Archaeological Documentation and Restoration using Contemporary Methods

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Abstract
The monument of Zalongon is situated on top of an 80 m high and steep cliff about 30 km north of Preveza. It is a fairly recent monument, built during the 50's by G. Zongolopoulos, an internationally known Greek sculptor, depicting the heroic sacrifice of the Greek women in 1803, who preferred to dance to death from dishonor. The sculpture is about 18m long and 15m high and is a composition of several female figures. Although fairly recent, the sculpture has suffered severely from whether erosion due to frost and strong winds and –of course- tourists inscribing their names on the monument's surface. The Zongolopoulos foundation together with the local authority decided to embark on a complete restoration of the monument. For this purpose a complete and detailed geometric documentation and a three dimensional model of the construction was required. Given the size and complexity of the monument, contemporary digital techniques were employed for this purpose.

Keywords: Terrestrial laser scanner, digital orthophoto, 3D model.

1. Introduction

Archaeological works need support from other disciplines. During the past few years, technological advancements have armed scientists with digital methods able to support in a remarkable way the work of archaeologists and curators. Novel instrumentation such as terrestrial laser scanners, digital high resolution cameras and automated imaging total stations, together with the development of specialized software have contributed decisively to this end. A typical case of such collaboration is described in this paper. The basic steps and considerations for exploiting multi-source data for 2D and 3D documentation products are presented. This work serves as an investigation of the value of 3D high resolution textured models for restoration and preservation, which culminates to the actual interaction with the 3D model in order to assist the restoration, i.e. a form of computer assisted restoration.

2. Description of the Monument

The object of this study was to produce contemporary geometric documentation products for a huge sculpture. The main objective of this paper is to present a method for the creation of a high resolution model and to investigate in which ways engineers are able to interact with textured 3D data through various programs. The related research is carried out for the 3D textured model which was created for the monument of Zalongon, a complex of four sculptures, 15m high and 18m long, built in the late 1950's and located on top of an 80m high cliff in Epeiros region in northwestern Greece (Figure 1).

Figure 1. *View of the front (west) side of the monument of Zalongon*

The monument commemorates the sacrifice of the Souli village women, who in 1803 preferred death from humiliation by the ottoman conqueror. They chose to dance over the top of a steep cliff. The four huge abstractive figures of the sculpture depict exactly this moment of fatal dance. The restoration work which is currently carried out involves cleaning the object surface, extraction and replacement of large pieces that have suffered damages from weather and are deteriorating rather quickly, and the completion of parts that have been destroyed by frost, especially the top of the heads of the two tallest figures. The detailed geometric documentation of the current situation of the monument included the production of 2D drawings, including orthophotos and accurate 3D models.

Figure 2. Aerial v*iew of the cliff with the the monument of Zalongon on top*

Access to the monument is done only via a steep path with about 420 steps, winding its way upwards along the steep hill from a monastery which is situated at the cliff's foot (Figure 2).

3. Data Acquisition

The data required to build high resolution 3D textured models include 3D scans, geodetic measurements and a significant number of digital images. The equipment used in this case was a time-of-flight terrestrial laser scanner, the Leica HDS 2500, two total stations, TOPCON GPT7003i and PENTAX R323N, and a 8MP digital camera, CANON MARK II, with numerous lenses available. For the survey of the monument a 12 station geodetic network was established in the vicinity of the monument. A total of 761 points were measured, i.e. 148 points for the survey of the surrounding area, 327 control points, another 144 points of detail and 99 points for a horizontal section near the basis of the monument. Also, 16 scans were acquired from 9 scanner setups and 16 reflective targets were placed and measured for the registration process and for the integration of the scanner data into the geodetic reference system. Finally, 239 images were also acquired for metric purposes. The adjustment of the geodetic network and the calculation of the geodetically acquired points were carried out in Tachymetria© software achieving a maximum standard deviation of 5mm.

Two field campaigns were necessary. The second one after the contractor had built a rather shaky scaffolding, which enabled access to the damaged parts, i.e. the heads of the two taller figures, and acquisition of detailed and more accurate measurements (Figure 3).

Figure 3. *Data acquisition in the field*

For the production of 2D drawings (1 topographic drawing, 3 façade line drawings and one horizontal section) Autodesk's AutoCAD Civil 3D was used. Topcon's Image Master™ was used for the photogrammetric orientation of the images. For the production of the 60 orthoimages, which fully cover all the non flat surfaces of the monument, Topcon's Image Master™ and Intergraph's Image Station™ were used, whereas, SISCAM's ARCHIS 2D™ was used for the creation of 8 rectified images, for the flat surfaces. A total of 5 orthophoto-mosaics were assembled and processed with Adobe Photoshop CS2. In Figure 4, a horizontal drawing displays the five vertical planes that were chosen for the othroprojection and the final orthophoto.

4. 3D Texture Modeling

The most interesting product, possible only with the use of contemporary digital methods, was the 3D model. For the creation of the surface of the 3D model all of the original scans were registered into a common reference system by applying a method that was developed by the authors (Valanis & Ioannidis, 2008, Valanis et al. 2009). After all the scans were registered the data were transformed to the geodetic reference system, by means of the geodetic coordinates of the reflective targets in Leica's Cyclone software. A total of 16 million points of 2 cm resolution resulted into a moderate resolution 3D mesh of 700.000 polygons with an average edge length of 3cm as demanded by the project specifications. The 3D meshing and the required editing were carried out in Raindrop Geomagic Studio 9.

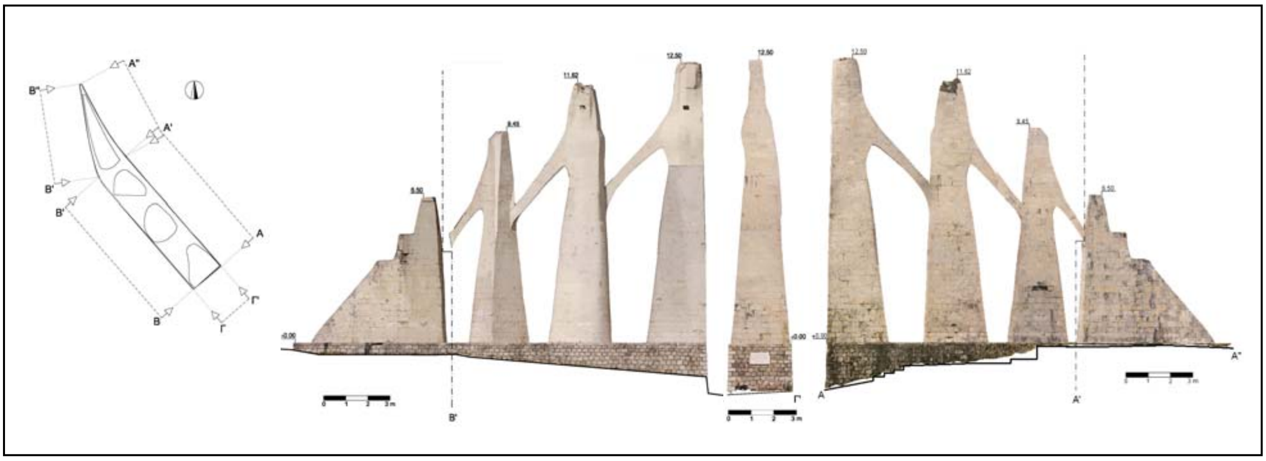

Figure 4. *On the left a horizontal drawing that displays the five vertical levels that were chosen for the othroprojection and on the right the final orthophotomosaics.*

For the texture modeling process, this data was reduced to a 10% with adaptive algorithms that retain a greater density in areas of interest (details, curvature change etc). At this stage, the surface was cut into pieces so as to facilitate the next steps of the process and improve the texture mapping results. The final model as it was formed initially is displayed in Figure 5.

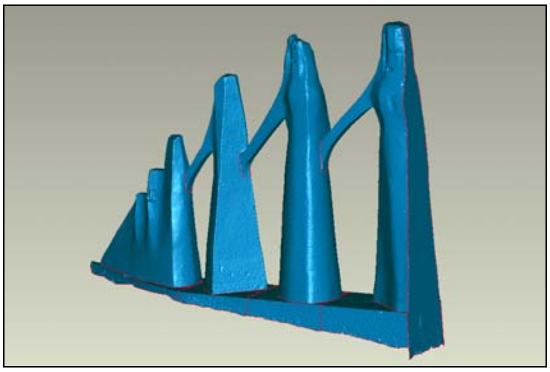

Figure 5. *The complete 3D model surface, ready for the texture mapping process*

In Figure 6 the workflow for producing a 3D model is presented. The three coloured areas denote the main tasks, i.e. 3D processing of the point clouds (red area), Photogrammetric processing of the raw imagery data (blue area) and texture mapping (grey area).

Texturing occurred with the help of Topcon's Image Master software, where suitably acquired images were directly oriented and mapped onto the already produced 3D model (Figure 7).

The main problems in this task are

- occlusions, i.e. areas non imaged, or not properly imaged,
- shadows, i.e. areas where details are not imaged because of adverse lighting conditions,
- non-orientable images, i.e. images whose orientation is not possible, despite the adequate number of control points
- stretched areas, i.e. areas where colour information from the available images is not sufficient
- gaps, i.e. cases where there is no image information at all and
- interoperability issues, i.e. difficulties arising from the necessity of using many different pieces of software, which require file compatibility

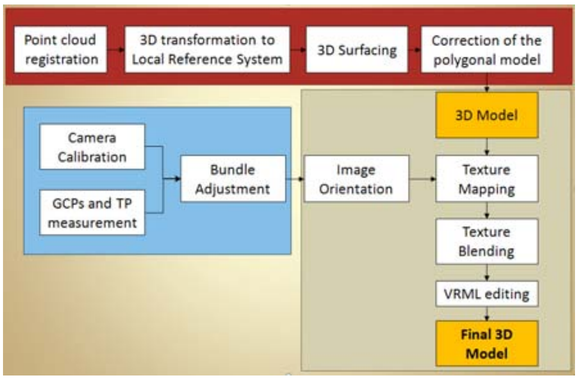

Figure 6. *The 3D model production Workflow*

5. Virtual Restoration

Scientists involved in restoration are greatly facilitated with a 3D model, since they may immediately obtain various kinds of information by measuring various distances, areas, volumes, by creating cross-sections, outlines or even by formulating and adding missing parts. However, in cases where the formulation and addition of 3D data is desired different methods and algorithms are required. This was also the case for the monument of Zalongon, where the upper parts of the two tallest figures were almost destroyed. In this case although the area of interest was acquired by the laser scanner, the amount and quality of information was not considered to be adequate and these areas where photogrammetrically processed in detail with special images acquired from a close distance, when the scaffoldings were built.

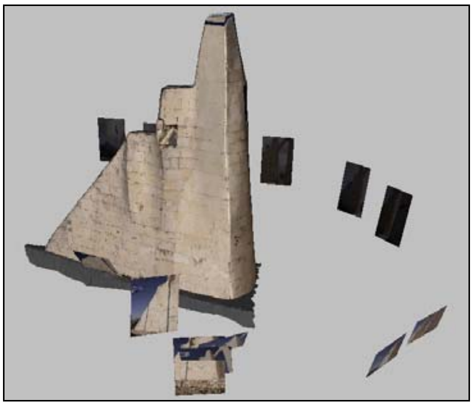

Figure 7. A snapshot of the program during the texture mapping process and a result for part of the model

Efforts were concentrated to completely restore the original surface in a virtual way. In order to obtain a better result, it was preferred to have a sculptor, create a 1:5 model of the missing area based on existing old photos and drawings by the original artist. This was done on a physical model produced based on the 3D model created.

The new plaster models were scanned with an XYZRGB SL2 structured light scanner and the data acquired were registered in the GSI software. In Figure 8 the XYZRGB scanner setup is presented. The final mesh was exported, appropriately scaled and registered with the original laser scanner data in Geomagic software. In Figure 9 the new surface model is presented in combination with the original photogrammetric and laser scanner data.

Figure 8. XYZRGB structured light scanner setup for the acquisition of data for the plaster model

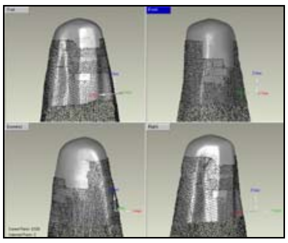

Figure 9. The new surface model integrated with the original photogrammetric and laser scanner data

6. Concluding remarks

In order to create a 3D textured model for the Zalongon monument sustaining a certain level of accuracy, the application of advanced data acquisition and processing techniques, such as geodetic, photogrammetric, scanning, programming, surfacing, modeling, texturing and mosaicking processes have been combined. The creation of high resolution textured 3D models is undoubtedly a non-trivial task.

For achieving virtual interaction, such as e.g. restoration, the basic steps to be followed are identify the destroyed parts, interact with the 3D model, extract the geometry of the parts to be restored, insert them virtually into the 3D model and finally assess the result, before final decision

In the present case the main points of interest were of course the destroyed heads, but there were also many other damages to be restored, e.g. missing stones, cracks etc.

Figure 10. *The virtually restored model fully rendered*

It has been shown that the production of hi-res polygon textured 3D models is still a challenging process, but a very important product for restoration work nowadays. At the same time the level of interaction with these models through freeware is quite low as they may be efficiently handled only by commercial, and expensive, software. Engineering applications require CAD or CAD-like data, whereby it is still difficult to retain and take advantage of the colour. Finally, contemporary methods have proven to be very helpful for restoration works if exploited carefully.

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References

VALANIS, A., IOANNIDIS, C., 2008. Markless registration for scans of free-form objects. In: *Proceedings (Full Papers) of the 14th International Conference on Virtual Systems and MultiMedia (VSMM) dedicated on Digital Heritage*, Limassol, Cyprus, pp.24-31.

VALANIS, A., TAPINAKI, S., GEORGOPOULOS, A., IOANNIDIS, C., 2009. High resolution textured models for engineering applications. In *Proceedings 22nd CIPA Symposium, October 11-15, 2009, Kyoto, Japan*