of balloon images have been acquired for top views of the hill, but also the walls and the rock. After camera calibration, triangulation and orientation of the images, Digital Surface Models (DSMs) and orthoimages have been produced, with examples shown in Figures 4 and 5, respectively. Terrestrial laser scanning has been performed for the walls (from outside and inside) and the rock. An example of the textured laser scanner point cloud in shown in Figure 6.

Regarding the Erechtheion, more then 5 billion points have being collected by laser scanning. This amount of data is impossible to handle, as a whole. A reduced, but still large, 10 million polygon model has been produced. Image-based modeling results of the Erechtheion are shown in Figure 7. A detail from the high-resolution, full 3D model showing one of the Caryatid statues is shown in Figure 8.
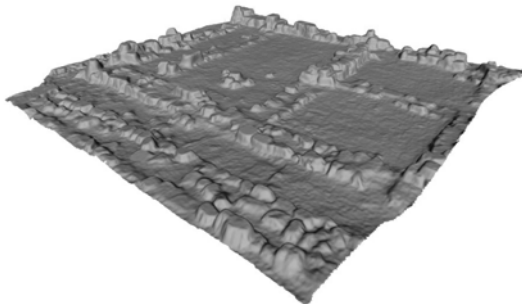

Figure 4. A detailed part of the DSM generated by balloon images on the Acropolis (Tsingas et al., 2008).

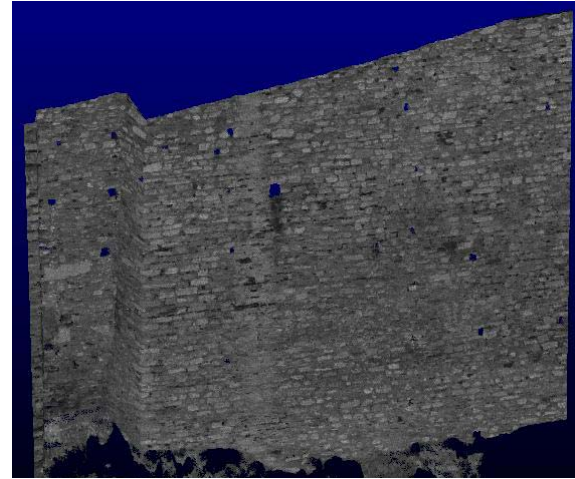Figure 5. Detail of an orthophoto from balloon images (Tsingas et al., 2008).

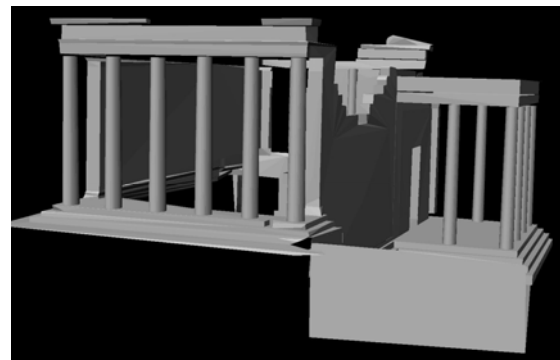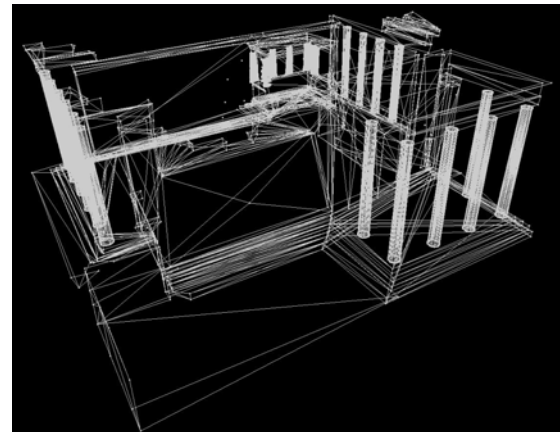Figure 6. Part of the laser scanner point cloud in the south wall (Tsingas et al., 2008).

Figure 7. Results of the image-based 3D modeling of the Erechtheion shown in wireframe, shaded and textured mode (Remondino et al., 2008).
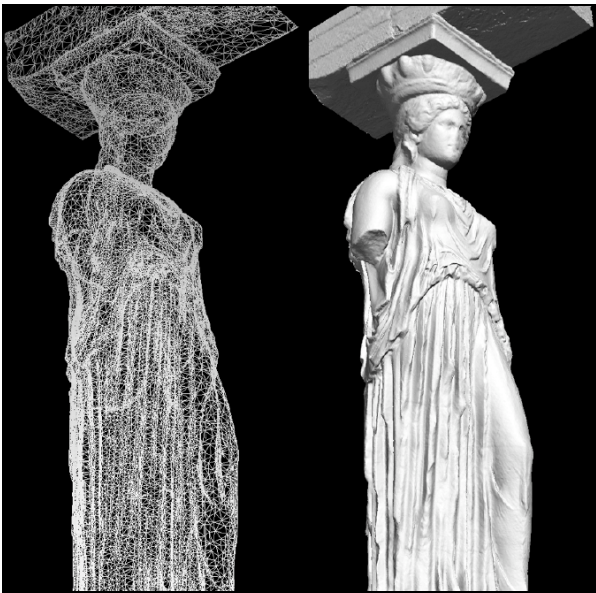
Figure 8. High-resolution model of a Caryatid statue (El-Hakim et al., 2008).

4. CONCLUSIONS

We have presented a large, complex project on acquisition of 3D data for the Acropolis of Athens. The data acquisition, processing, problems encountered, and some results of the digital reconstruction of the Acropolis of Athens have been presented. Multiple sensors and techniques, mainly use of digital imaging and photogrammetry, and terrestrial laser scanning, were employed and some tools had to be adapted for use with large complex monuments. Especially, in the case of cultural documentation, where the accuracy requirements are often high and the visual quality of the final products is indispensable, the fusion of different state-of-the-art methodologies is a must. The lesson of the work reveals once more that a single technique is not enough for the complete and detailed modeling of large heritage monuments and sites. The combination of different techniques is still the best choice for these kinds of projects, exploiting the inherent strengths of each approach, where it is best suited.

The current project, due to its complexity and archaeological interest can be characterized, as an important case study for similar research, involving large and complex cultural heritage sites. The gained experience and lessons learned will be valuable for future projects of modelling comparable structures. The incorporation of the 3D model in a GIS database with other information will be the final phase of the project.

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