

Integration of Different Methods for Architectural Survey of Historical and Cultural Heritages

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ABSTRACT

Protection and documentation of cultural heritages which have historical significance for the sake of continuity of culture are inevitable events. In the light of this thought, using new techniques, in comparison to classic methods arising of new techniques in parallel with technology in order to achieve the most reliable results in works such as restoration, reconstruction, building survey and documentation of cultural entities are inevitable. In this study, Sille Aya-i Eleni Church, which has historical and cultural significance that can be evaluated in terms of architecture and allows the application of different techniques, was chosen. Different purchasing methods and drawing operations were carried out in accordance with the features of the selected object. The exterior drawings of the object, which will be created in a three dimensional model, are made with the photogrammetric method, while roof surveys that have risk are made thanks to the photographs taken with UAV. The surveying and drawing of the interior of the same object was also performed with a laser scanner. As a result, it is recommended to use the methods together in documentation studies of objects with different properties.

1. INTRODUCTION

Accurate and precise recording of cultural heritage is of vital importance because the current-state documents are the basis for conservation studies such as art history research, architectural and structural analyses, materials and deterioration analyses, determination of intervention strategies and application projects (Altay and Sağıroğlu, 2019). It is of great importance that the speed and accuracy of the work increases and also the cost decreases. Alternatives to traditional methods have increased with developing technology. Many types of research have been conducted on alternative methods for documentation purposes. As a result of these studies, the advantages and disadvantages of approaches have been listed. It is claimed that each method produces safer, more accurate and faster data than other methods (Uzun and Spor, 2019; Varlık et al., 2016).

In the statical survey and documentation studies of architects, the transition from classical methods to modern techniques is seen as an

advantage. Advanced techniques do not only the traditional methods but also offer different solution alternatives in the process steps that have difficulty in analysing (Güleç, 2007). Also, it provides new solutions to facade survey of narrow spaces that do not allow measurement or roof survey and modelling them and making them ready for the project (Themistocleous et al., 2015; Themistocleous et al., 2016).

In addition to the terrestrial photogrammetry technique, the use of kinematic Global Navigation Satellite System (GNSS) survey method in making layout plan in statical survey is essential for speeding up the process.

Today, the rapid development of Unmanned Aerial Vehicles (UAV) with the developing technology has expanded the range of use of these vehicles and has taken its place in many different occupational disciplines (Vacanas et al., 2015; Yakar and Mırdan, 2017; Xue et al., 2019).

Historical sites to be modelled in 3D and inaccessible points of cultural heritage such as roofs should also be photographed and surveyed. At this

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point, terrestrial photogrammetry is insufficient (Böge, 2013). Furthermore, terrestrial photogrammetry can be challenging to work indoors (Yakar and Mirdan, 2017).

It is observed that when examining existing legislation in Turkey regarding the statical survey, multiple detailed works needs to be done in the statical survey operations and has many advantages in a particular purpose, of all the methods used in the studies. However, it is difficult to state that no technique can be used to cover all of the mentioned statical survey steps.

The exterior modelling and drawings of the Aya-i Eleni Church, which is the largest church of Sille, have been realized by both photogrammetric method and laser scanning technology and its drawing from the top has been missing. Besides, its interior has been scanned with laser scanning technologies, and no sectional drawings have been made (Yıldız et al., 1999; Göktepe et al., 2009). This research aims to reveal whether different methods of a statical survey of historical and cultural assets will be used together. The benefit expected from this research is to guide the people who survey statical to determine the historical and cultural assets in different locations and conditions to determine the statical survey. Within the scope of this study, 3D modelling of the exterior of Aya-i Eleni Church in Konya Sille was made. GNSS technology and terrestrial photogrammetry technique have been used in the survey of the surfaces. Roof survey is created and modelled with UAV technology and combined with exterior drawings in the computer environment. The indoor is scanned with laser scanning technology for the interior. Sections and drawings of the interior are created.

2. MATERIALS AND METHODS

2.1. Studying Area

Within the scope of this study, Konya Sille Aya-i Eleni Church was chosen as the study area (Figure 1). Sille Aya-i Eleni Church is located on the 3rd map section, the 3635th parcel in the urban protected area to the left of Tatkoyn turnout, Selcuklu district of Konya province. Being the biggest church of Sille, Aya-i Eleni Church started to be built in 327 during sacred pilgrimages (Koyuncu, 2013).



Figure 1. Sille Aya-i Eleni Church

2.2. Hirobo Shuttle ZX Model Helicopter Unmanned Aerial Vehicle

UAV, high resolution images with low flight altitude can be produced at a lower cost than images obtained from aerial photogrammetry (Esposito et al., 2014). It also provides easy purchasing in hard-to-reach areas with less risk.

For the aerial photographs of the study, the Hirobo Shuttle ZX model helicopter was preferred. Futaba 7C brand remote control was used with equipment such as receiver, servo, battery that completed the flight of the helicopter (Figure 2).



Figure 2. Hirobo Shuttle ZX model helicopter

This model provides an efficient and balanced flight without loss of power thanks to its superior design compared to other models. This fueled model is a model with stable flight due to its large size (Böge, 2013). In order to minimize the cost of the study, this type of simpler structured helicopter has been preferred. Although the stabilization feature is better than other models, the tracking of the propellers has been made to minimize the motor vibration.

2.3. Canon Sx 150 IS Camera

The Canon Sx150 IS, which is preferred for use during flight, is slightly larger than the portable cameras, but not as equipped. However, it is an ideal choice considering the price/performance evaluation and weight. It is preferred because it is a camera that supports vibration prevention and autofocus system. In this way, the photo has improved quality. Besides, the camera is mounted with the help of a unique apparatus that will tolerate vibration during the flight (Figure 3).

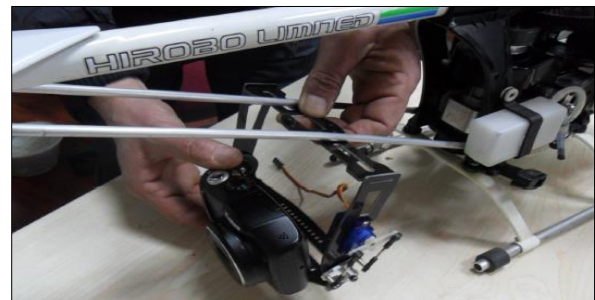


Figure 3. Mounting the camera

2.4. Nikon D80 Digital Camera

During the terrestrial photogrammetry application stage, 24mm lens was used with Nikon D80 digital camera to take photographs.

2.5. ILRIS 3D Optech Terrestrial Laser Scanner

ILRIS-3D terrestrial scanner has been preferred in the scanning stages of the study due to its high resolution, having a distance measurement from 3 meters to 1 kilometer, using class one laser and not requiring levelling. ILRIS-3D terrestrial scanner is a portable package integrated with digital cameras and advanced software tools prepared for commercial surveys, engineering, mining and industry applications (Karabörk et al., 2007).

2.6. Topcon GPT 3007 Total Station

Considering the size of the object to be measured, the Topcon GPT 3007 total station was preferred to be able to read the details using the laser at heights that cannot be affixed.

2.7. Photomodeler Software

Photomodeler is a software which has the capability of camera calibration, photogrammetric evaluation and vector drawing. It can also envelop pictures on the drawings. It was used in the drawing works of the church after the survey by the terrestrial method. The camera calibration process, which is expressed as the finding of the parameters that best represent the camera system, was also carried out by software.

2.8. Parser, Polyworks and Z-Map Softwares

Parser software converts the .hdr file, which is obtained as a result of the survey made in the field with a laser scanner, into various formats that can be processed in Polyworks software. Polyworks software is software that processes point clouds. In IMAlign module, it is possible to combine point clouds and georeferencing. IMInspect module, on the other hand, is a tool for surveying and calculating on surfaces. Within the scope of this study, these two modules were used.

Z-Map software, which is capable of creating a digital elevation model (DEM) on point clouds, georeferencing pictures with the help of a point cloud, drawing, orthophoto and mosaic can be used.

2.9. Photogrammetry Survey

Photogrammetry is a technology and science where information about objects and the environment is obtained at the end of the recording, survey and interpretation of photographic images formed by the rays reflected from the objects and their surroundings and the electromagnetic energy

they emit. While photogrammetry is first used to obtain the topographic structure of the earth, it also includes new and different application areas today. Today, photogrammetry is used to survey and model the geometric and structural properties of objects.

Roof photographs, which are difficult to survey due to height of church, were obtained with the help of UAV in this study. Pictures taken from terrestrial photogrammetry were also acquired with the help of digital cameras.

2.10. Laser Scanning

With the developing laser scanning technology, the surveying system has started to be widely used in the documentation of cultural heritage. Laser scanning is a technology that can collect three-dimensional position data quickly, reliably and in detail for many different applications (Uzar et al., 2019). Thanks to its speed and precision, terrestrial laser scanning has gained more importance as a surveying tool in the field of architecture and cultural heritage (Korumaz et al., 2010). Thanks to advances in terrestrial laser scanner technology, the point cloud of large-scale structures can be obtained quickly (Chen et al., 2014). The laser scanning technology preferred in the documentation of architectural objects was used in the interior of the church in the study.

3. RESULTS

In this study, it is aimed to determine the most appropriate surveying and drawing method by considering the size, height and historical-cultural importance of Sille Aya-i Eleni Church. The terrestrial photogrammetry technique surveyed the exterior facade of the church, and its roof was surveyed with UAV. Both data modelled and combined in a computer environment. The interior of the church and the ceiling decorations were surveyed with laser scanning technology, and their sections were created.

3.1. Statical Survey of Sille Aya-i Eleni Church Exteriors by Photogrammetry

For the survey of details of the object, in the Selcuklu 22/a Cadastre Renewal study carried out by Land Registry and Cadastre General Directorate (TKGM) in 2009, starting from C1, C2, C3 and Turkish National Fundamental GPS Network (TUTGA) points, a static session was held for at least 20 minutes, and cadastre polygons, whose coordinates were obtained and registered by the Directorate of Cadastre, were started. When the tool is installed on the polygons we have installed on the ground, the marks that allow us to easily survey on the object are affixed to the object so that the tool can read (Figure 4).



Figure 4. Facade marking of Aya-i Eleni Church

It was decided to print the images of the church before the field study and arrange it as a sketch, and the points whose coordinates were read were marked on the drawing. Also, unmarkable locations were targeted and read with the laser of the instrument (window edges, areas with different stones, sharp places). The points that were read numbered and their locations were indicated on sketches and markings were made to relevant areas at office stage. With the help of the Nikon D80 digital camera, of which we previously determined the calibration value, photographing of the church was started after the signs were applied. More photos were taken than needed, as some images may have poor lighting or poor focus settings.

A total of 128 photographs were taken locally around the church, and 16 of them were used during modelling. Besides, since the photos of the upper part of the North-East facade, which provide sufficient vision, could not be taken, four photographs taken by UAV. The total station surveyed the polygon points placed in the study area according to the local coordinate system. The data was collected by surveying the angle and distance (horizontal angle, vertical angle, oblique distance) data during the detailed survey of the points with the total station (by laser) to re-calculate when necessary.

Except for the roof of the object, a total of 69 points were surveyed homogeneously for all facades. While surveying facades, panels on the roof coordinated by reflector. Then the survey process was completed. In the office part of the study, the calculations of all the details collected in the field were made by connecting to the registered cadastre polygons, and the coordinates (y, x, h) of all surveyed points were calculated before modelling. Twenty images that can be used for facade drawings were transferred to the program and adjusted. With the conclusion of the adjusting, drawing operations had been started on two photographs that were required by photogrammetric modelling.

3.1.1. South-East facade

For the south-east facade, which is the front entrance part of the church, a total of 32 photos were

taken from different angles, in the horizontal and vertical positions of the camera. 4 of these photos were used during modelling. 19 detail points were surveyed from the south-east facade of the church, marking and then adjusting the surveyed detail points and drawing was completed in the photomodeller program (Figure 5).

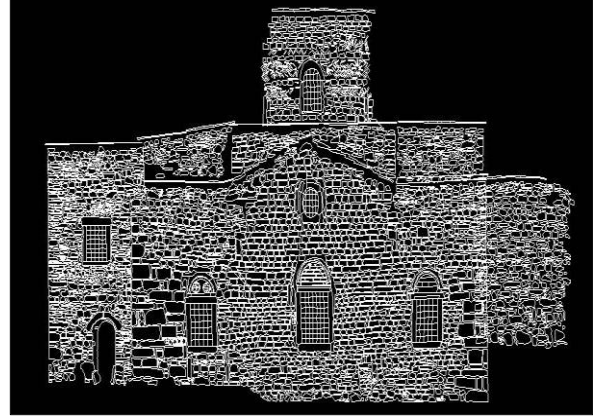


Figure 5. South-East facade drawings of the church

3.1.2. South-West facade

Starting from the front entrance of the church and turning clockwise, a total of 29 terrestrial photographs were taken from different angles for the other facade, the south-west facade. Among these photos, 4 of them facing the facade were chosen to be used. 14 detail points were surveyed from the south-west facade of the church, and the location of these points were defined on photographs and adjusted and drew (Figure 6).

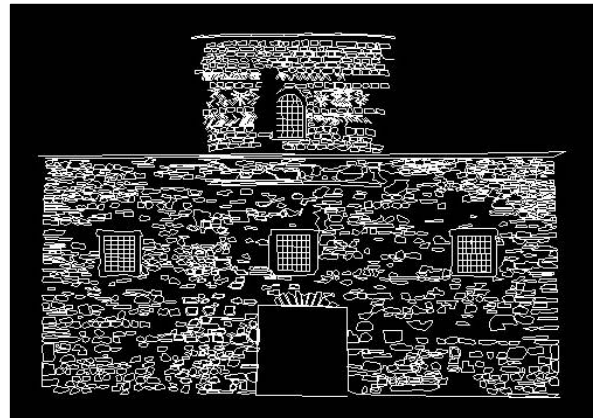


Figure 6. South-West facade drawings of the church

3.1.3. North-West facade

A total of 28 terrestrial photographs were taken from different angles and locations for the north-west facade, the rear entrance of the church. 4 of these photographs were selected to be used to meet the needs. During the field study from the north-west facade of the church, 16 detail points were surveyed, these points were marked in the relevant parts of the

photographs, adjusted and drawings were completed (Figure 7).



Figure 7. North-West facade drawings of the church

3.1.4. North-East facade

A total of 39 terrestrial photographs were taken for the north-east facade of the church, which we described as the last facade of the church during the study. 4 of these photos were selected to be used. In addition, 4 more photos taken by unmanned aerial vehicles for this facade were used in the drawings. A total of 20 detail points was surveyed from the north-east facade of the church, the photos and the points were matched, adjusted and their drawings were completed in the program (Figure 8).

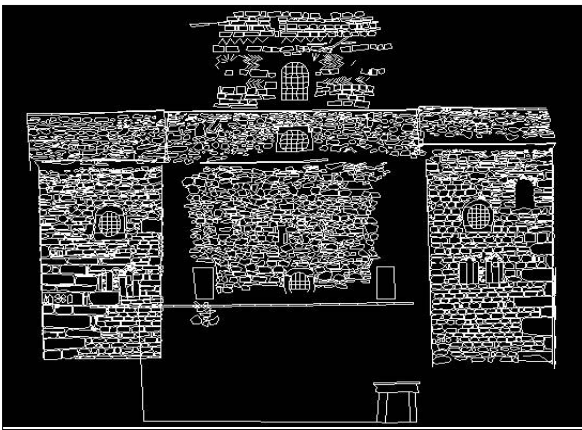


Figure 8. North-East facade drawings of the church

3.2. Roof Statical Survey with Unmanned Aerial Vehicle

UAV and photogrammetry explain the photogrammetric measurement platforms, the activities of a pilot and UAV sitting on the platform without the need for photogrammetric processing, or remote, semi-independent or independent activities. It includes balloons, kites, gliders, rotating and fixed-wing UAVs with its wide definition, photogrammetric data collection, semi-automatic and automatic flight mode. In this part of the study,

UAV was prepared to show how they can be used for photogrammetric data collection and processing. For the surveying and modelling of the upper part of the church, the commanded Hirobo Shuttle ZX helicopter to be used in images was used. In the stages of preparing the unmanned aircraft for flight, it is aimed to minimize the vibration of the engine and to take good photographs. To adjust the required propellers, the camera is fixed with a piece of specialised equipment (Figure 3). Also, since the camera used is a camera with anti-vibration and autofocus system, the image acquisition may be at the desired quality.

A total of 20 plates were placed, only 9 of them were adjusted for reasons such as solar flare and coordinate shift, modelling was made. For the measurement of the upper part of the church, photographs were taken from different angles on the days and hours when the weather was favourable since it was not required to leave a shadow in the photo and the plates should not shine from the sun. On take-off from the north facade and once from the south facade, flew twice in total and took photos. The first take-off, reaching the desired height and acquiring images and landing took 10-15 minutes. It was decided to fly from the facade in the other direction to make the adjusting and modelling healthier. The photoshoot was completed within the same period considering the size of the object. Take-off and landing were done twice with the 300g camera and was left in the air for about 25 minutes with 300 ml of fuel. First, the flight was done, and then the phases of coordinating the plates with the total station were followed. Placing the plates, making the flight and giving the coordinates were all done in about 60 minutes. A total of 134 photographs were taken, including take-off and landing. Ninety-five images are available with the exact view of the object. Three images that saw the church not from piecemeal, but from the top and as a whole, were selected of the 95 images. Then marked with the coordinates given to the plates, adjusted and roof modelling was performed (Figure 9).

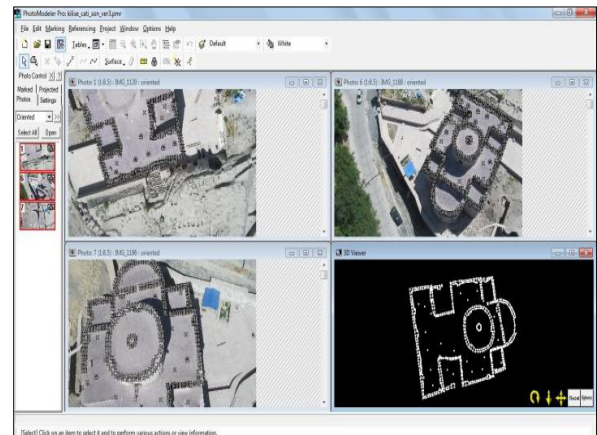


Figure 9. Roof drawings of Aya-i Eleni Church

The 3D model of the church was completed by combining the drawings of the facades and the roof of the church (Figure 10).

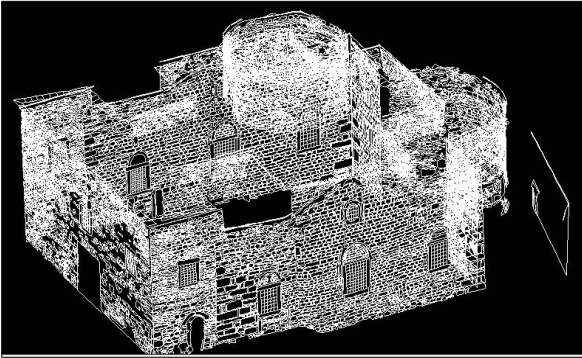


Figure 10. 3D version of Aya-i Eleni Church in AutoCAD environment

3.3. Survey of the Interior of Sille Aya-i Eleni Church with Terrestrial Laser Scanner

Scanning operations were carried out from different station points of the interior of Sille Aya-i Eleni Church (Göktepe et al., 2009). Processing and merging of point clouds belonging to the interior of the church was carried out. Sections of the model obtained in AA', BB', CC', DD' directions (Figure 11) were taken and their appearance was obtained (Figure 12, 13, 14, 15) (Böge, 2013).

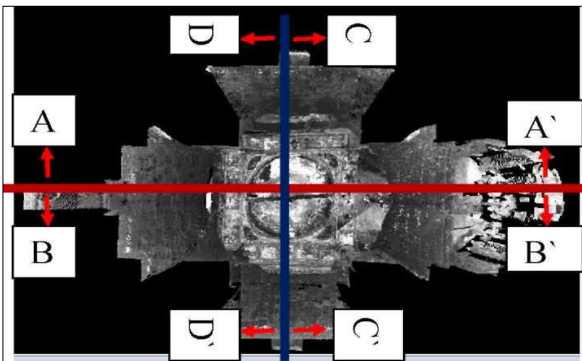


Figure 11. Sections taken inside the Aya-i Eleni Church

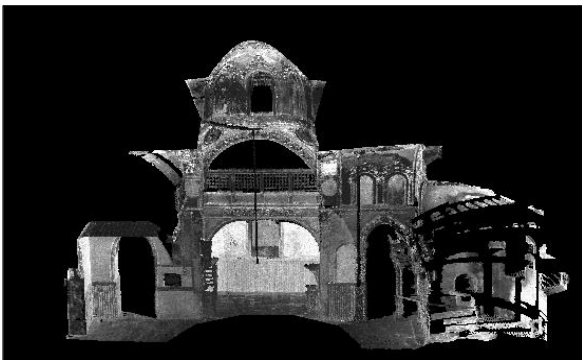


Figure 12. AA' section of the interior of Aya-i Eleni Church

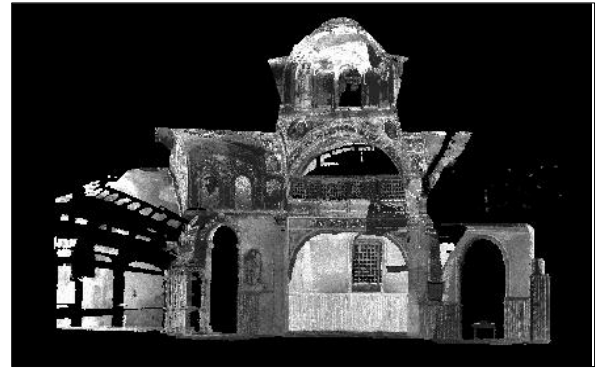


Figure 13. BB' section of the interior of Aya-i Eleni Church



Figure 14. CC' section of the interior of Aya-i Eleni Church

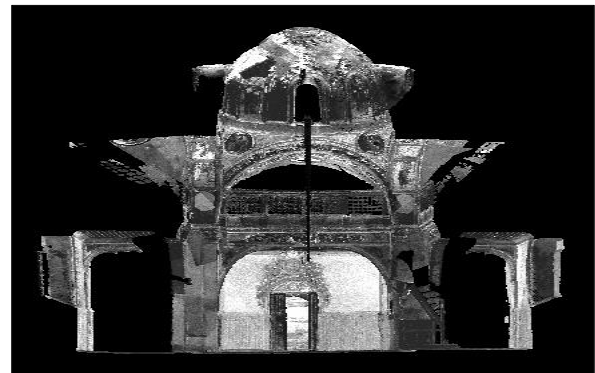


Figure 15. DD' section of the interior of Aya-i Eleni Church

3.4. DEM, Orthophoto and Drawing of Some Views of Sille Aya-i Eleni Church Interior

DEM, orthophoto and drawings of some sections of AA', BB', CC' and DD' sections specified in Figure 11 were realized in Z-Map software. Point clouds previously combined in the IMAAlign module of Polyworks software have been imported into the IMInspect module. Other points in the IMInspect module have been deleted, except for point clouds from the entry part (DD'). After this process, the part of the point cloud to be transferred to the Z-Map software was selected and transferred to the .txt file

with the densities of the points. This file was opened in Z-Map software and also pictures taken with the previously calibrated Nikon D80 digital camera are included in the project. In the point clouds transferred to Z-Map software, a surface is passed through at least 4 points on the same surface. Now the defined coordinate system is the system of this surface. 3D coordinate transformation was realized by making picture matching with the point clouds included in the project (Table 1). Later, Digital Elevation Model (DEM) was created from point clouds. After DEM, orthophoto image with a pixel size of 3 mm was obtained. Thus, image shifts consisting of image skew and height difference were eliminated and a scaled image was obtained (Figure 16).

Table 1. Standard deviations resulting from the conversion between the point cloud and the picture of AA', BB', CC', DD' sections

Section Name	Image Number	σ_x (mm)	σ_y (mm)
AA'	190	15	3
AA'	192	7	2
BB'	165	12	5
BB'	166	9	2
CC'	161	13	8
DD'	202	14	11
DD'	201	11	12

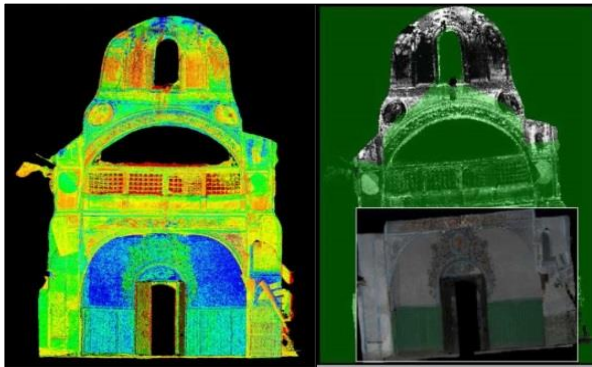


Figure 16. DEM and orthophoto obtained from point clouds of the entrance part (DD' section)

Processes of some parts of AA', BB', CC' sections are the repetition of the processes made for the input section (DD'). The conversion results obtained in the matching of the point clouds and the pictures are given in Table 1. As a result, DEM, orthophotos (pixel sizes 3mm) and drawings of each section were obtained (Figure 17, 18, 19, 20, 21).

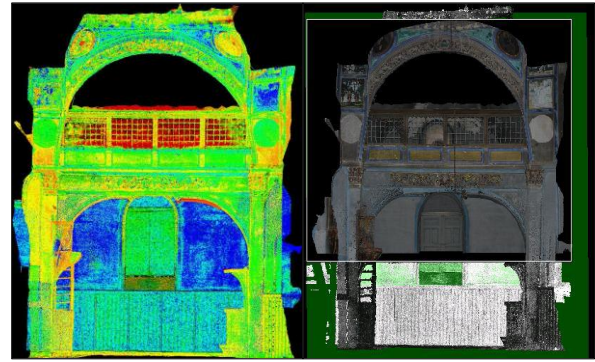


Figure 17. DEM and orthophoto (overlaid on point cloud) obtained from point clouds of AA' section

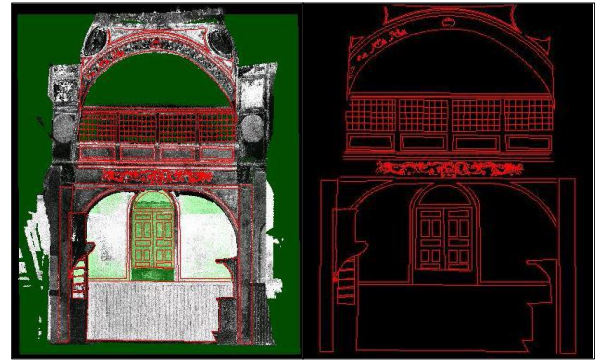


Figure 18. Drawing from point clouds of section AA'

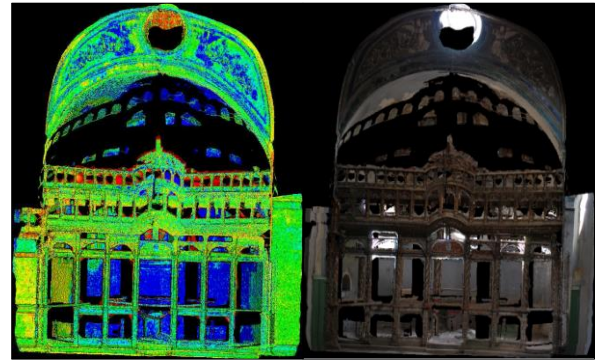


Figure 19. DEM and orthophoto obtained from point clouds of the CC' section



Figure 20. Drawing from point clouds of CC' section

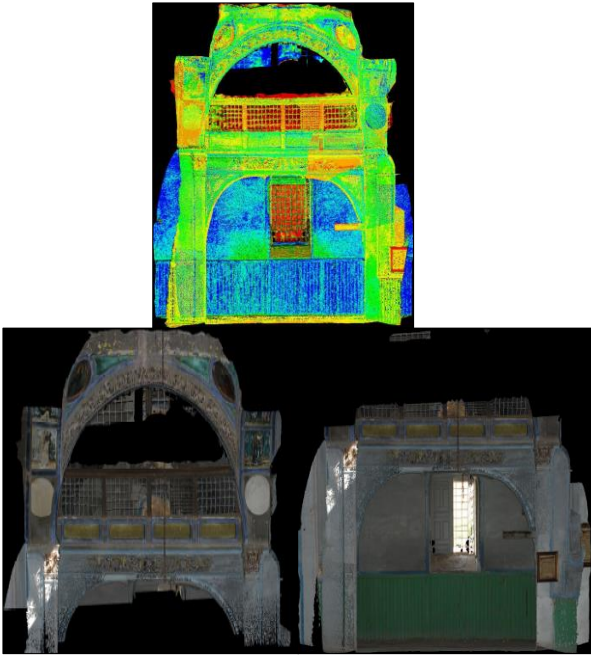


Figure 21. DEM and orthophoto obtained from point clouds of section BB'

Orthophoto mosaic processes were carried out to obtain the orthophotos of the BB' section in one piece. Two orthophoto images are combined in Z-Map software (Figure 22).

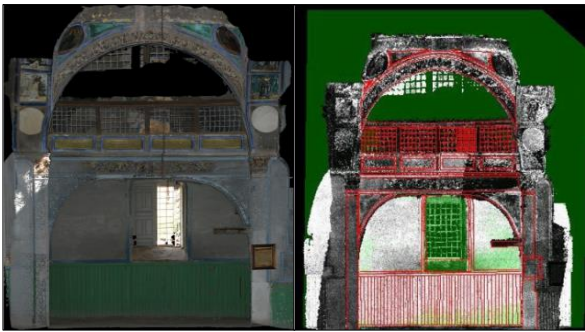


Figure 22. Drawing from mosaic and point clouds of section BB'

In addition to these sections, DEM, orthophoto image (pixel size 1cm) and drawing were obtained with the help of point clouds of an ornament on the ceiling, which is very difficult to reach (Figure 23, 24).

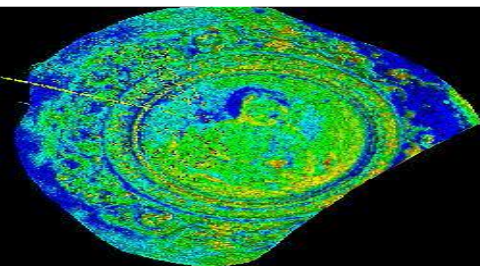


Figure 23. DEM obtained from the point clouds of the ceiling

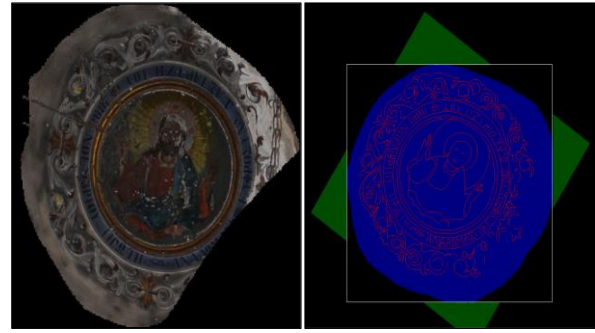


Figure 24. Orthophoto and drawing of the ceiling ornament from point clouds

4. DISCUSSION AND CONCLUSION

Exterior drawings of Sille Aya-i Eleni Church were made separately by the photogrammetric method and combined in the computer environment. The roof pictures of the church were taken with UAV, drawn by the photogrammetric way and combined with other exterior drawings; the 3D model of the object was created. Also, the interior of the church was scanned with a laser scanner, and some sections of its interior were drawn with the help of point clouds and pictures taken from the church.

In restoration projects, approximately 30% of the work consists of statical surveys. The statical survey consists of layout plan, plans, architectural details, exterior sections. In statical surveying studies, narrow street, high roofs, old writings and unsymmetrical detail surveys have difficulty in working. Scanning the interior of the object with the laser scanner made within the scope of the study allows both section drawings and archiving the purpose with its real dimensions. It is perhaps more critical than obtaining a 3D model of the object with its actual dimensions and the most exceptional detail than contributing to the section and exterior drawings. Currently, if there are different thoughts about the object, which is thought to be depicted with specific parts, in the following years, 3D point clouds in the archive can be used easily. We can say that it is not necessary to use laser data in the drawing of exterior facades that are open and without depth, and these drawings can be made efficiently and sufficiently with the photogrammetric method. Drawing with UAV on high and dangerous roofs is an efficient solution. Although it may be possible to bring roofs with lidar data later, it is not recommended now because it is costly in this method. Besides, images that can be taken from UAV can be used in obtaining sections of objects that have difficulties in taking photographs for various reasons (The upper part of the North-East facade in this study).

Both laser scanner data and photogrammetric methods provide an effective solution for studying more specific objects. With these methods, both drawings and orthophotos can be made. Orthophotos also offers an effective solution for

documenting. While studying the object with many details, it should be worked with the expert of the feature and the necessary corrections should be done in the detail drawing. Although effective solutions are offered with both methods, it can be said that drawing is more practical with point clouds when the ease of drawing is taken into consideration. Because to create a 3D coordinate in the photogrammetric method, the same detail point must be overlaid in at least two images (overlay of homologous rays). This process takes time and sometimes causes difficulty in marking the same detail point. However, the drawing of points in the same plane can be easily made in a plane passed through the points whose 3D coordinates known. This process is not recommended as an effective solution for uneven objects. In general, the images of the laser-scanned object are superimposed with hundreds of thousands of 3D point clouds, drawing and orthophoto are obtained. It is possible to say that these products are more accurate than the products obtained as a result of overlaying (made in practice) of a few 3-dimensional points taken with the total station.

Documentation of cultural and historical buildings is of great importance in terms of transferring the content of buildings between societies from generation to generation. For this reason, documenting cultural heritage is equally important. Architectural documentation is a complex process and contains much more information than other disciplines. From this point of view, it is thought that it is not right to document the cultural heritage only with laser scanning technology. Laser scanning is especially suitable for complex surfaces, surface analysis and visualization. However, instead of dealing with the dense point cloud, more straightforward terrestrial photogrammetry technique is recommended on uncomplicated surfaces. In addition to laser scanning technology, it is possible to say that according to the condition of historical buildings, to behave cost and time, UAV can be used on hard-to-reach surfaces, terrestrial photogrammetry technique on surfaces where detail drawing can be easy.

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