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Research Article

PHOTOGRAMMETRIC MODELLING OF SAKAHANE MASJID USING AN UNMANNED AERIAL VEHICLE

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ABSTRACT

Turkey has been home to various cultures and civilizations throughout history. Thus, it is a piece of land that has architecturally maintained the cultural structure of civilizations throughout history. This geography we live in served as a capital to many civilizations to this date. Considered as the birth place of civilization, the Anatolian soils historically accommodated many civilizations. To this end, Konya served as the capital of Anatolian Seljuk Empire between 1086 and 1308. Ergo, this geography houses a vast accumulation of cultural and historical heritage. We owe history a debt to show necessary effort in order to pass down these cultural assets that survived throughout history to future generations. Therefore, documentation and protection of cultural assets are important for them to be passed down from one generation to the other. This article discusses the 3D photogrammetric modelling of Sakahane Masjid from the Anatolian Seljuk Empire era, located in Ferhuniye Neighborhood in Konya Province. A Nikon D90 Camera and DJI Phantom 4 Unmanned Aerial Vehicle were used in taking photographs of the historical artifact for the purposes of 3D photogrammetric modelling. DJI Go 4 and Pix4Dcapture mobile applications were used to capture photographs using the unmanned aerial vehicle. The data obtained were evaluated via Agisoft PhotoScan software and 3D models of the artifact were acquired. The 3D model of the said cultural asset is meant to be a resource for future generations in terms of the protection of cultural heritage. It is foreseen that this model will also provide an opportunity for a faithful restoration in case of any possible damage to this historical artifact, as well as offering solutions to the problems of many professional disciplines today.

Keywords: *Unmanned Aerial Vehicle, 3D Modelling, Photogrammetry, Historical Artifact, Cultural Heritage*

1. INTRODUCTION

The geography we live in has been home to many different cultures and civilizations. Various societies sustained their lives on this soil as part of the said cultures and civilizations. These societies that lived on this land throughout history built assets reflecting their own cultures. These assets, the legacy of history to us, are defined as Cultural Assets. Protecting cultural assets is a duty of mankind in order to display ownership of universal assets and sustain the history. Documentation practices bear a great importance for historical development and protection of cultural assets, as they are aimed at documenting cultural heritage in order to display ownership of the historical values we inherited and make contributions to world heritage.

Cultural and natural heritage face the gradually-growing danger of deperdition due to natural and unnatural causes. Countries with cultural and natural heritage fall short of protecting such heritage owing to a lack of economic, scientific and technical resources. Thus, it is the duty of all nations to share scientific studies and recent techniques for the protection of such cultural heritage. Turkey has been home to various cultures and civilizations, and it showcases the cultural heritage passing down from these civilizations. It is as important for the world cultural heritage as it is for our country to protect these artifacts by meticulously documenting them (Yakar, M., 2011).

Today, documentation procedures for cultural assets can be performed quickly, accurately and in a reliable way thanks to the photogrammetry technique. Since cultural assets have elaborative and detailed architecture, it is necessary to employ state-of-the-art measurement tools and techniques for the documentation of cultural heritage. The 3D model obtained via digital photogrammetry technique can be used in many disciplines. It can be a resource for many professional disciplines in order to come up with solutions to problems that may occur in the future.

In this study, however, the aerial photogrammetry technique was used. Terrestrial photogrammetry technique was also employed to complement aerial photogrammetry. Aerial shots of the cultural asset were taken by unmanned aerial vehicle (UAV) while the facades of the artifact were photographed with a Nikon D90 camera. Tie points were used to link together and relate aerial and terrestrial photographs of the artifact, and a 3D model was then obtained. The study aimed at rendering the 3D model obtained from this study a resource for faithful restoration of the cultural asset following possible future damages, contributing to the promotion of the city as well as the country and, most importantly, protecting and passing down the cultural heritage to future generations.

Since photographs were taken from different altitudes and camera angles above the asset to get a 3D model of the artifact, it is also aspired that this study will serve as a model and guide for upcoming studies as regards the points to be mindful of while creating a 3D model.

2. PROTECTION AND DOCUMENTATION OF CULTURAL ASSETS

Today, there are studies and products that can set the basis for the restoration of the cultural assets we have in our country in the case of damages to and partial or total destruction of cultural assets due to natural disasters such as earthquakes and fire as well as providing new research opportunities for other disciplines. The 3D models obtained via photogrammetry technique constitute an accurate point of reference for administrators of the city and the country alike, facilitating their decision-making process.

The information to be obtained from documentation studies towards the protection of cultural heritage needs to be organized in a way that it will be understood and used by specialists from different disciplines that are to take part in the protection of documents having a variable quality and quantity. Metric, written and visual documentation can be used as baseline data for the determination of current status and problems of cultural heritage and for all protection studies regarding the solutions to these problems, and they are also a way of passing down the cultural heritage to future generations and promoting cultural heritage within the society (Yakar, M., 2015).

The documentation and 3D modelling of cultural assets, the integration of all information on attributes and features through these studies and the employment of cutting-edge technologies to do this contribute to the development of history, the world cultural heritage and the publicity of the city as well as tourism, technology and science within the country.

3. FIELD OF STUDY

3.1. Sakahane Masjid

Sakahane Masjid is the second cultural asset for which a 3D model is prepared. It is located in Sultan Mesut Street of Ferhuniye Neighborhood in Selçuklu District of Konya Province. The coordinates of Sakahane Masjid, a Cultural Asset, are 37°52'30.31" N latitude and 32°29'29.11" E longitude.

It was built by Emir Kemaleddin in 1248 during the era of Anatolian Seljuk Empire. The artifact was registered by Konya Regional Board of Cultural Heritage Protection on November 13, 1982. It was originally built as a masjid and is still used for the same purpose (Gümüş, H., Koçak, F., 2010).

Some research studies suggest that this masjid was the masjid of Konya Alaeddin Darüşşifa (Hospital). The artifact is made up of rubble stone and bricks. The masjid has a square plan with four walls made up of bricks and stone. Rising on these walls is a small brick dome which was later covered with lead. The Turkish triangle was used as pendentive at zones of transition to the dome (Gümüş, H., Koçak, F., 2010).

Sakahane Masjid is also called Şifahane (Hospital). Research shows that it is also named Hızır İlyas Masjid in historical resources.

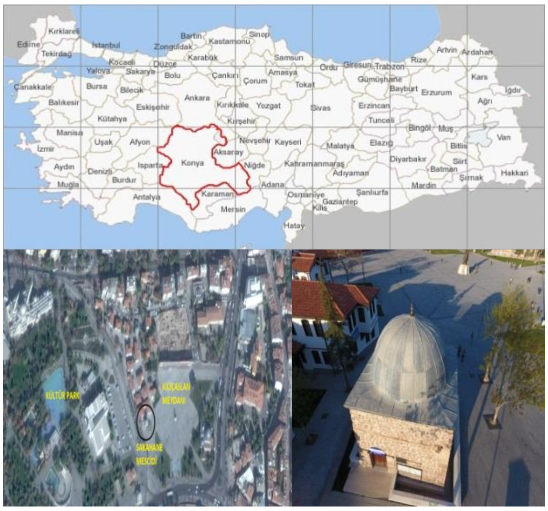

Fig. 1. Location of Sakahane Masjid

3.2. Technical Equipment and Software Used in the Study

For the 3D modelling of cultural assets, a Nikon D90 camera and a DJI Phantom 4 unmanned aerial vehicle were used to capture images. For flying the unmanned aerial vehicle, the DJI Go 4 mobile application was utilized. Weather conditions were monitored via UAV Forecast mobile application to ensure favorable weather conditions were present for flight.

Fig. 2. Nikon D90 camera and DJI Phantom 4 unmanned aerial vehicle

Agisoft PhotoScan software was used for the photogrammetric evaluation of the photos taken.

3.3. Photogrammetric Evaluatıon

In this 3D modelling of the cultural asset, we employed the photogrammetry technique using a DJI Phantom 4 UAV. Moreover, in order to obtain better results from the modelling of the artifact's facades, the terrestrial photogrammetry technique was used with the help of a Nikon D90 camera.

The 3D modelling of Sakahane Masjid via the photogrammetry technique was carried out through field surveys and desktop work. In field surveys, cultural heritage sites were terrestrially and aerially photographed. Since aerial photographs taken with the DJI Phantom 4 contain latitude, longitude and altitude information thanks to IMU, compass and GPS features of the UAV, the model reflects the true coordinates of the cultural asset.

The software used in the evaluation of the photographs creates a calibration report of the camera used. In order to integrate terrestrial and aerial photographs, tie points were determined and photographs corresponding to these points were aligned and matched. Following the alignment process, all information obtained in field surveys and desktop work via photogrammetric software was evaluated.

*3.3.1. **Field Survey for Sakahane Masjid***

For the sake of flying the unmanned aerial vehicle in the field, firstly, the DJI Phantom 4 unmanned aerial vehicle was registered at the Directorate General of Civil Aviation. Then, a flight permit was obtained from Konya Governor's Office and the district police department was provided with information on the location and time of the flight. All these processes are extremely important in terms of public safety as well as flight safety. After the flight permit was obtained and relevant departments were notified, conditions for a safe flight were ensured. In the field surveys for the 3D modelling of Sakahane Masjid, photographs of the historical artifact were taken thanks to the DJI Go 4 mobile application by manually flying DJI Phantom 4 unmanned aerial vehicle. There is a high level of overlapping among the photographs of the cultural heritage. All photographs of the artifact were taken in line with this principle.

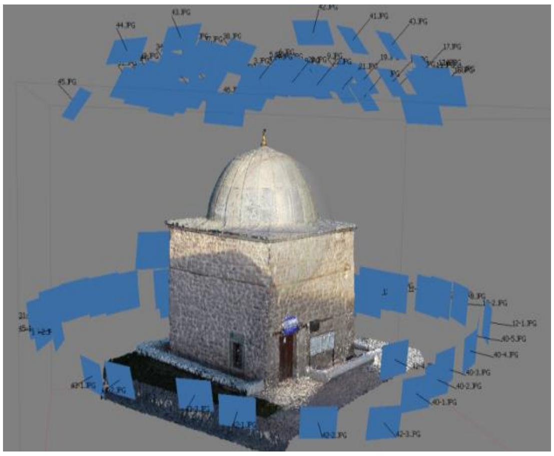

Fig. 3. Overlapping photographs of the artifact

Prior to the flight, UAV Forecast application was used to determine whether the field is fit to fly the unmanned aerial vehicle. This application utilized the information regarding sunrise and sunset time, the speed and direction of the wind, if available, whether the weather is overcast as well as sight distance to determine whether it was a day fit to fly.

Fig. 4. Checking weather conditions for flight

After making sure that the weather conditions were fit for flight, we went on to the field to take photographs. The unmanned aerial vehicle was matched with the DJI Go 4 mobile application prior to the flight. The Compass and IMU of the unmanned aerial vehicle were calibrated. These calibrations are important as they ensure the unmanned aerial vehicle vertically suspends in the air in a stable manner without vibrating.

The Compass is calibrated by rotating the unmanned aerial vehicle 360° around its own axis both horizontally and vertically.

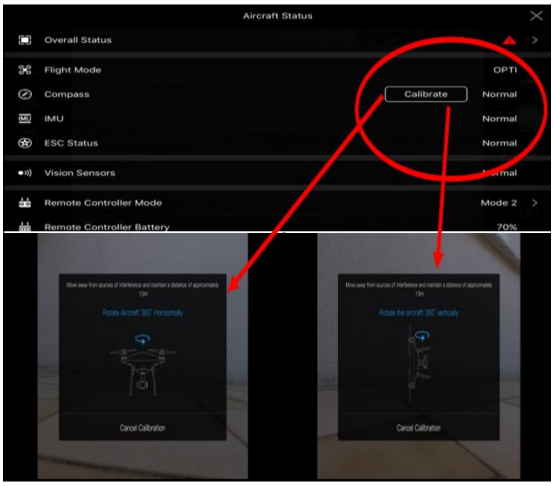

Fig. 5. Calibrating the compass of the unmanned aerial vehicle

The compass calibration was followed by the calibration of the IMU. The IMU helps stabilize the unmanned aerial vehicle especially in windy weather conditions and eliminates drift errors in photographs. The calibration process took approximately 5 minutes.

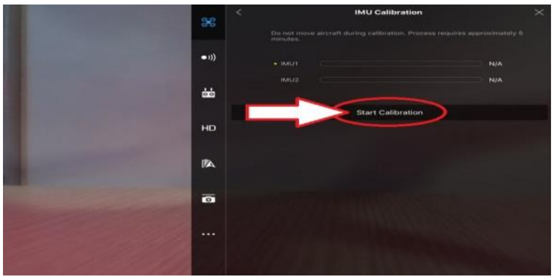

Fig. 6. Calibrating the IMU of the unmanned aerial vehicle

After obtaining the required permits for the field of flight, it was determined that the field of flight was fit for flying the unmanned aerial vehicle. Completing the required IMU and Compass calibrations, we flew the UAV. Photographs of Sakahane Masjid were taken by the manually-controlled unmanned aerial vehicle. Each facade of the cultural heritage was photographed, ensuring a high overlapping rate. Aerial photographs were supported by terrestrial photographs taken with the Nikon D90 camera.

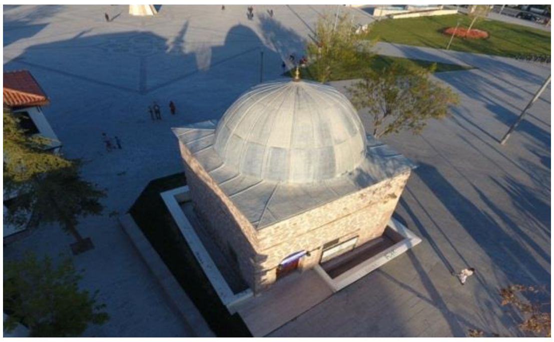

Fig. 7. Aerial photographs of Sakahane Masjid

The accuracy of geographical coordinates of Sakahane Masjid photographs which were taken by the unmanned aerial vehicle was checked via Google Earth. The program allows for conversion into the national coordinate system at a later time. Thus, the final model is produced with coordinates.

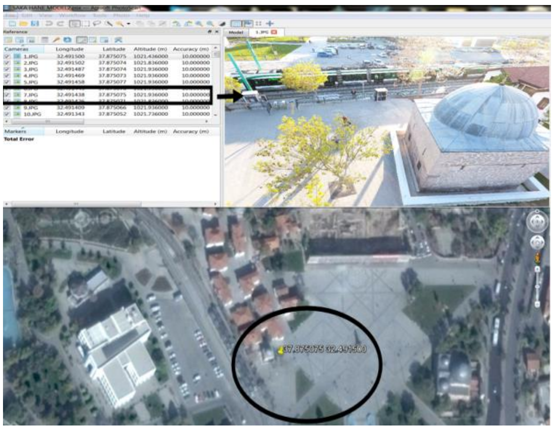

Fig. 8. Consistency of photograph and satellite coordinates

Field surveys for Sakahane Masjid were thus completed. The next stage involved the desktop work regarding the 3D modelling of the cultural assets. Photographs were processed with Agisoft PhotoScan software and the 3D models of the historical artifacts were obtained as an end product.

*3.3.2. **Desktop Work for Sakahane Masjid***

Photographs of Sakahane Masjid were evaluated with the Agisoft PhotoScan software. First, the photographs were aligned with a high overlapping rate.

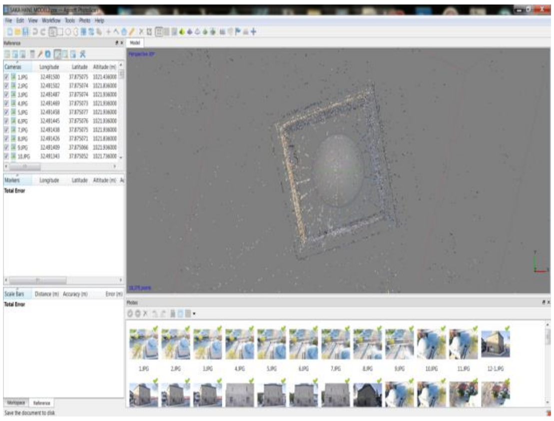

Fig. 9. Alignment of Sakahane Masjid photographs

The aligned photographs helped acquire a point cloud via the high overlapping rate. The second step was to build a dense point cloud. Workflow - Build Dense Cloud – High – Mild option sequence was followed. This process took 8 hours and 7 minutes. As a result, 9.043,919 point clouds were generated.

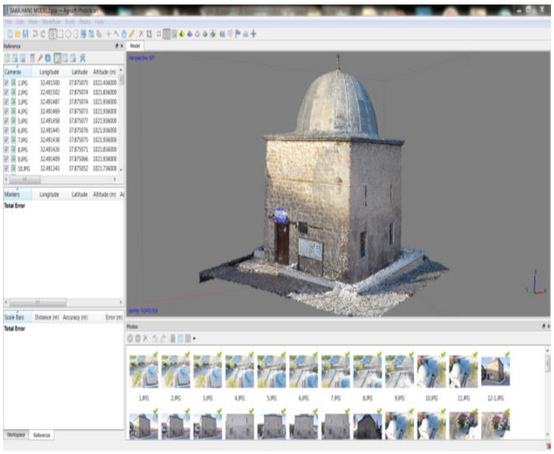

Fig. 10. Building a dense cloud for Sakahane Masjid

Following the completion of building the dense cloud, Workflow-Build Mesh option sequence was followed in order to create a solid model of the dense cloud. Generally, in building modelling, Arbitrary - Dense Cloud - High option sequence was followed and a solid model was obtained by choosing Enabled in Interpolation tab.

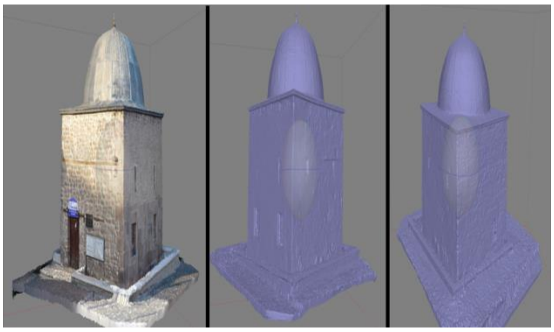

Fig. 11. Solid Model Creation - Build Mesh - Triangle Model (Build Mesh)

Following the Build Mesh process, Workflow - Build Texture option sequence enabled the texture building. In this study, Adaptive Orthophoto (used for vertical texture building) - Mosaic and Enable Color Correction options were used. Following the process, texture building for the solid model was completed.

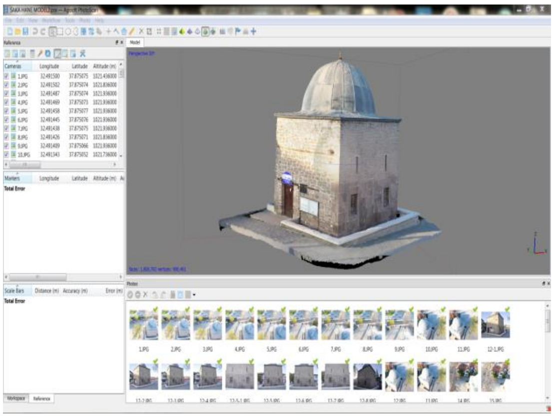

Fig. 12. Texture building for the solid model

In order to obtain a high-quality look for the details and the meshes of the object, the Build Tiled Model option was chosen from the Workflow menu. The 3D model of Sakahane Masjid then involved coordinates.

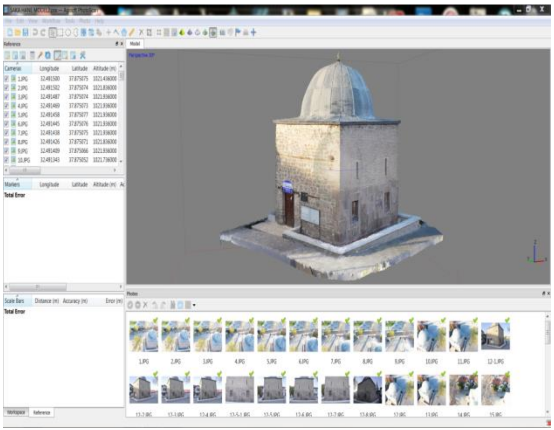

Fig. 13. General view of the 3D model (Build Tiled Model)

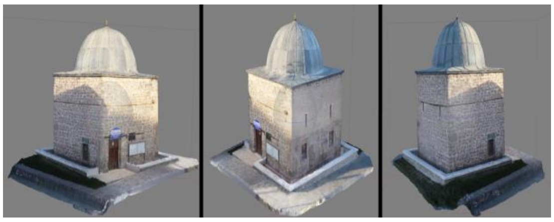

Fig. 14. Facade views of the 3D model (Build Tiled Model)

4. FINDINGS

During the study, the following issues regarding the creation of better models in 3D modelling via unmanned aerial vehicle were determined.

• There must be an adequate number of oblique photographs of the objects and details in suitable positions regarding the objects for which 3D models will be produced. Photographs must be taken in a way to ensure a high overlapping rate.

• It is preferable to take the photographs when the sun is close to setting or after the sun rises in order for the artifact not to be shadowed. This way, the modelled artifact cannot have one shady facade while another one is bright.

• The ambient amount of light around the artifact to be modelled should be sufficient. Details of the artifact cannot be seen clearly under dark and insufficient ambient light.

• Attention should be paid to homogeneously distributing the tie points on the object which are placed in order to relate the photographs to each other.

• It is of crucial importance for 3D modelling that the alignment of photographs is done with a high overlapping rate via Agisoft PhotoScan software.

• During the densification of the point cloud obtained through alignment of the photographs, the densest point setting should be selected while the mild setting be opted for in building modelling.

5. CONCLUSION

In this study, 3D models of Sakahane Masjid, which is located in Ferhuniye Neighborhood of Selçuklu District in Konya Province, were produced. The 3D modelling consists of two stages, namely field survey and desktop work. A Nikon D90 camera and a DJI Phantom 4 unmanned aerial vehicle were used to take photographs of the historical artifacts. Photographs taken were evaluated with Agisoft PhotoScan software. Since the photographs taken by unmanned aerial vehicle contain geographical coordinates, the model also involved the information on coordinates.

This 3D model belongs to a historical artifact which has survived since the era of the Anatolian Seljuk Empire and bears an important historical value for our country. It is a significant cultural asset for both our country and state. Thus, I intend that this study emerges as a future resource for both our country and the world cultural heritage for a faithful restoration of such historical artifacts. This study constitutes a reliable and accurate resource for faithful restoration practices against deformation that might be observed in relation to the historical artifact due to possible natural disasters or physical interventions.

The study we have conducted also contributed to creating documentation on cultural assets across the country.

ACKNOWLEDGEMENTS

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