Documenting and visualizing deterioration of monuments on a 3D environment

Projection of 2D documentation drawings on a 3D SfM model

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Abstract: The purpose of this study is to display a building's structural condition, through the use of multiple layers, inside a 3D digital environment. The creation of interactive 3D models, that incorporate vector and raster documentation, for non-pervasive studies of historical monuments in Cultural Heritage, could in many ways facilitate a study by offering a mix of advantages. The object of study is a small Ottoman hammam, a listed monument, which is located in the village of Mournies, Chania, in Crete. It is a building of great historical and architectural interest which has an impressive amount of rare, decorative and morphological elements. Several deteriorations are located, that vary depending on where they are and require immediate restoration. This paper presents the process of creating a 3D documentation model that could be considered as a multiple-use documentation tool. The main stages of this process are Work on site, Creation of Virtual Replica, Creation of 2D documentation drawings and Creation of 3D documentation. Although the quality and timing of the outcome depend on some technical features, the 3D documentation model can be created using common software and hardware. It is a fast, low cost and flexible technique for documenting and visualizing deterioration of monuments in a 3D environment and offers the potential for future work.

Keywords: *3D documentation—virtual archaeology—structure from motion—cultural heritage—deterioration*

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Introduction

Team, vision and objective of research

The following research was realised under the Postgraduate Programme "Space, Design and Built Environment", in the School of Architecture at the Technical University of Crete, for the 3D

visualization of structural damages and deteriorations of an ottoman hammam using common software and hardware.

The vision is the existence of a tool helping in overall perception, by non-pervasive studies, of a monument's condition. This tool could support the decision making process at any stage, from first contact and sketches till detailed specialised documentations. To be enhanced this tool should be a bridge of communication between the professionals involved in the monument study as well as for anyone else interested from any distance (in cases where the monument is not safe to visit).

The goal is to create an interactive multi-layer 3D model that could incorporate vector based and raster-based documentation.

The ability to create a three-dimensional replica of a monument could in many ways facilitate a study by offering a mix of advantages (Table 1). The researcher could make observations about the actual scale and condition of the monument, in almost the same quality and detail as in situ, while retaining the advantages, the flexibility and the security of his office.

Characteristics	In situ	2d environment	3d environment
Safety – Comfort		●	●
In detail observation	●		●
Move freely			●
Zoom in – Zoom out		●	●
Multi-layering Observation		●	●
Hardware independence		●	

Table 1. Comparing Observation Methods' Benefits.

The typical procedure for studying a historical monument requires multiple visits to the monument to repeat the observation. Photographic recording can only be used as documentation. The proposed procedure (Fig. 1a) replaces a significant proportion of these visits with digital replica's visits. This enables a faster, equally qualitative, safer, and more economical examination of the monument.

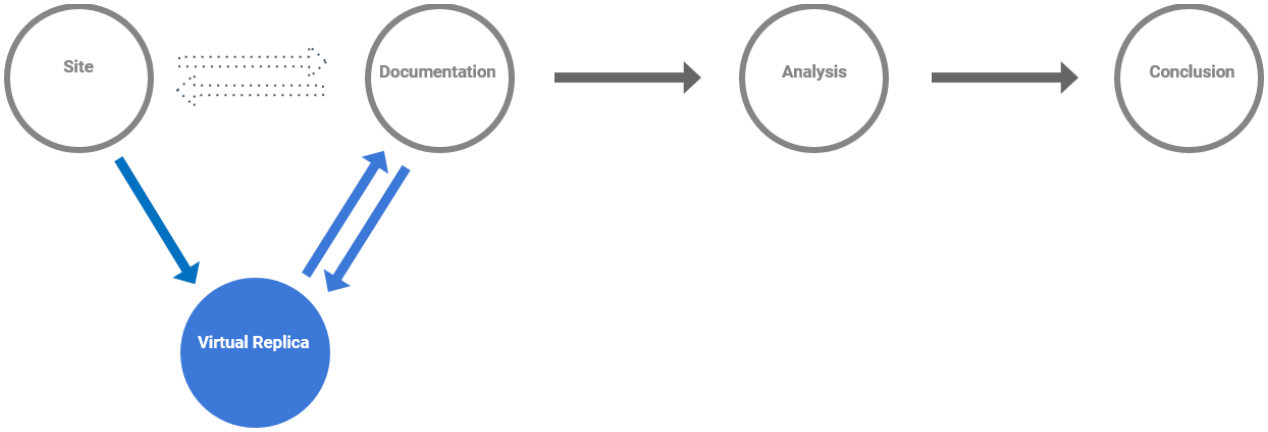


Fig. 1a. Suggested Workflow – Partly replacement of site by a Virtual Replica improving visitability and quality of observations.

In this paper, the above workflow it is implemented (Fig. 1b) using:

1. Structure for Motion (SfM) method and Agisoft Photoscan software for the creation of Virtual Replica
2. Autodesk Autocad for vector documentation
3. Adobe Photoshop and Photoshop 3D for raster documentation
4. Adobe Photoshop 3D for incorporation of raster and vector documentation
5. Sketchfab as online viewer

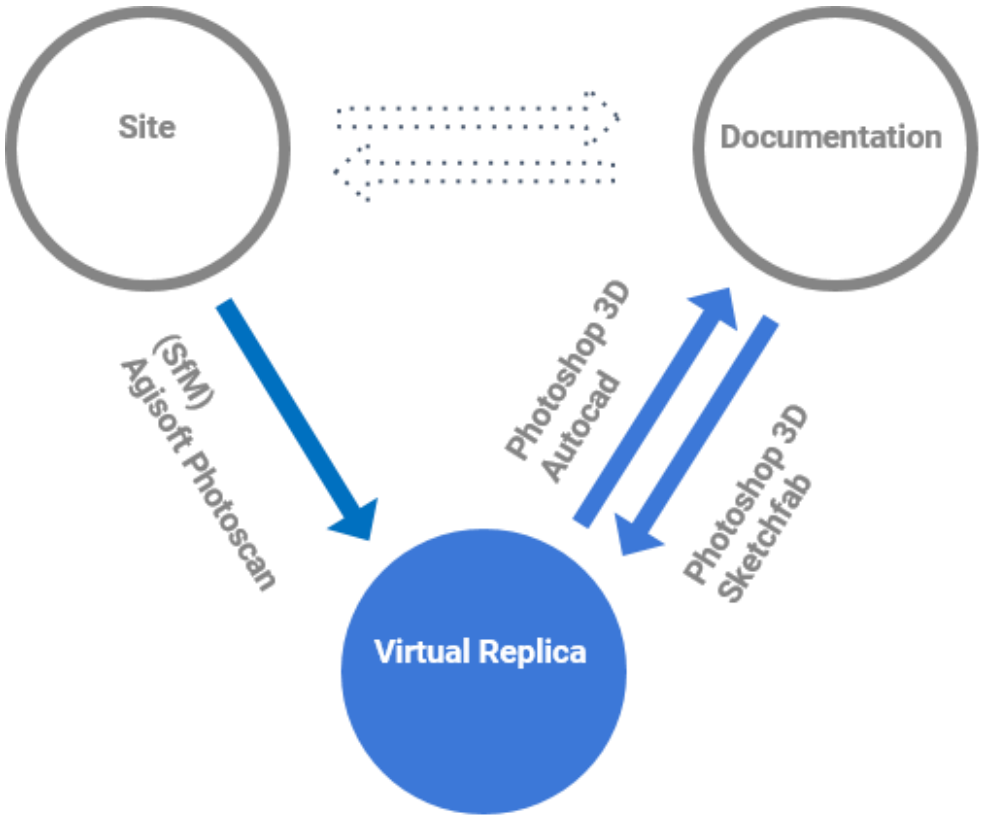


Fig. 1b. Case Study Workflow.

Case Study

Historical information

The listed monument is located 4 km south of the city of Chania, Crete, in the settlement of Mournies (35°28’56.6”N 24°00’39.5”E), in an old privately owned area. The building hosted a Turkish hammam and has a great historical and architectural interest, as well as an impressive amount of decorative and morphological elements (Fig. 2, Fig. 3). Hammams were typical buildings of the Islamic world. The spaces were designed according to operational criteria and the basic layout was similar in all buildings.

Fig. 2., Fig. 3. Decorative and Morphological Elements.

Condition – Deteriorations

Constructively, the particular hammam is made of a semi-carved stone masonry, it has a number of damages and deteriorations, and needs immediate restoration. Its construction was quite complex due to the configuration and maintenance of the optimum indoor temperature and humidity conditions for the operation of the hammam. The different mortars and coatings used per room relative to the operation of each space have brought different types of deterioration.

The building due to long-term abandonment presents considerable damage, with a significant crack in the intermediate semicircular dome. At the same time, rising moisture and covering much of its outer envelope with vegetation and soil are constant aggravating factors (Fig. 4).

Fig. 4. Section -Main Deteriorations.

Process, tools and methodology

Work on site

Two visits took place on site. On the first visit, the monument was identified and the lack of adequate natural indoor lighting for the subsequent photography was recorded. On the second visit, photogrammetric capture took place, taking 195 overlapping photographs (Table 2) that were used in the next stage. The photo shooting took place only inside the hammam, as it was impossible on the outside due to lack of accessibility. A Canon EOS 450D camera and a LED strip of about 3 m, 6400 K, 10.8 w / m, 1000 lumens / m for interior lighting, were used. The largest area illuminated with the above equipment had dimensions of 3 m×3 m and an average height of 4.5 m.

Camera Details	
Company	Canon
Model	EOS 450D
ISO	400–800
Focal Length (mm)	18
Aperture	F/3.5 –F/6.3
Exposure Time	1/13–1/100
Tripod	No

Table 2. Camera Details.

Virtual Replica

The next stage of the process was the virtual 3D reconstruction using a common desktop PC (Table 3), using SfM in Agisoft Photoscan software (Table 4), where 195 photos were used to produce a point cloud model (Fig. 5). The result was a 144 MB file (.psz). For later use, a file (.obj), 10.9 MB in size, and a file (.jpg) of 5.89 MB were exported.

PC specs	
Company	DELL
Model	Optiplex 980
CPU	Intel i7 870@ 2.93 GHz
GPU	Nvidia Quadro FX 580
RAM	16 GB
OS	Windows 7

Table 3. PC Specs.

Process in Agisoft Photoscan		
WORKFLOW		EST.TIME
Align Photos (195 Photos)		130 mins
Accuracy	High	
Pair Selection	Disabled	
Advanced Settings	Default Values	
Point Cloud Output	99,871 points	
Build Dense Cloud		60 mins
Quality	Medium	
Depth Filtering	Aggressive	
Dense Point Cloud Output	10,990,384 points	
Build Mesh		90 mins
Surface Type	Arbitrary	
Source Data	Source Data	
Face Count	Medium	
Interpolation	Disabled	
Mesh Output	169,515 faces	
Build Texture		4 mins
Mapping Mode	Generic	
Blending Mode	Mosaic	
Texture Size / Count	6,000 × 1	

Table 4. Time per Workflow stage in Agisoft.

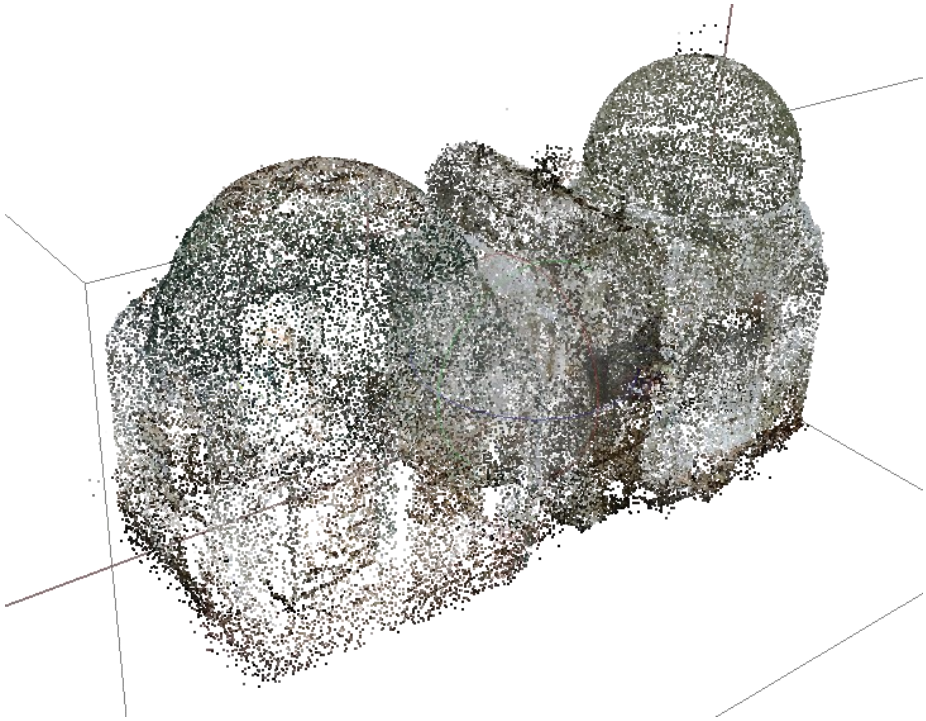
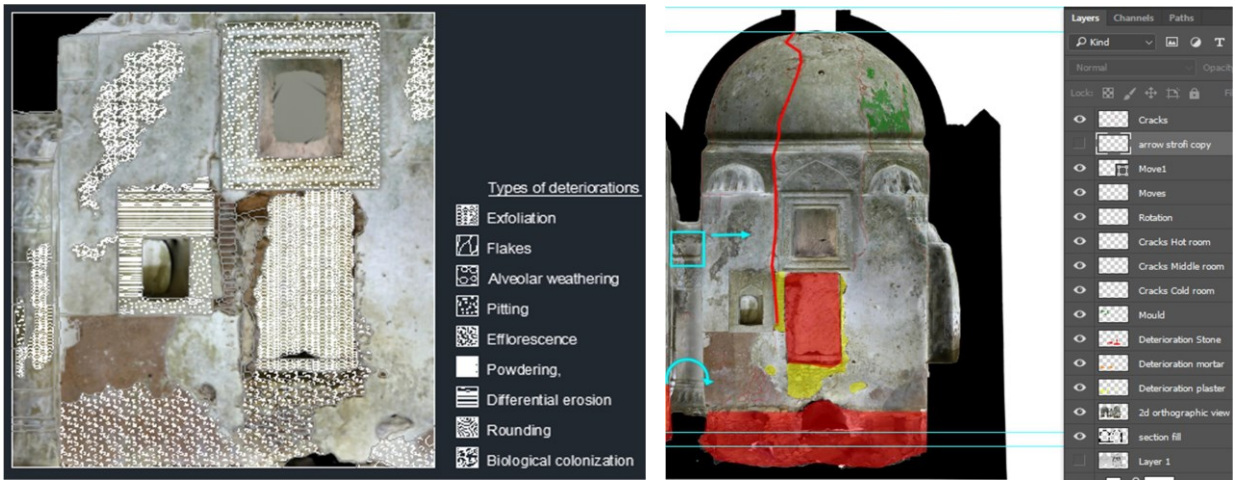


Fig. 5. Point Cloud Model.

Creation of 2D documentation drawings

The (.obj) file that was produced by Agisoft Photoscan, was inserted to 3Ds Max and the unnecessary geometry was cleaned. 2D orthographic views of all the interior faces of the building and the resonance were extracted through sections made in the model. The images that were produced were subsequently used as backgrounds for recording the deteriorations.

Two procedures were used to create 2D deterioration visualizations: 1) the first one (vector) involved the production of (.dwg) drawings through Autodesk Autocad (common process), where the 2D interior facades were imported as a background, and the layers of the deteriorations were designed using the appropriate hatches (Fig. 6a). 2) the second procedure (raster), focused on the same recording by importing the backgrounds in Adobe Photoshop and processing the visualization of the deteriorations layering separately (Fig. 6b).



a *b*

Fig. 6. 2D deterioration visualizations: a) Autodesk Autocad, b) Adobe Photoshop.

Creation of 3D documentation

In order to create a 3D display of the building's deterioration, Photoshop was used in its 3D environment. The 3D documentation model can be created with two different ways that are presented next (Table 5).

After the Agisoft Photoscan (.obj) file was imported in Photoshop, the following steps took place:

<table>
<tr><th>2D documentation drawing to 3D</th><th>Direct 3D documentation</th></tr>
<tr><td colspan="2">Process</td></tr>
<tr><td colspan="2">1. The material of the model was replaced by the (.jpg) file which was exported as a texture file from Agisoft.</td></tr>
<tr><td colspan="2">2. The texture (.psb) file was edited with added layers in order to store changes made on the texture of the (.obj) file</td></tr>
<tr><td>3. Returning at the .obj file, the camera was aligned to the desirable section plane in order to view the same internal views of the model as the 2D drawings</td><td rowspan="3">3.Direct documentation on 3D model using photoshop tools, even in a VR environment.</td></tr>
<tr><td>4. The desired 2D documentation drawing was imported and placed relative to the camera view</td></tr>
<tr><td>5. The different layers with the deteriorations were “merged down” in order to project the damages on the 3D model material</td></tr>
<tr><td colspan="2">Advantages</td></tr>
<tr><td>Fast transfer to a 3D model of already produced 2D drawings</td><td>freedom of movement and focus, plus being able to approach very close points of the monument which the physical space requires equipment</td></tr>
<tr><td colspan="2">Disadvantages</td></tr>
<tr><td>Low accuracy of positioning 2D drawings over 3D model</td><td rowspan="2">Depending on the quality of the model</td></tr>
<tr><td>Distortion due to projecting on 3D objects. (eg dome)</td></tr>
</table>

Table 5. Process, Advantages and Disadvantages of 3D documentation Methods.

The same procedure can be followed for every different deterioration. The final result (Fig. 7), which includes all the deteriorations, is one .psd file for the 3D model and one (.psb) file relevant to textures with all deteriorations on layers. Inside the Photoshop 3D environment, one can browse the model and observe all the desired deteriorations by turning on/off the layers from the texture file (.psb).

Fig. 7. The final result in the Photoshop 3D environment.

Sharing – Internet applications

There are a large number of free web applications for viewing 3D models in WebGL. This research utilizes the Sketchfab platform (www.sketchfab.com) due to its simplicity, speed and ease in changing textures inside the platform, but also because it offers the ability to view the 3D model in VR mode, using cheap viewers or expensive VR headsets. The different deteriorations, which are stored as .jpg files through the .psb texture file, can be uploaded on the 3D model inside Sketchfab, under the Materials tab in 3D Settings. By switching between different .jpg files as textures in the materials, one is able to navigate through the different deteriorations inside Sketchfab's 3D model. The final models are available at the following links:

https://skfb.ly/UMvP, https://skfb.ly/UZqE

Issues

During the whole process a number of issues arose. When editing in Photoshop 3D the bump of the space does not allow for the complete matching of the two-dimensional with the three-dimensional backgrounds and creates some losses and deformations of the final visualization of the deteriorations. These deformations are intensified in the case of study by the geometry of the hemispheric domes and generally the convex surfaces of the monument. Also, the fact that the building is housed by domes, has created overlaps of deterioration visualization during the implementation of the "Merge Down" command, since parts of the dome in the reflected ceiling plan coincide with parts of the dome on the internal aspects. The result was the display of unnecessary information and double lines.

Evaluation and Future Work

This method proved to be a fast, low cost and flexible technique for documenting and visualizing deterioration of monuments in a 3D environment.

Documentation in both Photoshop 2D and 3D environments is offering for sketches and promising to be an ideal solution for incorporation of raster documentations like for example these of remote sensing methods.

The process suggested in this paper offers a valuable visualization tool for a non-pervasive study of historical monuments and their different kinds of deteriorations. As a tool helps researchers stay focused in the overall perception of the condition of a monument, being able to incorporate drawings, information or even notes from several specialties of professionals.

Future work may:

- incorporate in the suggested workflow the 3DHOP (3D Heritage Online Presenter) framework for the creation of interactive Web presentations of high-resolution 3D models.
- examine the success of incorporating of remote sensing documentation in 3D model
- be recording and analyzing directly on the 3D model using VR technologies such as VIVE (Fig. 8) as well as recording and analyzing in situ using AR technologies.

Fig. 8. Future Work

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