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Data Fusion of Unmanned Aerial Vehicle (UAV)-Based Photogrammetry and Close-Range Photogrammetry in Historical Sites Monitoring

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ABSTRACT

There are various methods for monitoring historical sites ranging from classical drawing techniques to, classical surveying techniques etc. Along with developing technology, modern methods have become more preferable to classical methods. In this context, UAV-based photogrammetry and close-range photogrammetry appear as popular methods for historical sites monitoring and documentation studies. It can be said that each method has its own advantages and disadvantages. In this study, a historical monument was modeled by using UAV-based photogrammetry and close-range photogrammetry. Then, two models were integrated with each other in order to have a complete representation of the object to be modeled. The metric accuracy of the resulted model was also investigated.

1. INTRODUCTION

Photogrammetry is the process of determining shape and location of an object through image interpretations and measurements.

Usually, it is divided into two categories as close-range photogrammetry and aerial photogrammetry. In close-range photogrammetry, images are acquired from the locations near or on the surface of the earth. The close-range photogrammetric data provide detailed dimensional information of objects. In contrast, aerial photogrammetric data are collected via overhead shots from an aircraft and provides land use details (Jiang, Jáuregui, & White, 2008).

UAV photogrammetry introduces new application areas such as new real time applications to classical manned aerial photogrammetry with being able to combine both aerial and terrestrial photogrammetry.

Unmanned Aerial Vehicles (UAVs) have many different usage areas ranging from Computer Science to Robotics, Artificial Intelligence, Photogrammetry, and Remote Sensing. In addition, the terms such as Remotely Piloted Vehicle (RPV) or Unmanned Vehicle Systems (UVS) can be used in place of UAVs. RPV can be described as a robotic aircraft controlled by a human using a ground controller. The term UAV photogrammetry stands for a system that is remotely operated semi-autonomously or autonomously without having a human-being inside the vehicle. The systems also include a photogrammetric measurement platform which consists of video, thermal or infrared camera systems, airborne LIDAR or combination of both systems. Today, the registration and the determination of the position and orientation of the sensors carried by the UAV platforms are possible in a local or global reference system. Therefore, UAV photogrammetry can be accepted as a new photogrammetric measurement tool. There are various advantages of UAVs in comparison with classical aerial photogrammetry. The first advantage can be shown as the availability of operating in dangerous and inaccessible sites without endangering pilots. Such situations can be listed as, reaching the natural hazard zones such as floods, volcanic eruptions, earthquakes, etc. In this case, UAVs can be the only solution where reaching disaster sites is nearly impossible. This situation indicates the importance of UAVs in such cases. Besides, UAVs can fly and acquire data in low-altitudes which is not possible in classical manned photogrammetry. On the other hand, UAVs are both time and cost-efficient (Eisenbeiß, 2009). UAV technology is also a popular choice for historical sites monitoring and modeling studies due to being able to

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produce high resolution and geo-tagged images (Themistocleous, Ioannides, Agapiou, & Hadjimitsis, 2015).

Close-range photogrammetry is a valuable tool for three-dimensional (3D) modelling with its long history. In recent years, there have been many important changes and growth in the close-range photogrammetric measurement area (Fraser & Hanley, 2004).

In this study, two point clouds were produced by using UAV and close-range photogrammetric images in Agisoft Photoscan software. Then, two point clouds were integrated in 3DF Zephyr software. The resulted point cloud was also examined.

2. METHOD

2.1. Close-Range Photogrammetry

Photogrammetry is basically a method which produces shape and location information of an object from photographs through measurement and image interpretation. In principle, it can be said that, photogrammetric techniques can be used in any situation where the photographs of the objects to be measured can be taken. The main objective of the photogrammetric process is to produce a 3D reconstruction of the object to be measured. Photographs or images which are the results of the photogrammetric process, supply information that can be used at any time (Luhmann, Robson, Kyle, & Harley, 2007).

The close-range photogrammetric survey is divided into two phases such as field work and office work. During the field work phase of the study, total of 106 photographs of Fountain of Ahmed III were captured, later 80 of them were used for 3D modeling process. The images were captured by using Nikon Coolpix A10 digital camera featured a 16.1 megapixel 1/2.3" CCD sensor. As the next step of field work, 4 Ground Control Points (GCPs) were established around the fountain. These GCPs were later used for bringing two models in a common reference system. The 3D coordinates of established GCPs were measured in Continuously Operating GNSS Kinematic Reference Stations System (CORS-TR) with Trimble R6 GNSS receiver in UTM projection, ITRF-96 datum (EPSG:5255), GRS80 ellipsoid, 2005.0 epoch and 3-degree zone 30. 81 detail points in total were determined on the facades of the fountain. 41 of the detail points were printed paper targets while remaining 40 points were selected from characteristic points of the fountain such as corners, eaves bottoms, etc. A tacheometric measurement was carried out by the use of Pentax R-1505N electronic tacheometer in order to determine the 3D coordinates of the detail points. The coordinates of detail points were calculated on Netcad software with respect to GCPs by using angle and distance measurements obtained from tacheometric measurements. In this way, both GCPs and each detail points were brought in a common reference system. 17 of detail points were used in geo-referencing of the close-range photogrammetric 3D model (Figure 1).

Figure 1. Detail points from one facade used for the geo-referencing in close-range photogrammetry

During the office work process of close-range photogrammetric survey, camera calibration parameters were determined at first by using Agisoft Lens software (Figure 2 & 3).

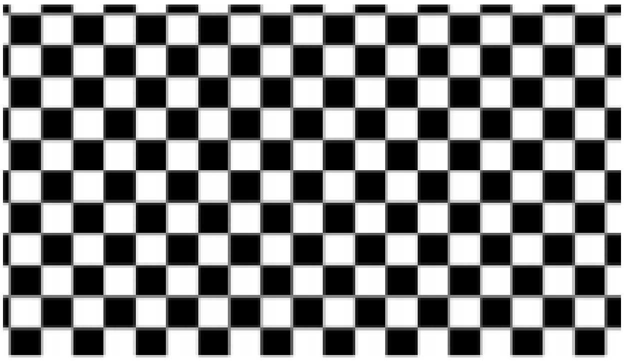

Figure 2. Agisoft Lens software calibration chessboard

Parameter	Value	Std Error
Image width	4608	
Image height	3456	
Focal length (x)	3547.47	1.50455
Focal length (y)	3547.61	1.46078
Principal point (x)	2353.24	0.743895
Principal point (y)	1775.38	0.604964
Skew	1.99832	0.11242
Radial K1	-0.0527827	0.00276451
Radial K2	0.548142	0.0186619
Radial K3	-1.4373	0.0496565
Radial K4	1.21602	0.00203453
Tangential P1	0.00363844	5.37707e-05
Tangential P2	0.00344985	6.89058e-05

Figure 3. Camera calibration in Agisoft Lens

Then, these parameters were imported into Agisoft Photoscan software. As the last step of the office work, the point cloud and textured model were produced by processing the photogrammetric data in Agisoft Photoscan software. The point cloud consists of approximately 12 million points and the textured model of the monument were obtained as a result of the close-range photogrammetric survey (Figure 4 & 5).

Figure 4. Point cloud produced after close-range photogrammetric survey

Figure 5. Textured model

2.2. UAV Photogrammetry

UAV-based photogrammetric survey is divided into two phases as well as the close-range photogrammetric survey such as field work and office work. During the field work process, a double grid mission flight plan for 100 m flight height was created in Pix4D Capture software and total of 48 photographs were captured by using Parrot Anafi UAV. The flight took approximately 10 minutes around the fountain. Due to obstacles around the artifact such as walls of Hagia Sophia Mosque and Topkapı Palace, acquiring data from facades of the object in double grid mission was not possible. Therefore, only roof of the fountain was documented by using UAV photogrammetry. In office work process, 48 images were processed in order to obtain point cloud in Agisoft Photoscan software. The 3D coordinates of the GCPs were used for geo-referencing the model. The resulted point cloud can be seen in figures 6 and 7.

Figure 6. Point cloud obtained from UAV imagery

Figure 7. Point cloud obtained from UAV imagery

2.3. Data Fusion

Data fusion (also known as data integration), is the process of combining data, acquired by using different sources or sensors. The fusion data coming from different sensors are generally acquired at different resolutions. On the other hand, the both data represent the same object for obtaining a complete and accurate representation of the object to be modeled. Data fusion can be classified as low, intermediate or high with respect to processing stage at which fusion takes place (Klein, 2004; Ramos & Remondino, 2015).

Since the two point clouds are in a common reference system, both of them were imported in 3DF Zephyr software and integrated with each other as shown in figure 8. Thus, a complete model of the monument was obtained.

Figure 8. The resulted point cloud after data fusion

2.4. Accuracy Assessment

In order to determine the accuracy of the resulted model; 15 distances in total were measured on the model between selected detail points. The distances were also calculated using 3D coordinates obtained by GNSS and electronic tacheometer measurements. The calculated distances were imported to Agisoft Photoscan software. The accuracy of the model is found ± 6.72 cm after creating scale bars between selected detail points.

3. RESULTS

In this study, a close-range photogrammetric and UAV-based photogrammetric surveys carried out respectively.

Fountain of Ahmed III was selected for the 3D reconstruction (Figure 9). The fountain was built in 1729 by the Sultan Ahmet III, upon the proposal of the grand vizier Nevşehirli Damat İbrahim Pasha. It is located in front of the Bab-ı Hümayun gate of Topkapı Palace in Fatih district of Istanbul.

Figure 9. Selected monument for the 3D reconstruction

Two separate models were generated in Agisoft Photoscan software by using UAV and close-range photogrammetric images. Acquiring images from the facades of the monument was not possible due to walls of Hagia Sophia Mosque and Topkapı Palace in double grid mission UAV survey. Therefore, the facades were acquired from the close-range photogrammetric survey. The two models were integrated for obtaining a complete 3D model of the monument. In order to integrate these models, each model should be in a common reference system. GNSS and tacheometric measurements were carried out in order to bring two models in the same reference system. Thus, the point clouds were integrated in 3DF Zephyr software. Then, accuracy of the resulted model was investigated by measuring the distances between selected detail points on the facades and comparing them with the ground truth data. The accuracy of the model is found ± 6.72 cm.

4. CONCLUSION

Documentation of cultural heritage elements is very important in terms of preserving and transferring them to future generations. In this context, many different methods have been used from past to present. Close-range photogrammetry and UAV photogrammetry can be shown as two of these methods.

It is seen that, the close-range photogrammetry is successful in documenting the facades of the monuments, while it cannot represent the roofs completely. In such cases, UAV photogrammetry can be a great solution since it can acquire data from the above. Hence, the both data can be integrated with each other in order to obtain a complete 3D model of the historical monuments.

Metric accuracy is one of the most important factors in the documentation of cultural heritage. The accuracy is extremely crucial in order to renew the building in accordance with its original situation and to create the models of the building properly and correctly. It has been observed that the 3D model obtained can be used as a base for the documentation and preservation of cultural heritage. These models play an important role in the restoration works as well as determining the deformations that will occur on the historical artifacts. In conclusion, it is thought that this study, which is examined for the purpose of documentation of cultural heritage, can contribute to studies in the field of preservation, photogrammetry and data fusion.

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