FUSION of CULTURES

Abstracts of the XXXVIII Annual Conference on Computer Applications and Quantitative Methods in Archaeology,

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F. Javier Melero · Pedro Cano · Jorge Revelles

Editors

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Fco. Javier Melero, Pedro Cano & Jorge Revelles (Editors)

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Integrating 3D data acquisition techniques for comprehensive study of the ancient Hellenistic-Roman Theatre of Paphos, Cyprus

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1. Introduction

The documentation of complex cultural heritage is a fundamental step to study and preserve the ancient artifacts which undergo deterioration processes. The use of modern technology for documentation is a challenge not only because of the sophisticated techniques, but also for the integration between different methodologies.

Integration of data from different survey methodologies is a common problem in cultural heritage surveys. The main difficulty is to find a common topographical network for the data alignments and data transfer.

Currently laser scanning and photogrammetry represent a versatile solution for the real time acquisition of large amounts of data maintaining a high level of accuracy.

The integration of these technologies can been applied for the survey of complex architecture as a theatre.

While the aerial photogrammetry allows a comprehensive visualization with an accuracy of 2 cm on the ground, the close- range laser scanning can be used to acquire those parts, as the vertical walls, that are not visible from the aerial acquisition.

Experimental techniques have been used in this study to acquire different parts of the Hellenistic-Roman theatre of Paphos.

2. Case Study

The site of the ancient theatre of Nea Paphos is located in the modern town of Kato Paphos. It was built on the southern slope of a hill, which is in the very north-east of the ancient walled city. It measured m 90 × 195 from side to side and had a seating capacity for over 8000 spectators. The angle of rise of the seating is 26.5 degrees.

The theatre has been built around 300 BC. It is possible to identify at least five major phases of remodelling and rennovation during the theatre's history representing the changing nature of performance during Greek and Roman audiences, and the responses to earthquake damage. At its peak, in the mid-second century AD under the Roman Antonine emperors, when the stage building was façaded in marble, the theatre measured over 90 meters from side to side, and had a seating capacity of over 8000 spectactors.

By the end of the third century AD, probably after the devastating earthquake of 365 AD, the theatre was abandoned and much of the stonework was robbed and later quarried for use elsewhere in the town. After a period of abandonment, the site of the ancient theatre sees renewed activity in the 12th and 13th centuries AD, when the harbour of Paphos became once again a major economic point of activity, this time for the Crusaders on their way to the Holy Land.

3. The Project

In April 2009, the digital acquisition campaign of the theatre was carried out, involving the University of Sydney, the Cyprus Institute - STARC, CNR - ITABC and UNIOR – CISA. The aim of this project was to create a realistic 3D model of the original appearance of the whole theatre, for spatial and architectural analysis, documentation, dissemination and for testing two different technologies: aerial photogrammetry and terrestrial laser-scanning.

3.1. Aerial photogrammetry: system overview

An innovative device (Fly-Scan), developed and tested in collaboration by the Institute for Technologies Applied to the Cultural Heritage of the CNR of Rome (ITABC) and the Menci Software of Arezzo (Figure 1), was used for the aerial photogrammetry.

The device allows to undertake an archaeological - topographical survey through automatic aerial photogrammetry in a fast and reliable way, using an aerostat in order to get a three-dimensional model of the archaeological areas, complete plans of buildings, DTM (Digital Terrain Model) for detailed analysis of the area/surface and orthophoto. The reduced dimension of this system allows simple mobility in such environments as the theatre.

The device is composed by two aluminum bars (T shaped) of 2 m in length. Aerial images are taken from a helium balloon with a set of three cameras (Nikon D80) with 24 mm lens fixed on the frame and previously calibrated and placed at known range. This device hangs under a balloon which is 4,7 m in diameter. It can lift up to 8 kg. The balloon is guided by three operators using ropes, while a fourth operator uses the remote control to take photos from the ground.

Figure 1: *Fly-Scan system, during the assembling.*

3.2. Laser scanning: system overview

3D laser scanning emerged in recent years as a new and powerful measurement technique.

In the framework of the Paphos project the research has been focused on the development of a methodology for the digital survey of architectural monuments starting from the integration of different technologies.

The instrument used, the scanner 3D Imager 5003 (Figure 2), is produced by the German company Zoller & Frohlich *(www.zf-laser.com)* and was developed for applications on short and medium range (minimal distance between 40 cm and 53,5 m). It also guarantees an elevated acquisition resolution (max. 36.000×15.000 pixel: horizontal per vertical) with a speed of 500.000 pixel per second. Three profiles can be selected: Superhigh, High and Medium: at a distance of 10 meters the step of sampling of a High resolution is of 6 mm, while for the Superhigh it is double.

Figure 2: *Laser scanner ZF Imager 5003.*

The data is acquired both in spatial coordinates x, y, z, and in the reflectance values. The latter, expressed in tones of gray, corresponds to the response of the materials to the beam. The system needs one or two operators on the field.

4. Planning and data acquisition

Before planning the survey analyzed the extension of the archaeological site in order to define the flight plan. The laser scanner was used to acquire the vertical walls of the theatre, as it was not possible to scan them from the balloon.

A4 papers printed black with a white cross were used as control points for aerial photogrammetry, in order to reduce the sun's glare; for the alignments of the laser scanner shots A4 targets were used. All of them were measured by terrestrial methods with a Trimble 5600 total station. So both acquisitions, by means of aerial device or laser scanner have been linked to the same topographical network.

About thirty photos were taken in two days with the photogrammetry platform in order to cover the whole theatre. Part of these were taken with a rotation of 45 degrees of the cameras, while the others with a zenithal view. The flight altitude was about 40 m above ground, according to the optimal accuracy of the survey (Figure 3).

Figure 3: *The Fly-Scan system during the flight.*

Laser scanner fieldwork was carried out in only two days, following a well-consolidated pipeline. First of all it was made a sketch of the position of the targets. These targets allow the registration of each scans.

A total of 25 scans were made: 10 scans for *summa* *cavea* and 15 scans for left *parodos*, with a medium resolution range of 220 sec. Then a complete campaign of photographs was carried out, which included the scanned structures. The photos have a resolution of 3488×2616 pixels, 72 dpi, with a digital weight 2.2 MB.

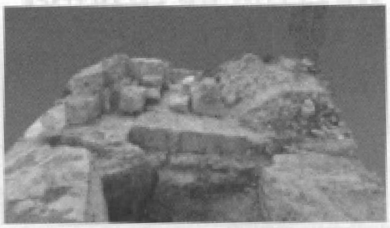

Figure 4: *Laser scanner colored point cloud.*

5. Point Cloud Processing

The result of the survey with Fly-Scan system (realized by Menci Software, Arezzo) is a set of three images for each shot. The images were processed with two softwares: Z-Scan and Z-Map (created by Menci Software, Arezzo). The first step is to extract from each triplet a single point cloud that contains spatial and color information. The next step is referencing the single point cloud in the same coordinate system obtained by the total station survey. The final outcome is a textured color per vertex model.

In the survey of the area, the Fly-Scan shown many issues. It was possible to guarantee an high accuracy of the geometric data changing the resolution during the data acquisition and the post processing. However other application problems were found: the sensitivity of the balloon to the wind and data loss in areas with deep shadows or high exposition to the sun.

After acquisition, all the scans were processed with the JRC 3D Reconstructor software (www.reconstructor.it.) (complete processing software for 3D data and for topographical measurements in combination with 2D digital images).

After cleaning the scans and eliminating redundant noises, the shots were filtered, combined and registered; the merging process gave at the end an error of only 6 mm. Images were mounted on the various scans, creating textured point clouds (Figure 4) and virtual scans. Then various sections were created, exported to CAD and placed on existing plans.

The point clouds were processed by referencing all the data captured from each methodology to a single object coordinate system in order to create the realistic 3D model of the theatre. The residual error of the registration process was better than 6 mm in XYZ coordinates (Figure 5).

Figure 5: Parodos: *photogrammetric point cloud and integration with laser scanning data.*

6. Conclusions

Using different technologies has given optimal results in terms of accuracy and photo-realistic outcomes (Figure 6).

The model generated from the integration of photogrammetry and laser scanning shots can be used for different aims: for the documentation of the monument_(plans, sections, views, axonometries, perspectives) or for an interactive navigation (Figure 7).

Howewer It is possible to integrate the 3D data with the traditional documentation of the archaeological area.

Figure 6: *Final point cloud by registration of the photogrammetry and laser scanning data.*

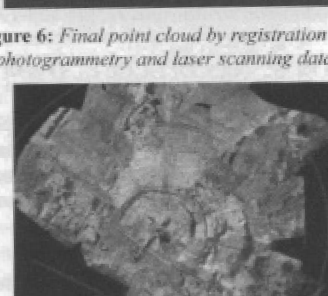

Figure 7: *Overlap of orthophoto from photogrammetric survey and CAD drawing.*

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