

Three modes of a monument's 3D Virtual Reconstruction

The case of Giali Tzamissi in Chania, Crete

Panagiotis Parthenios

School of Architectural Engineering
Technical University of Crete, Greece
parthenios@arch.tuc.gr

Sofia Lousa

School of Architectural Engineering
Technical University of Crete, Greece
sofialousa@yahoo.gr

Alexandros Petinarelis

School of Architectural Engineering
Technical University of Crete, Greece
apetinarelis@isc.tuc.gr

Nicky Efraimidou

School of Architectural Engineering
Technical University of Crete, Greece
nicky_efraimidou@yahoo.com

Abstract— The scope of this paper is to highlight the challenges, advantages and disadvantages, as well as solutions to some of the issues that arise during the process of a monument's virtual 3D reconstruction using Structure from Motion (SfM) techniques. Yali Tzamisi, a 17th century monument located in Chania, Crete, has been photographed appropriately by three separate student groups, one for the building's envelope, one for the building's interior space and one for the surroundings of the monument. Different levels of detail and various file formats have been documented according to their scope of use, before the three models were merged into one unified 3D scene.

Index Terms— Virtual, 3D, reconstruction, point clouds

I. INTRODUCTION

The following research was realized during the first semester of the academic year 2014-2015 in the School of Architecture of the Technical University of Crete, according to the curriculum of the Msc Postgraduate program "Architectural Space, Design and Build Environment". Two courses, "Advanced Digital Technologies" and "Information Technology and Cultural Heritage", were combined to encourage interdisciplinary research and joint results. The research focused in the creation of 3D digital geometry of the monument „Yali Tzamisi“ of the 17th century that is located in the city Chania of the island Crete, in Greece. YaliTzami Mosque or YialiTzamisi is a fine example of Islamic art of the Renaissance in Chania. It was the first mosque built in Crete after the Turkish conquest of the city of Chania in 1649, in honor of the first garrison commander of Chania, KüçükHasan. The monument was photographed, using consumer grade digital cameras and in combination with the appropriate computer software, without using any specialized equipment, a 3D mesh model was created. This procedure aimed to speculate and discover methodologies that could produce novel and innovative applications making use of 3D models and

3D point clouds, -the products of photographs and SfM software.

II. EXISTING SIMILAR WORK

A variety of studies focused on the technical advances in 3D recording using structure from motion (SfM) techniques and dense stereo-reconstruction algorithms in low-cost or open source computer vision based software packages[1]. Several researchers have combined GPS or Total station field recordings with image based modeling in archaeological surveys or in reconstruction and presentation of cultural heritage sites, buildings and artifacts [2]. Three case studies were studied and valuable conclusions were made which were taken into account in the process we developed: At the Great barn at Harmondsworth near London, a comparison was made between laser scanning and photogrammetric technique[3]. A similar comparison was made in the Zubarah fortress in Qatar [4]. In the case of the documentation of the mausoleum “Torre del Ballerino” [5], the photogrammetric system (Image Based Modeling) was used in conjunction with a classical survey method, that employ a total station.

III. HYPOTHESIS, PROCESS, TOOLS AND METHODOLOGY

The starting point of this research was the investigation of the available software, which offer the possibility to process image data and generate 3D model data. The first goal set, was to produce a small scale object 3D model, as the result of a set of photographs, using a list of selected available software. The software and the 3D model outputs were evaluated and this evaluation formed procedurally the rest of the research, setting new goals and making decisions that would form methodologies, according to the software potentials and the intuition of the research team. After these series of tests, the case

study was decided to be Yali Tzamisi, located in the Venetian Harbor of Chania. At this point, our main focus was to explore novel and innovative applications of the 3D point clouds and their 3D models, which were directly interrelated with the properties and the manipulation options of the produced 3D geometry. At the beginning of the research the following software were presented. These cover a wide range of options, when dealing with SfM (Structure from Motion), point clouds and mesh editing.

- Photosynth (www.photosynth.net/)
- Meshlab (meshlab.sourceforge.net/)
- ARC3D (www.arc3d.de/)
- Autodesk 123D Catch (www.123dapp.com/catch)
- Autodesk Recap (www.autodesk.com/products/recap)
- Agisoft Photoscan (<http://www.agisoft.com/>)
- Rapidform XOR (www.rapidform.com/products/xor)

Each student had to present a 3d model of a small scale object that was processed and edited. The purpose of this first mini assignment was to get acquainted with the software and to spot the pros and cons of each. Most students chose 123D Catch and Agisoft Photoscan for the 3d reconstruction and Rapidform Xor3 for the mesh editing. Finally Agisoft Photoscan and Rapidform Xor3 were chosen to be used for the Yali Tzamissi case study, because both offer flexible options, have friendly user interface and don't require that the user is specially skilled to use them. Another consideration was that Agisoft Photoscan does not require a cloud or remote server to compute the point cloud and 3d geometry, which is not an option, when dealing with sensitive, unpublished photos of cultural heritage.

Three teams were formed, each being responsible for an image data set. Team A documented the interior space, Team B the outside building envelope and Team C the surrounding area of Yali Tzamisi (Fig. 1). These photo sets required sufficient overlap areas, in order to combine later the 3 outcomes in one file. Each team used a different digital camera, without following Agisoft's suggested calibration procedure. Before

proceeding to the photograph sets the following requirements were to be met:

Cameras - Settings - Capturing strategy: Each set will be created with the same digital camera. Different cameras for the same photo set, would create uneven results, due to the different digital sensor color profiles etc. A different camera was used by each one of the 3 teams in order to test the tolerance of PhotoScan and verify that non experts could utilize the proposed method.

- Maximum resolution setting: Since Photoscan samples the pixels to estimate and construct a 3d point cloud, more pixels yield better point cloud and geometry representation.

- ISO setting of 100: Higher ISO settings produce image noise that leads to reprojection errors.

- TIFF or JPEG file format: The best option is to have TIFF files, since JPEG files are compressed introducing image noise.

- No flash: Flash introduces abrupt local exposure variation, leading to errors during point cloud processing.

- Capturing will be done according to Agisoft's recommendation: Each team developed a capturing strategy diagram (fig.2)

- No ground control points

- Images with sufficient overlap: There is not an explicit guideline for the number of the images. According to Agisoft "more than enough is better than not enough". The most important consideration is to have paired images, so that Photoscan's algorithm can produce many matching points and estimate with precision the depth in 3d space.

- In order to capture the vaults and the roofing of the building envelope aerial photography was considered using properly configured drones, but the solution of using a car crane was selected. This method allowed us to obtain higher resolution photos, compared to the camera we could mount to a drone, but the shortcoming was the limited positions that could be provided by the crane.

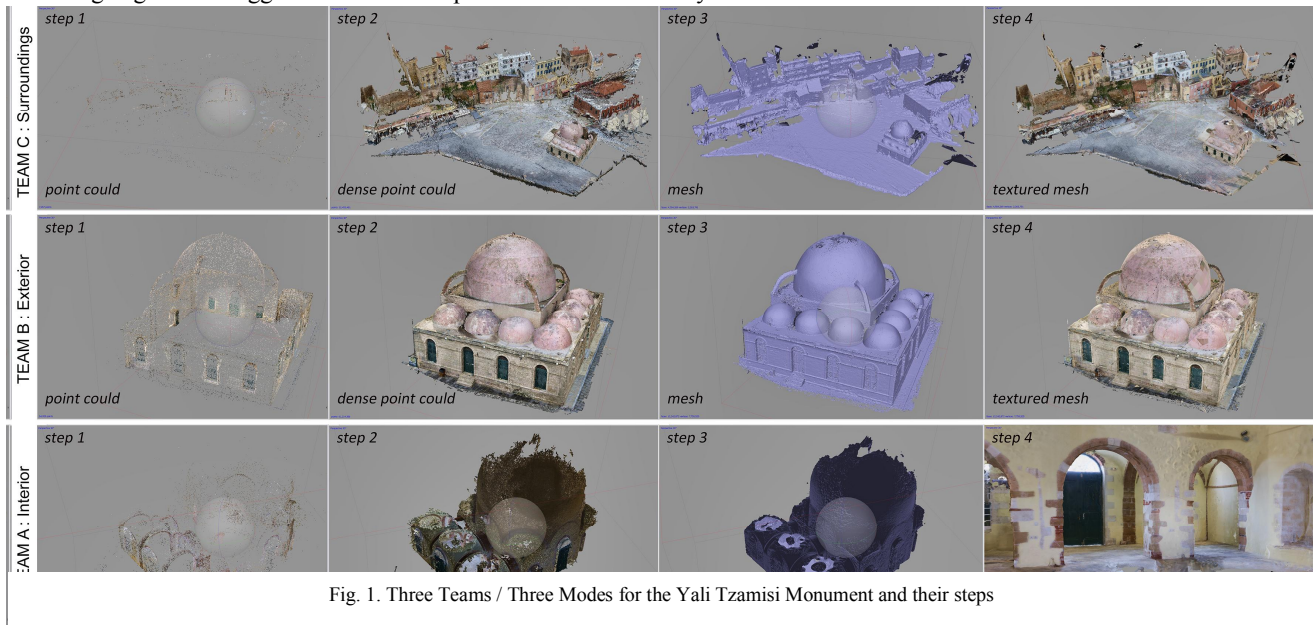


Fig. 1. Three Teams / Three Modes for the Yali Tzamisi Monument and their steps

IV. AGISOFT PHOTOSCAN

This procedure would output 3 different point clouds and models, which would be combined into one file (Fig. 2). The registration elements are geometries found in overlapping areas, between the three sets. Before proceeding with Agisoft's 4 step workflow, 1.Align Photos, 2.Build Dense Cloud, 3.Build Mesh, 4. Build Texture, all teams masked the photos so that unwanted pixels would not be part of the calculations, in order to reduce the output artifacts and calculation time, as also to remove irrelevant objects.

The above data processing was executed in the PCs found in the Digital Media Lab at the School of Architectural Engineering, Technical University of Crete. Team C took advantage of Agisoft's Cluster processing option, which distributes calculations into several computer nodes, after setting up a server and the nodes at the PC, according to the specifications provided by Agisoft.(version 1.1.2.built 2014) The 3D mesh models were exported in .obj format, along with the .mtl file storing the texture coordinates and the texture in PNG format. The 3D point clouds were exported in various formats, in order to test the mesh reconstruction algorithms of Rapidform XOR3. Both the reconstruction and the mesh editing proved to be impossible for such large files, in contrast to the small objects that were tested during the mini assignment. So the various resolution options were handled eventually exclusively in Photoscan, using the decimate Mesh tool. This procedure made clear that, when opting for a small resolution mesh, or point cloud, the settings of the Build Dense cloud step must be set accordingly. If the Dense point cloud has been derived from high quality settings, the build mesh step, even in medium or low setting, failed to complete, due to RAM shortage, as the decimation of the mesh and point cloud has to preload a massive amount of pre-calculated dense points, in order to reconstruct the geometry. The scale and registration between the three models was done using reference known distances and objects found in all the 3D models overlap areas.

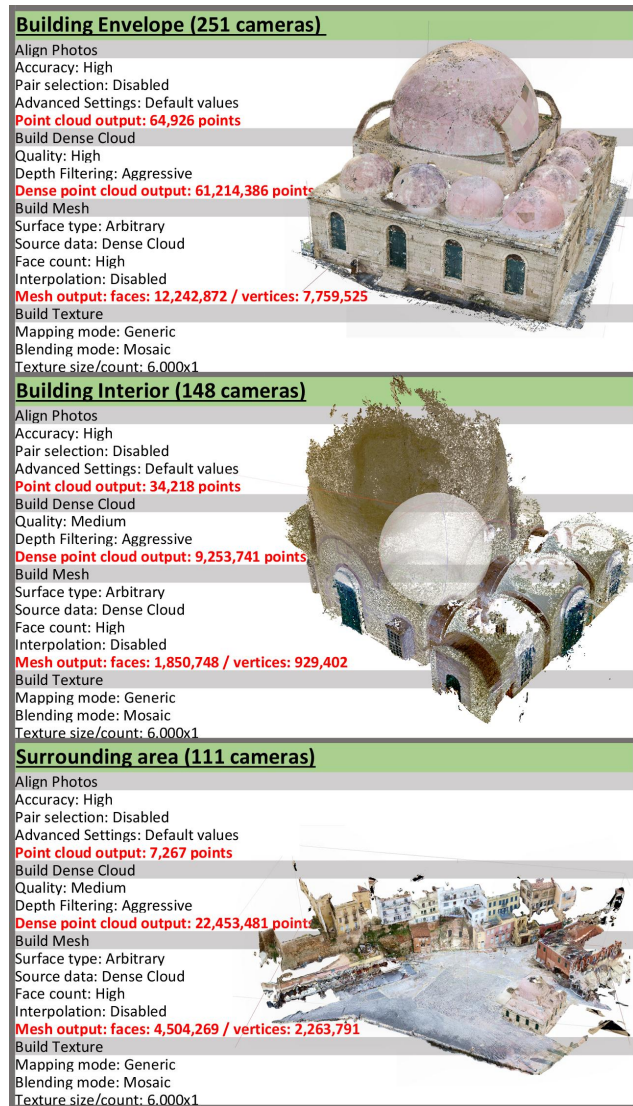


Fig. 2. Data from the 3 Modes of the Yali Tzamisi Monument

File Formats	Exterior	Interior	Surroundings
Agisoft	862 MB (high quality)	34 MB (m.q.)	319 MB
Agisoft optimized	555 MB (decimated)	312 MB (u.h.q.)	266 MB
.obj	1,500 MB (raw)	4 MB (m.q.)	143 MB
.3ds	560 MB (decimated)	40 MB (m.q.)	143 MB
	137 MB (agisoft export from decimated)	396 MB (u.h.q.)	51 MB
		14 MB (m.q.)	
3dsMax (from .3ds)	224 MB	134 MB (u.h.q.)	92 MB
		27 MB (m.q.-no textures)	
		241 MB (u.h.q.-no textures)	
3dsMax (from .obj)	750 MB (decimated)	25 MB (m.q.)	88 MB
		232 MB (u.h.q.)	
Rhino	250 MB (decimated)	20 MB (m.q.)	119 MB
SketchUp (from .3ds)		148 MB (u.h.q.)	321 MB
		218 MB (m.q.)	

m.q. = medium quality | u.h.q. = ultra high quality

Fig. 3. Different file formats and sizes of the 3 Modes of the Yali Tzamisi Monument

V. ISSUES

During the whole process a number of issues arose, the most interesting of which are the following:

Team A, responsible for the interior, took the photos in poor lighting conditions, that introduced excessive digital image noise. The amount of light available, resulted in the following step, a model with „holes“. In addition weather conditions affected the process. Because of the repetitive winter rain, water entered the monument, introducing shining areas that troubled the specifically the floor 3D reconstruction procedure. The team had to conduct multiple photo sessions, in order to overcome these challenges.

Another challenge were the vaults, for Team A and Team B. Team A had trouble documenting the vault geometry. The first interior photo set, imported to Photoscan, could not produce a 3D point cloud that could form the vault. Team A resolve this issue by adding small colored sticker, as registration and reference points. That made possible the identification of the vault's 3D depth. Team B had incomplete vaults geometry, due to the some blind spots, that could not be photographed with the car crane, but also because of pigeons, that like to hang out on the big vault.

Team C had to confront sun reflections, which proved to be their main trouble. Shiny and reflective surfaces, as mentioned in Photoscan's manual, cause 3D geometry inconsistencies.

VI. RESULTS - EVALUATION

The exported, in various formats, results, have been imported to different 3D editing software, in order to validate and compare file sizes, viewport working and editing response etc, which have been documented in a table for future reference (Fig. 3). All three models were exported to 3Ds max, where they were merged manually -using reference points- into one single 3D model.

The method proved to be fast, economical and flexible. Depending on the purpose of 3D modeling, it can be a straightforward technique, which can potentially be used for digital documentation, by people with no technical background [6]. Moreover, the minimum time of fieldwork, that is required, including the low cost equipment and software, classifies it as one of the most convenient existing methods of surveying. Even though the existing study did not focus on discovering possible findings regarding the structure of the monument, the proposed technique can assist in identifying potential structural distortions or points that require further structural analysis.

The limiting factors, regarding the reliability, are the lighting conditions and a potential difficulty of the program to analyze and reconstruct curved or flat surfaces, which are described by photos without substantial detail variation. Also, the long computation times, during the data processing, along with the

high performance hardware requirements, should be mentioned as drawbacks. In general high settings, produce high quality geometry, which has two drawbacks. It can be non-editable, due to the very high GFX card requirements, in order to represent the geometry and it demands a lot of storage HDD space, in order to have all the files which document the complete process.

REFERENCES

- [1] T.P. Kersten, M. Lindstaedt, "Automatic 3D Object Reconstruction from Multiple Images for Architectural, Cultural Heritage and Archaeological Applications Using Open-Source Software and Web Services" in: Photogrammetric, Remote sensing, Geoinformation, Photogrammetrie, Fernerkundung, Geoinformation (PFG) Issue 6, 2012, pp.-727-740
- [2] S. Gianolio, F. Mermatiand G. Genovese, "Image-based 3D modeling for the knowledge and the representation of archaeological dig and pottery: Sant'Omobono and Sarno project's strategies". ISPRS Technical Commission V Symposium. [ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5, Rome,2014,pp.243-250].
- [3] D.P. Andrews , J. Bedford , P.G. Bryan, "A Comparison of Laser Scanning and Structure from Motion as Applied to the Great Barn at Harmondsworth, UK" in ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5/W2, 2013, pp.31-36 [Online] Available: <http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-5-W2/31/2013/isprsarchives-XL-5-W2-31-2013.html>
- [4] T. Kersten, K. Mechelke, L. Maziull, "3D Model of Al Zubarah fortress in Qatar- Terrestrial laser scanning vs dense image mapping". 6th International Workshop 3D-ARCH 2015: "3D Virtual Reconstruction and Visualization of Complex Architectures", Avila, Spain, 25-27 February 2015 [ISPRS-International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5/W4,2015]
- [5] M.G. Giuliano, "Cultural Heritage: An example o graphical documentation with automated photogrammetric systems". ISPRS Technical Commission V Symposium. [ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5, 2014, p.251]
- [6] J. De Reu, G. Plets, G. Verhoeven, P. De Smedt, M. Bats, B.Cherretté, W. De Maeyer, J. Deconynck, D. Herremans, P. Laloo, et al., "Towards a three-dimensional cost-effective registration of the archaeological heritage" (Journal of archaeological science ISSN :0305-4403) 2012, p.1108-1121