

## DIGITAL DOCUMENTATION OF MONUMENTS OF NATURAL BEAUTY: A CASE STUDY

E. Stylianidis

Aristotle University of Thessaloniki, School of Engineering, Department of Rural and Surveying Engineering,  
Thessaloniki, Greece – [stratos@geoimaging.com.cy](mailto:stratos@geoimaging.com.cy)

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### ABSTRACT:

Monuments of natural beauty are protected by international treaties similarly to cultural heritage objects. Some of them need to be preserved due to abandonment and other need to be protected due to a range of reasons, like for example structural or geological. The paper presents a case study of 3D documentation of a rock cliff, which is protected as a monument of natural beauty. In specific, the rock suffers from stability problems and thus its accurate 3D documentation is in urgent need. Digital photogrammetric techniques combined with laser scanning campaign are used in order to perform an accurate 3D reconstruction and monitoring analysis. The specific problems encountered, the methodology used, the produced outcomes and the related studies for stability assessment are presented and discussed.

## 1. INTRODUCTION

### 1.1 General

The documentation of monuments, speaking in a wider view, is a topic with an interdisciplinary character that extensively takes into concern by the scientific community. The different disciplines that are involved in such topics like for example Photogrammetry, GIS, IT, etc. provided the opportunity for a multilevel approach in the area of recording and documenting any view or subject that is related with the monument.

The paper illustrates the role of photogrammetry and laser scanning for the digital documentation and reconstruction of a monument of natural beauty: the rock cliff at the Episkopi village, a small village at the Pafos district, Cyprus. The rock has a total length of 260 meters and a height of 60 meters.

In addition, the paper describes the digital recording of the rock cliff and an overview of the use of photogrammetry and laser scanning in such projects. This hybrid approach which is discussed is a powerful approach where under conditions may provide excellent results.

Photogrammetry is based on the three-dimensional data collection from two or more images. The multiple images provide both geometric information and surface texture for any kind of object that presented on the images. The effectiveness of photogrammetric data could significantly get better while using digital image processing tools. The development of laser scanning gives a new standard for the collection of 3D data. It is of great importance that these instruments give the opportunity for the quick and accurate acquisition of millions of 3D points (point clouds).

Regardless of the substantial developments of these systems, we still face some restrictions, which mainly have an effect to the quality and accuracy of the final products. But this has to do

only with the real needs and the scale of the documentation process.

Although existing laser scanners have the capability to collect huge amount of points in a quick, easy and accurate way, the resolution of the point clouds are still not enough, mainly in cases where the objects appear with linear features and edges which have to be collected and mapped. On the other hand, photogrammetry is surely more accurate in outline interpretation and restitution, if these features are clearly illustrated on the images. Furthermore, the points are detected and measured manually or semi-automatic and this option requires a long time, especially in cases where a huge number of points is needed to represent the object.

In this paper we are approaching the issue by combining photogrammetry and laser scanning in order to produce high quality products; an accurate geometry and high visual quality of the 3D reconstructed object.

### 1.2 Motivation

The recording and documentation of monuments of natural beauty in most of the cases comprises a large number of challenging tasks. Firstly, the comprehensive and thoroughly detailed requirements and technical specifications are necessary in order to achieve the high quality of the results. In addition, quality standards have to be prepared, so as to define the base for the selection of the equipment. The technical specifications which are of great significance for the subsequent steps normally have to be prepared in close collaboration between persons having different specialized background, like for example in the current case between surveyors, civil engineers and geologists.

In the project that paper refers, one of the main reasons for the documentation was real need to prepare an integrated study for the structural and tectonic analysis of the rock. For many years the rock is suffering from sliding and structural pathologies and

a decision for the stabilization of the rock was taken from the relevant public and local authorities.

The cooperation between surveyors, civil engineers and geologists was necessary. The effort of our team focused on the detailed mapping and documentation of the rock through the use of digital photogrammetry and laser scanning. Time was also a critical parameter not only due to the pressure of public and local authorities but also for reasons related to the safety of the village.

The results of the project, i.e. of our effort, are of great interest due to the fact that have been used by geologists and structural engineers, within a wider project dedicated to the stabilization of the rock cliff that suffers from sliding and other types of structural pathologies.



Figure 1. The rock cliff at Episkopi village

## 2. DATA ACQUISITION

The data acquisition concerns three different sections: (a) data from topographic measurements in order to establish the control points' network on the object, (b) data from laser scanning campaign and (c) acquisition of high resolution images for photogrammetric processing.

### 2.1 Topographic measurements

The definition of a network of control points on the object, with coordinates refer in a local reference system was necessary in order to realise a stereoscopic view and restitution of important geological structures.

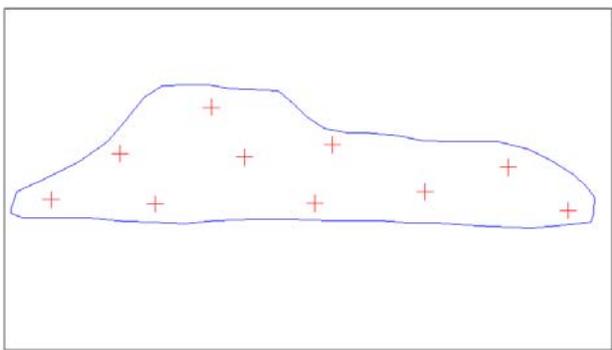


Figure 2. The control points' network on the rock cliff

A typical topographic survey using intersection method was performed by handling a total station (accuracy of angular measurements 5" and  $\pm 2\text{mm} \pm 2\text{ppm}$  in distance). The total station has the capability to work in a reflectorless mode.

Ten (10) points (Figure 2) regularly distributed to cover the whole area of the rock cliff were measured with a redundant number of readings. These control points were used to establish the reference system in order to be used for the image stereo-pairs processing. The least squares adjustment provided a result for point accuracy at 2cm (95% confidence level). The coordinate system which was defined under this procedure established the appropriate georeference of the point cloud obtained with the laser scanner.

One of the most difficult parts during the data acquisition was the identification of natural control points. The rock cliff was unreachable for safety reasons and thus non-signalized points should have been selected for photogrammetric processing. It was not only the difficulty to recognize them on the field but also in the digital images during the processing. For this reason an on-line portable system was used for downloading images in the laptop and though a visual cross-check between screen and "natural view" through total station lens we were choosing the appropriate control points.

### 2.2 Laser scanning campaign

The Mensi GS200 laser scanning system was used for the acquisition of point clouds. The scanner has a rotating head and two internal high speed rotating mirrors that allow the acquisition of a scene with a wide field of view, i.e.  $360^\circ$  H x  $60^\circ$  V, reducing the need for a large number of scanning stations. The accuracy of this scanning system can reach down to 1.5mm at a distance of 50m with a beam diameter of 3mm at a distance of 50m as well. Furthermore, the laser, except X, Y and Z coordinates is able to capture the reflected beam intensity and RGB colours.



Figure 3. Mensi GS200 laser scanner

The Mensi GS200 laser scanner (Figure 3) has an on board video camera with low resolution characteristics, i.e. the video camera can capture colour images at a resolution of  $768 \times 576$  pixels. This resolution is extremely low for the production of high accuracy photogrammetric products. For this reason, a high resolution camera, the Canon EOS 350D SLR was used to overcome the low resolution on board video products captured by the laser scanning system.

The laser scanning campaign needs an operator that handles the system and defines each one of the scanning windows in order to collect the point clouds. This scanning window is a critical

parameter during the scanning procedure because it is restricted by:

- The field of view of the lens system; depends on which region of the view the system points and
- Any possible occlusions of the laser or the camera which is mounted on the laser scanner system.

### 2.3 Photogrammetric data acquisition

The photogrammetric images were taken independent of laser scanning campaign. From each location, images were taken using the Canon EOS 350D (Figure 4).

The Canon EOS 350D has a 22.2 x 14.8 mm CMOS, 8.0 million effective pixels and focal length of  $c=50\text{mm}$ . The mean shooting distance from the rock was around 75m. For this reason the mean scale of the images was 1:1.500 and thus the accuracy of pixel is ground coordinates was around 1cm.



Figure 4. Canon EOS350D

Image acquisition has been realized from a smooth hill in front of the rock hill. In Figure 5 indicative illustrations from the image acquisition campaign are given. Around ten (10) images have been obtained in a convergence arrangement for further photogrammetric processing.



Figure 5. Images of the rock for photogrammetric processing

## 3. PROCESSING AND PRODUCTION

### 3.1 General

In projects with multi-thematic characteristics there are scientists that are more familiar with the mapping and documentation of objects by means of traditional techniques, like for example conventional surveying. On the other hand collaboration with professionals that are using edge-technology and novel techniques initiated from photogrammetry, laser scanning or GPS is more fascinated and gives better results and more attractive products.

The 3D reconstruction and visualization techniques provide the necessary tools for the creation of a «real» representation of the object. Many different visualization processes exist; CAD drawings, GIS systems, 3D representations, animations and fly/walkthroughs or even stereoscopic representations in virtual reality applications.

The representation of the rock must make provide sufficient geometry and effectively detailed textures so as to be examined by the engineers. On the other hand, the 3D representation must be «light» enough, so as to manageable in interactive viewing by the experts.

### 3.2 Point clouds processing

Merging point data which are collected from terrestrial laser scanners can be located in both data sets. Nevertheless, in order to merge two or more data sets, these must have at least some common targets. This is always the case in close range photogrammetric problems.

Thus, in order to align and combine the multiple point clouds captured from the different stations, the Realworks software was used. For this reason, referenced and well-defined reflector targets (Figure 6) were used to merge the multiple point clouds.

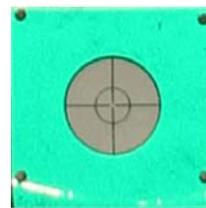


Figure 6. Signalized target

All signalized points located in distinct areas, with optimum geometry, around the object where it was possible to be observed by at least two different scan stations. In addition, the signalized points were registered in the local coordinate system.

The unified point cloud became by the merging of 4 different scans from equal in number stations. Even though the size of the point cloud data for the 3D model of the rock was huge, a unified model was setup.

In the following step, the “noisy” (for instance trees, pylons etc.) points were detached from the cloud in order to make the processing of the rock-model easier and produce the optimum representation for the study object.

The next figure (Figure7) shows the entire point cloud of the rock cliff after the removal of the noise. This gives a very good impression for the situation and the status of the rock cliff.

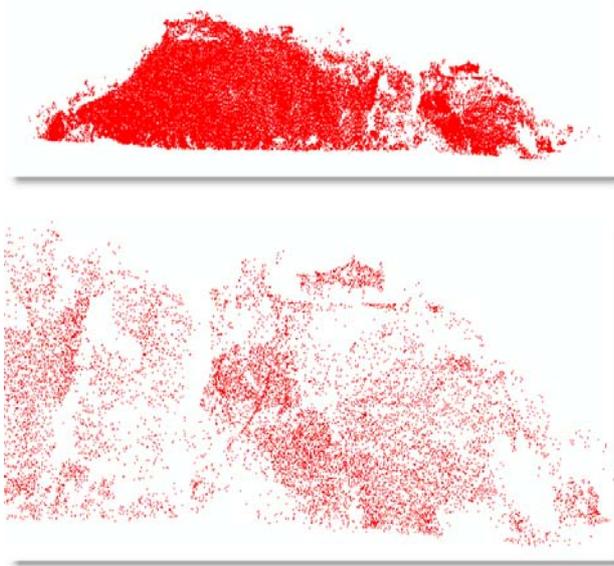


Figure 7. The entire point cloud data of the rock (up) and a zoom in the cloud (down)

Furthermore, processing at the point cloud can illustrate different approaches for the surface of the rock (Figure 8). During the project and for the needs of the engineers, some more products, as shown below, were prepared.

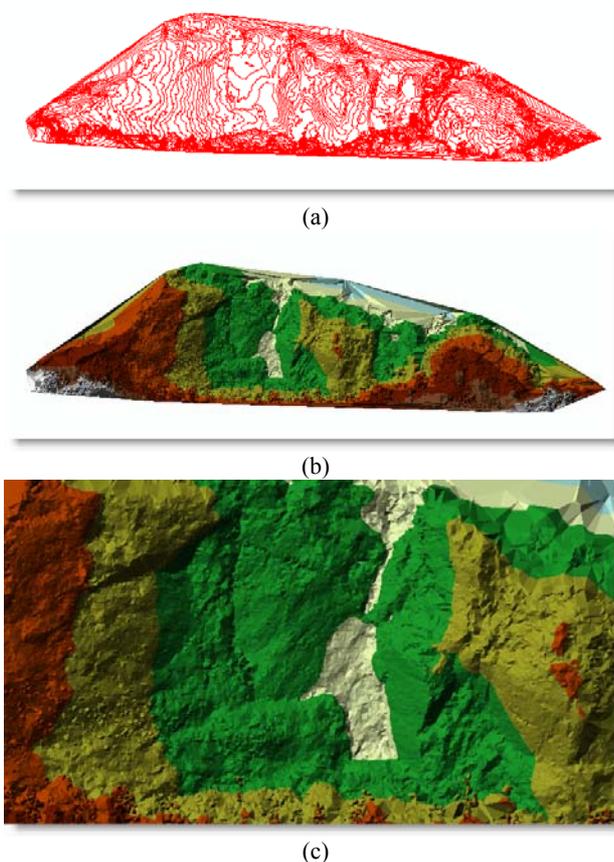


Figure 8. The contours (a) of the rock and the TIN model (b,c)

### 3.3 Texture mapping – 3D model

Normally, the images acquired by the laser scanner are in very low resolution and their quality is inadequate for such projects. It is well known, that the coloured images collected by the laser scanner are in a resolution of 768 x 576 (colour resolution) in case of the Mensi G200 laser scanner.



Figure 9. Texture mapping of the rock cliff

For this reason, other techniques are following to enhance the illustration of the recorded object; for example either the texture mapping or the point clouds with the use of colour per vertex. Because of the dense arrangement of the point within the

clouds, the point-based rendering and modelling is feasible but still covers only specific needs. The point-based modelling and rendering point clouds is a simple and smart solution due to the reduction of the amount of data used. These approaches mostly preferred in cases of internet portals, virtual museums or e-libraries.

The need to enhance the quality of the colour information given by the low resolution colour images of the laser scanner, led to the use of high resolution images acquired by Cannon EOS 350D SLR. Every single image was processed with the use of a corresponding 3D image.

This is feasible if more than six (6) points, both in the high resolution image and the image acquired by the laser scanner are matched. The matching process was done using the Realworks software. The example of three images in Figure 9 gives a representative illustration of the rock cliff according to the above mentioned technique.

### 3.4 Photogrammetric image processing

#### 3.4.1 Orthoimages

For the production of the rock's orthoimage three key factors are necessary:

- The interior orientation of the images and the calibration model (if necessary)
- The exterior orientation of the images according to the local reference system and
- The DTM of the rock cliff which has been created by laser scanning.

Following a typical batch process for orthoimage production we may reach to results like the ones presented in the following figure (Figure 10).

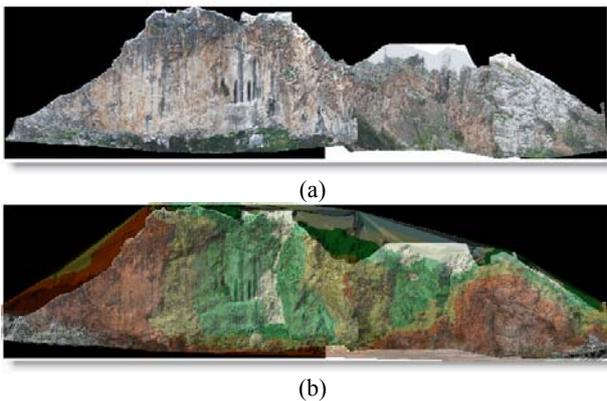


Figure 10. The orthoimage (a) of the rock and the orthoimage superimposed with the TIN model (b)

### 3.5 Additional products

Due to the nature of the project, few more products were created to help the geologists and the structural engineers. One of these products is the topographic survey of the surrounding area as presented on Figure 11. In addition to this, 13 cross sections in specific locations where selected to be drawn. An indicative example of these sections is given on Figure 12.

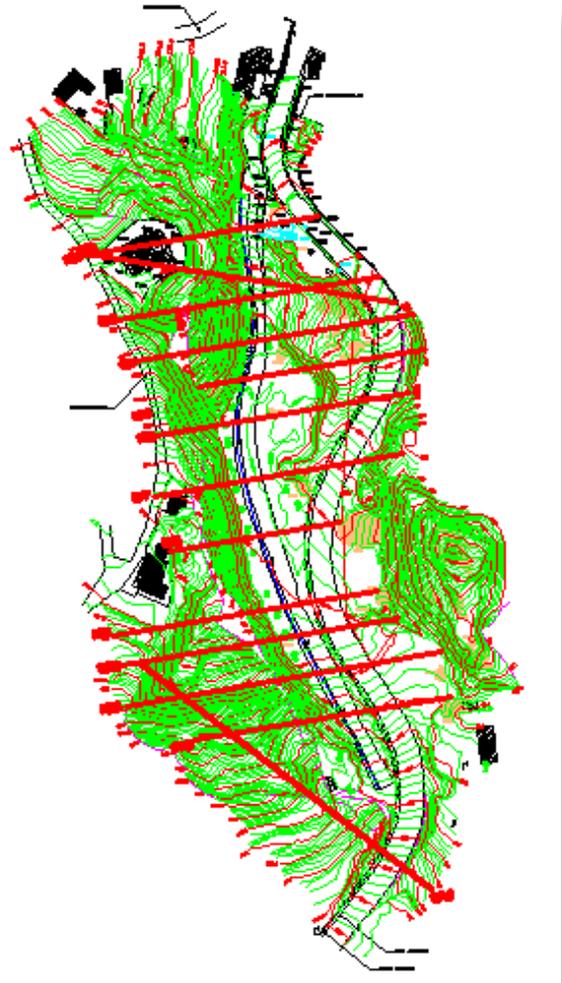


Figure 11. Plan view of the area surrounding the rock cliff

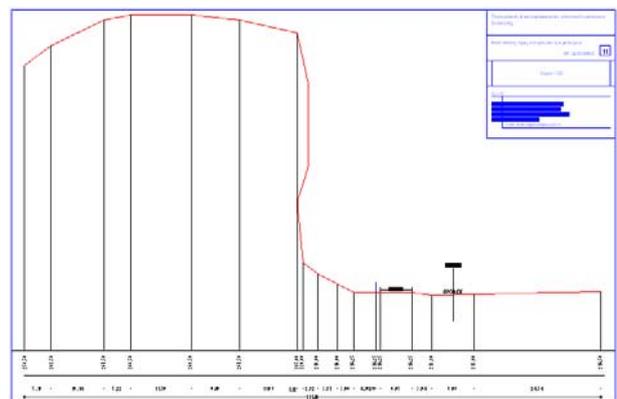


Figure 12. Cross section

Finally, a fly-through video of the rock cliff and the surroundings was produced in order to provide an attractive communication tool for the representation of the natural monument.

## 4. CONCLUSIONS

Photogrammetry gives well-designed scientific measurement tools for mapping and documenting objects which are of great interest. Although the hybrid approach of photogrammetric and

laser scanning techniques can deliver attractive visual types of products in a faster, accurate and fascinated way.

## 5. ACKNOWLEDGEMENTS

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