VISUALIZATION OF FRESCOS BY MEANS OF PHOTOGRAMMETRY AND LASER SCANNING

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ABSTRACT

The role of Photogrammetry and Laser Scanning for the digital recording and documentation of frescos in a church of 15th century A.D. in the village Louvaras, Lemesos-Cyprus, will be presented and discussed.
The country church of Saint (Agios) Mamas in Louvaras village, Lemesos-Cyprus, appears to have precious frescos. Louvaras, is mountainous village, 28 km north of Lemesos on the south of the Troodos range. In the centre of the village is the small church of Agios Mamas built in 1455 with mural paintings signed by Philip Goul, while the frescos have been recently preserved. The preservation campaign has been already implemented under the authority of the Department of Antiquities, Republic of Cyprus and the need for a photogrammetric survey campaign after the conservation was necessary. The new illustration inside the church was visualized by means of Photogrammetry and laser scanning-based surveying techniques. Several products like plan views, cross sections, 3D model and walk-through videos have been prepared for a full documentation of the church monument.

1. INTRODUCTION

1.1 General

The recording and documentation of culture heritage is always an interesting and intriguing issue for the scientific community (CIPA, ICOMOS, ISPRS etc.). The various disciplines involved in these projects such as Photogrammetry, Modelling, Animation, Visualization, Computer Graphics, Archaeology etc. provide the prospect for the opportunity for a multidisciplinary cooperation in the area of recording, documentation and archiving the cultural heritage.
The paper illustrates the contribution of Close Range Photogrammetry and Laser Scanning technology within the framework of the digital recording and documentation of frescos in the county church of Saint (Agios) Mamas in Louvaras village, Lemesos, Cyprus.
The development of laser scanners raised a new approach for the recording, documentation and preservation of cultural heritage. Laser scanners have the ability to measure automatically 3D coordinates. This is a good infrastructure to start building 3D models of objects using the captured cloud of 3D points.
On the other hand, lasers scanners appear to have drawbacks. A laser scanner still remains in high costs and is not an approachable equipment to be used in cultural heritage recording and documentation. In addition, the quality of the captured colour images is not so good and thus more qualitative images must be acquired. Thus, in order to catch the true colour of the recorded object, high resolution images must be taken using the suitable camera.

1.2 Historical Background for the Church

The small wooden roofed church of Saint Mamas (Figure 1, top) is situated in the village of Louvaras, a small village in the mountainous Lemesos, Cyprus. According to the inscription that is positioned above the west entrance, the Saint Mamas church was built in 1455 and it was decorated 40 years later in 1495 by the painter Philip Goul. One year before, the painter signed the church of the Holy Cross of Ayiasmati which belongs to the monastery bearing the same name and is in the village of Platanistasa.

The frescos of the Saint Mamas church, which decorate the interior of the church, and part of the west wall in the exterior part, are preserved in an excellent condition. Particularly interesting information concerning the donors and the painter of the church are provided by a property inscription, which is found on the west wall of the church.
The painter Philip Goul is loyal to the Byzantine tradition; however, in his work one can clearly distinguish influences on paintings on his paintings by the the western iconography. The iconostasis (Figure 1, bottom) as well as the two portable icons depicting Christ and Saint Prodromos are possibly works of Philip Goul dating back to the same period of the foundation of the church.

Figure 1. Exterior (top) and interior view of the Saint Mamas church (bottom)

1.3 Motivation & Aims

The official decision for the recording and documentation of the frescos in Saint Mamas church was taken by the relevant authorities, i.e. the Department of Antiquities, Republic of Cyprus. The restoration of the church and the preservation of the frescos were finished a few months ago and the recording process was necessary for archiving.
The goal of the project was the photogrammetric survey of the new illustration inside the church. The new situation was visualized by means of Photogrammetry and laser scanning-based surveying techniques and a number of digital products like orthoimages, plan views, cross sections, 3D model and walk-through videos were prepared for a full documentation of the church.

2. INSTRUMENTS

The *Trimble GS200* (Figure 2) laser scanner was employed for the laser scanning process. This scanning system is provided with a rotating head and two inner high speed rotating mirrors that allow to acquire a scene with a large enough field of view, i.e. 360° H x 60° V, reducing the need for lots of scanning stations. The accuracy in such a sensor is to down to 1.5mm at 50m distance with a beam diameter of 3mm at 50m. Furthermore, the laser expect X, Y and Z coordinates is able to capture the reflected beam intensity and RGB colors.

Figure 2. GS200 laser scanner (www.mensi.com)

Additional technical characteristics of the Trimble GS200 laser scanner are shown on Table 1.

Manufacturer	Trimble	
Product	GS200	
Range	optimized to 200m, with 350m OverScan™ capability	
Resolution	down to 32µrad (3mm at 100m)	
Accuracy	down to 1.5mm @ 50m (typical)	
Speed	up to 5000 pts/s	
Field of View	Horizontal	360°
	Vertical	60°
Weight	13.6 kg	
Size	340mm D x 270mm W x 420mm H	
Minimum Resolution	3mm @ 100m (32µrad)	

Table 1. GS200 laser scanner specifications (www.mensi.com)

A high resolution camera, the *Cannon EOS 300D SLR* (Figure 3) was used to overcome the low resolution on board video products of 768 x 576 colour resolution captured by *Trimble GS200*.

Figure 3. Canon EOS 300D SLR (www.canon.com)

Canon EOS 300D SLR	
Sensor Resolution	6.3 Megapixel
Image Size	3072 x 2048
Lens	50 mm
Body	Cannon

Table2. Camera system specifications

3. DATA COLLECTION

The small size of the church gave the opportunity for only one day data collection, i.e. the laser scanning, image acquisition and few additional measurements.

3.1 Laser Scanning

The Trimble GS200 laser scanner was used to scan the internal of the church in order to product the needed products for the documentation of the frescos.
The scanner was located at 9 stations and scanned 19 objects of the internal part of the church. The number of measured points was approximately 21 million.
The sampling step was setup from 0.98 to 0.17 mrad according to the significance and situation of the recording object. Special interest was given to the mural paintings as well as to the temple and one picture of great importance.

3.2 Image Acquisition

The *Cannon EOS 300D SLR*) camera which is a 6.3 MegaPixel with a 50mm lens was used to record high resolution images in order to be used as texture information for the 3D model and orthoimage production. The camera produces 3072 x 2048 pixel high resolution digital images. Approximately, 20 images were taken to cover the internal part of the church.
The images have been acquired in order to provide overlap between the adjacent images while the perpendicular shooting position relatively to the church walls has been taken into account.

4. DATA PROCESSING

4.1 Processing the Point Clouds

In order to align and merge the multiple point clouds captured from the different stations, *Realworks* software was used. For this reason, reference artificial spheres and well-defined reflector targets (Figure 4) were used to join the multiple scans.

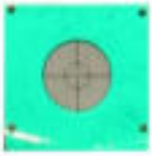

Figure 4. Artificial reflector target

All the artificial points (targets & spheres) were registered in a local coordinate system.
Even though the size of the point-cloud data for the 3D model of the church was huge, a unified model was setup. To give an impression about the extent of the data, a spatial sampling was created with minimum distance between the points of 20 mm and 1.9 million triangles were created, while the file size was about 96 MB and the cloud data file was about 430 MB.
In the following, "noisy" points were removed to make the processing of the model easier. The next figure (Figure5) gives the first impression for the situation and the status of the recording object.

Figure 5. The point-cloud data for the 3D model in gray scale intensity mode (panoramic view above and close-up of the north wall below)

The 3D model presented in Figure 5 has no texture but colour information is attached to the vertices. This illustration is due to vertex colour, i.e. the colour captured by the *Trimble* scanner and significantly differs from the original colour.

4.2 Colour Information in Point Cloud

In general, the images captured by the laser scanners are not in a high quality as usually is a requirement on recording cultural heritage objects. For instance, the coloured images captured by the laser scanner are in a low resolution, i.e. 768 x 576 colour resolution in case of *Trimble GS200* laser scanner.
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.
Due to the dense structure of the point clouds acquired by the laser scanners, the point-based rendering and modelling is feasible and one of the important topics for the research community. On the other hand, the sizes of the polygon models processed from laser scanner data is huge enough. The software tools and techniques that nowadays exist for manipulating so huge 3D polygon models still need to be upgraded to face such issues.
The point-based modelling and rendering of laser scanner point clouds is an easier and smart approach because it reduces the amount of data used. Such solutions are preferable in cases of internet, virtual museums, e-libraries etc.
In order to improve the quality of the colour information given by the colour images of the laser scanner, high resolution images taken by *Cannon EOS 300D SLR* were used. Every single image was processed with the use of a corresponding 3D image. This was feasible if more than six (6) matching points, both in a photograph and a 3D image were used, in order the photograph was given X, Y, Z coordinates for the reference points. The matching process was done using the *Realworks* software. The example in Figure 6 gives an internal illustration of the Saint Mamas church using the above analyzed technique.

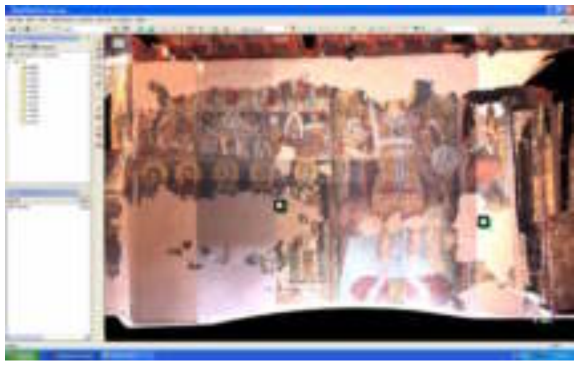

Figure 6. Colour information on the point cloud

4.3 Texture Mapping & 3D Models

The need for a more pragmatic product is always preferable, especially in cases concerning the recording and documentation of cultural heritage sites and objects. In the case of frescos the need for a high quality and realistic product sets higher standards because the illustration of the paintings and the diversity of the colours are so much characteristic.
Thus, in order to increase the quality of the representation of the frescos, texture was attached to the polygon models. The texture images were developed from the high resolution images acquired by *Cannon EOS 300D SLR*.

4.4 3D Model from high resolution images

In order to create the realistic 3D model of the church from high resolution images, a TIN was created by the point cloud. Figure 7 shows the 3D model of the church from a bird's eye view.
Due to the fact that the high resolution images appear to have different photometric characteristics, the processing was necessary to balance the attributes of the images.

4.5 Orthoimages

One of the main objectives of the project was the production of orthoimages for the frescos inside the Saint Mamas church.

Once the DSM of the object has been calculated by the laser scanning point cloud, the orthoimages can be generated automatically from rasterized image data of close range images based on central projection.

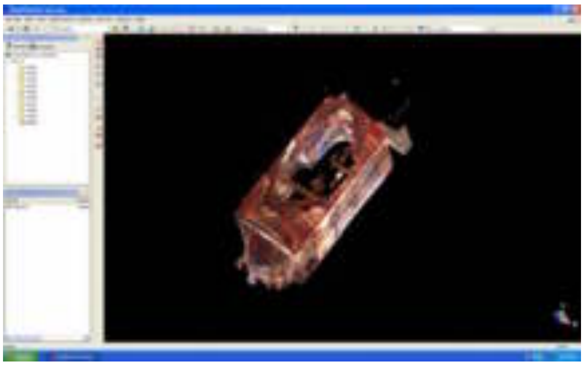

Figure 7. 3D model of Saint Mamas church from a bird's eye view

Respectively, Figure 8 shows the 3D model of the church from top view.

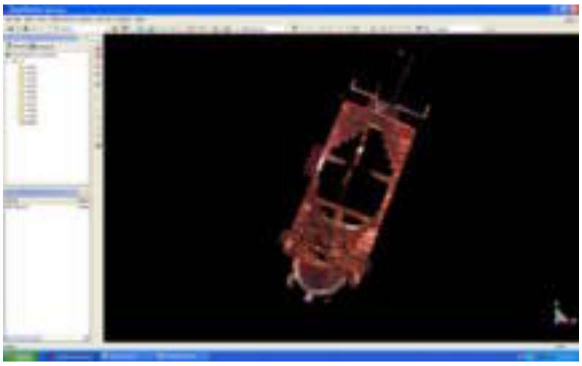

Figure 8. 3D model of Saint Mamas church from top

Five examples are provided in the following (Figure 9) to give an impression about the orthoimage products created during the implementation of the project.

(a)

(b)

(c)

(d)

Figure 9. Orthoimages of Saint Mamas frescos, east (a), west (b), north (c) and south (d)

Additional products were generated during the implementation of the project; for example the orthoimage production for valuable icons. Due to the importance of the object, an orthoimage was generated for the Mary's icon. A very detail DSM which was calculated using an extremely dense point cloud by the laser scanner was used for the orthoimage production.
Figure 10 shows the orthoimage generated for the Mary's icon in the Saint Mamas church.

Figure 10. Orthoimage of Mary's icon in Saint Mamas church

5. CONCLUSIONS

The paper reports the results of the project implemented for the photogrammetric recording and documentation of Saint Mamas church in Louvaras village, Lemesos, Cyprus. The use of a combine method by Photogrammetry and laser scanning was used for this reason. The case study proves the rule that practical knowledge adapts the solution for every single project, according to the needs in recording, documenting and preserving cultural heritage.

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