Proceedings of the 8th International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation 'ARQUEOLÓGICA 2.0' in Valencia (Spain), Sept. 5 – 7, 2016

COMBINING STRUCTURE FROM MOTION TECHNIQUES WITH LOW COST EQUIPMENT FOR A COMPLETE 3D RECONSTRUCTION OF A 13TH CENTURY CHURCH

THE CASE OF TRANSFORMATION OF THE SAVIOUR CHURCH IN MESKLA, IN CRETE ISLAND

Panagiotis Parthenios, Theano Androulaki[*], Evangelia Gereoudaki, Giorgos Vidalis

School of Architecture, Technical University of Crete Campus, Kounoupidiana, 73100, Chania, Greece. parthenios@gmail.com; theano.and@gmail.com; elizagere@gmail.com; g.d.vidalis@gmail.com

Abstract:

The use of 3D digitization and modelling in documenting heritage sites has increased significantly over the past few years. This paper presents the process of a monument's virtual 3D reconstruction using Structure from Motion techniques with common, user friendly, low cost equipment. The byzantine church of the Transformation of the Saviour in Meskla, Crete, aged back to the 13th c., has been photographed by two student groups and the two models were merged into one unified 3D scene.The detailed and high quality products of the 3D modelling can be used for educational and research purposes but also for the touristic promotion of the area through light, easy to use, 3D visualizations on the web.

Palabras clave: virtual archaeology, structure from motion, cultural heritage, documentation, 3D reconstruction

1. Introduction

1.1. Team and objective of research

The following research was realised during the postgraduate programme "Space, Design and Built Environment: Integrated conservation of historical built environment with advanced technology and materials", in the School of Architecture in Technical University of Crete for the documentation and the production of digital 3D models of a byzantine church through automatic photogrammetric software. The aim is the use of the 3D models for educational, touristic and research development in Cultural Heritage.

1.2. Historical information

The church is dedicated to the feast of the Transformation of the Saviour, lies at the northern part of the Meskla settlement, ca. 20 Km SW of Chania, in Crete Island. The ground-plan of the monument displays a typical example of a small single-aisled church, thus an architectural form that was very popular on the island of Crete during the era of the Venetian occupation. The iconographical programme of the church follows the typical concept of the single-aisled fresco painted churches of Crete. The church was initially erected in the middle of the 13th c. as it is implied by the first layer of frescoes that was discovered at the apsis. As it is concluded by the dedicatory inscription, the church was renewed and re-painted on the 15th of May 1303 by the painters *Theodoros-Daniel and Michael Veneris*.

1.3. Existing similar work

The use of 3D digitization and modelling in documenting heritage sites and monuments has increased significantly over the past few years. This is mainly due to advances in Laser scanning techniques, 3D modelling software, image-based-modelling techniques, computer power and virtual reality. There are many approaches currently available. Some examples of scanned cultural heritage models are developed at the following projects: The Digital Michelangelo Project: 3D Scanning of Large Statues, Three modes of a monument's 3D Virtual Reconstruction and The Cultural Electronic Network Online(http://cenobium.isti.cnr.it/).

2. Process, tools and methodology

2.1. Existing software research

The starting point of the research was the investigation of the available software, that offers the possibility to process image data and generate 3D model data via common, user friendly, low cost equipment. Photosynth, Autodesk 123D Catch, Agisoft Photoscan software were used.

[*] Corresponding Author: Theano Androulaki, theano.and@gmail.com

2.2. Work on site

Two teams were formed, to photoscan the interior and exterior of the monument, following the CIPA 3x3 rules.The photo sets required sufficient overlap areas, in order to combine later the 2 outcomes in one file.Team A photographed the interior with a digital camera, model Canon EOS 450D (Fig.1) and team B the exterior with an Olympus E 330. Low ISO setting is needed to avoid the production of image noise. No flash was used because it introduces abrupt local exposure variation, leading to errors during point cloud processing.

Figure 1: Process of photoshooting in the church.

Team A: The lighting conditions in the interior were poor. In order to take the proper photos, the interior space was photographed using a tripod and three headlamp lights. The lights were placed on the floor to achieve the sufficient level of light for the roof and the dark corners. The goal was the detailed and high quality images of the wall and roof paintings. Team B: The photo shooting included shots around the church and the roof (Table 1).

Table 1: Camera's settings

Setting	*Team A*	*Team B*
ISO	100	100
Focal length (mm)	18-55	14
Aperture	F/3.5 - F/5.6	F/ 5.6 - F/ 8.00
Exposure time	1/25 - 1.6	1/80 - 1/160

Furthermore, the overall length of the church's facade and the door opening were measured, in order to bring the resulted models into the right scale.

2.3. Agisoft Photoscan

The data processing was executed in the PC's of the Digital Media Lab at the School of Architecture, using Agisoft Photoscan software. The procedure would outpout two different point clouds and models that would be combined into one file. The workflow followed four steps: Align photos, Build Dense Cloud, Build Mesh, Build Texture. The products of the process were two 3D models, interior and exterior (Figs. 2 and 3). The files sizes are 512 Mb of the interior and 77 Mb of the exterior. According to the settings of the workflow different sized files can be produced, depending on the preferable use and desired quality (Table 2). A lower quality, smaller file size would be more appropriate for internet applications, while a higher quality, larger file size with higher level of detail could be used for further research, such as studying the frescos, or inspecting the monument's pathology (eg. through its inelastic dynamic response).

Figure 2: Exterior view of the church's 3D model.

Figure 3: High precision view of a wall painting of the 3D model's interior.

3. Import and assembly in 3ds Max

The 3D files exported from Agisoft were a file with obj format and a jpeg image of the texture. The obj file was imported in 3ds Max. Each file was rescaled. The adjustment of the scale was realised manually according to the measurements of the facade. The coordinate system of the 3D models was also manually repositioned. The rescaled models were merged. Using the large size files from Agisoft the merged obj model in 3ds max was 256 Mb. Even though the professional version of Agisoft would have been able to provide accurate scaling and georeferenced positioning, the scope of this study was to use only free tools, thus due to using the Standard edition we had to perform these manually, based on physical measurings. This method proved adequate for the purpose of our study.The total model was rendered as it was, with no additional lights, using default settings producing high accuracy images of both the interior and exterior.

Table 2: Agisoft Photoscan settings and results

Workflow	*INTERIOR*	*EXTERIOR*
Align photos	269 images	55 images
Accuracy: High		
Pair selection: Disabled	Est. Time 180 min	Est. Time 6 min
Advanced Settings: Default Values		
Point Cloud Output:	136,282 points	44,351 points
Build Dense Cloud		
Quality: Medium	Est. Time 90 min	Est. Time 10 min
Depth Filtering :Aggressive		
Dense Point Cloud Output:	48,789,557 points	2,920,700 points
Build Mesh		
Surface Type: Arbritary		
Source Data: Dense Cloud	Est. Time	Est. Time 3 min
Face Count : Medium	130 min	
Interpolation:Disabled		
Mesh Output:	2,288,685 faces	136,870 faces
Build Texture		
Mapping Mode: Generic		
Blending mode: Mosaic	Est. Time 5 min	Est. Time 25 sec
Texture size/count: 6.000x1		

4. Issues

During the whole process a number of issues arose. Team A, responsible for the interior, faced several lighting problems. In addition to the headlights placed on the floor, the two doors of the church had to be open during the photoshooting in order to light also with the natural daylight. This caused problems to the merge of the interior and exterior model at the openings creating noise around them. Team B, responsible for the exterior faced several problems during the photographing process. The surrounding area didn't offer the proper perspective to photograph the roof. As a result the exterior 3D model produced in Agisoft was produced with several gaps on the roof as the photos weren't correctly overlapped. Team B tried to shoot from a higher level using a ladder but the gradient of the surroundings wouldn't help. To solve this problem the team is in the process of using a drone. During the process of the union in 3ds Max, noise from the exterior model was placed in the interior and vise versa, so it had to be removed.

5. Internet applications

The resulted 3D model of the church's interior and exterior space was exported successfully to WebGL (Fig. 4) and is available to be viewed on the web without the need of any special software or plugin under the following address: https://skfb.ly/NnNR

Figure 4: Use of the Oculus in the lab.

6. Results – Evaluation

This method proved to be a fast, low cost and flexible technique of 3D modelling which can potentially be used for digital documentation by people with no technical background.

This practice allows a full and detailed compilation of data referring to the monument and a complete 3D model which can be edited from distance. The accuracy and precision of the results are remarkable and allow further use of the 3D models for recording and visualization of detailed wall paintings and in order to study the pathology and the structural behavior of monuments. The products of the 3D modelling can be used for educational and research purposes but also for the touristic promotion of the area.

Acknowledgements

We would like to thank Ephorate of Antiquities of Chania for their help during the study of the byzantine church of the Transformation of the Savior in Meskla and the students of the class: Androulaki Theano, Gereoudaki Evangelia, Vidalis Giorgos, Digalaki Tatiana-Christi, Ntoura Magdalini, Chadjidakis Giorgos and Spyrou Eleytherios.

References

AGISOFT LLC, 2011. AgiSoft PhotoScan User Manual: Standard Edition, Version 0.8.4. AgiSoft LLC

BILA, Z., REZNICEK, J. and PAVELKA, K., 2013. Range and Panoramic Image Fusion Into a Textured Range Image For Cultural Heritage Documentation, *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume II-5/W1, 2013 XXIV International CIPA Symposium*, 2 – 6 September 2013, Strasbourg, France

EL-HAKIM, S., BERALDIN, J.A. and PICARD, M., 2002. Detailed 3D Reconstruction of Monuments Using Multiple Techniques, *published in Proceedings of the Intern. Workshop on Scanning for Cultural Heritage Recording - Complementing or Replacing Photogrammetry*,.September 01-02, 2002.Corfu, Greece pp.58-64.NRC 44915.

PARTHENIOS, P., PETINARELIS, A., LOUSA, S. and EFRAIMIDOU, N., 2015. Three modes of a monument's 3D Virtual Reconstruction. The case of GialiTzamisi in Chania, Crete, *2015 Digital Heritage International Congress*, Granada, Spain, pp. 75-78.(DOI: 10.1109/DigitalHeritage.2015.7413838 Conference: 2015 Digital Heritage)

REMONDINO, F., EL-HAKIM, S., GIRARDI, S., RIZZI, A., BENEDETTI, S. and GONZO, L., 2009. 3D virtual reconstruction and visualization of complexarchitectures – the “3D-Arch” project Proceedings of the ISPRS Working Group V/4 Workshop 3D-ARCH "Virtual

SCOPIGNO, R., CALLIERI, M., CIGNON, P., CORSINI M., DELLEPIANE, M., PONCHIO, F. and RANZUGLIA, G., 2011. 3D Models for CH: Beyond Plain Visualization, ISTI-CNR,pp. 48-55.Issue No.07 - July (2011 vol.44)pp: 48-55

PHOTOSCAN AGISOFT, http://www.agisoft.ru (5/24/2016)