Mersin Photogrammetry Journal

https://dergipark.org.tr/tr/pub/mephoj

e-ISSN 2687-654X

3D modelling of bridges by UAV photogrammetry method

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Keywords
3D Model
UAV
Photogrammetry
Historical Bridges

ABSTRACT

Protection and documentation of cultural and historic heritages are very important issue in Turkey as it is important in the world. Lots of cultural and historic heritage are damaged because of indifference and natural effects. Determination and documentation of current situation of these heritages are important for conserving and the possible renewal works. Digital terrestrial photogrammetry is an important method in documentation of cultural and historical heritage. In this case, a photogrammetric surveying for documentation of the Roman Bridge of Silifke has been managed in Mersin province. The control points have been measured via GNSS device to prepare surveying project as a base for restoration studies and to create 3D point data and photomodel. 3D model of the ancient site has been generated by using PhotoScan programme.

1. INTRODUCTION

According to UNESCO, heritage is what we have left from the past, what we live today and that we will pass onto future generations. In Convention Concerning the Protection of the World Cultural and Natural Heritage of UNESCO (1972) decisions have been made on the definition, conservation and funding of cultural and natural heritage (Unesco 1972). Increasingly, cultural heritage is threatened with extinction or destruction, both for natural and human reasons. With the development of transportation and communication technologies around the world in the last fifty years, more contacts have been established among the peoples of the world. As a result, tourism activities have increased considerably and also continuing to increase. Therefore, the preservation of cultural heritage is an important responsibility for countries as well as an important place in terms of increasing tourism revenues. Cultural heritage must be protected from the destruction caused by natural disasters and wars, as well as from the corrosive factor of time (Yakar and Şasi, 2018). Nothing can resist time and eventually it gets worn out and lose its integrity. For this reason, it is necessary to carry out renovation and restoration works in certain periods in order to protect the cultural heritage that sheds light on the past of mankind and accumulates continuously. Renovation works become a necessity especially in historical buildings that are exposed to the corrosive and abrasive effects of nature. Many historical buildings are kept out of use today and maintained within the sheltered areas. However, most of these heritages should be renewed by restoration. There are also historical buildings (bridges, castles, palaces, mansions, amphitheaters) which are still in use, and it is of vital importance that all the procedures to manage in order to be protect them are carried out properly.

The first step to be taken for conservation, renewal and consolidation works starts with documentation. The architectural survey, which use as a base for restoration and restitution work are important for documentation and inventory studies. The fact that the survey will be used as a base is an indication that the studies need to be completed with high precision and accuracy. Photogrammetry technique has been used for archaeological and historical building measurements for years by providing high accuracy and precision. With the development of digital image processing techniques and algorithms, 3D models of structures have been created and used in many studies such as research, documentation and renovation. The photogrammetry technique makes use of terrestrial

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DOI: XXXXXXXXXXXX/Research Article

Cite this article

DOĞAN, Y . (2019). 3D MODELLING OF BRIDGES BY UAV PHOTOGRAMMETRY METHOD. Mersin Photogrammetry Journal , 1 (1) , 7-11

Retrieved from https://dergipark.org.tr/tr/pub/mephoj/issue/50329/636328
Received: 22/10/2019; Accepted: 19/11/2019

measurement techniques to create photo models over the overlapping photographs of the object. The photomodel is a three-dimensional geometric model (usually a CAD-Vector model) covered with photographic texture on the surface of the object. (Kraus, 2007). Three-dimensional point clouds of objects are created by SfM (Structure from Motion) method, which is one of the commonly used image processing algorithms, in addition to the photo models created by drawing on adjusted photographs. The point cloud obtained from photo pairs also has RGB (Red-Green-Blue) color values and a photo model is created by passing the surface through this point cloud. With the help of these 3D models, it is aimed to produce the surveys of structures or objects in a healthier way.

Unmanned Aerial Vehicle (UAV) technology developed in the last decade has increased the access to UAVs and their ease of use has led them to be widely used in photogrammetry studies. UAVs stands out in terms of flexible usage, cost and time (Ulvi and Toprak, 2016; Akar, 2017). Photogrammetry technique has been applied to UAV technology rapidly since it has been applied by using aerial photographs for last hundred years.

2. MATERIAL AND METHOD

2.1. Material

2.1.1. Field of study

The bridge is on the Göksu (Kalykadnos) River, which runs through the center of Silifke city center. The bridge was built by the governor of Cilicia L. Octavius Memor in the years 77-78 in the name of the emperor Vespasianus and his sons Titus and Domaitianus. It was understood from the stone inscription found during the restoration by Silifke Governor Mehmet Ali Pasha in 1870 (Çalışkan ve ark., 2009). In the repair, bridge was destroyed except the three arcs of the north side and rebuilt with help of people's money and bread, and wall barriers were placed on both side (Bakar ve Demir). In 1972, asphalt was poured over the bridge scope of expansion works and it was made suitable for vehicle transition. In 2016, the restoration decision was taken due to the fraying of the feet of the bridge and the works were started. After the restoration is completed, the bridge is planned to be closed to vehicle traffic and opened only for pedestrian crossing (Silifke Municipalitiy, 2017).

Figure 1. Position of the Roman Bridge in the city

2.1.2. Data gathered equipment

Photos were taken with DJI Phantom 3 Standard UAV with a 12 MP (4000x3000) resolution camera. The 3-axis gimbal of the UAV prevents the vibration of the camera connected to it with sensitivity to be within ± 0.02º tilted vibration range.

Figure 2. DJI Phantom 3 Standard UAV

The communication distance of the vehicle, which can reach a maximum height of 6000 m, is approximately 120 m. The weight of the vehicle is 1216 g and depending on the weather conditions, the flight time is approximately 25 minutes and can reach speeds up to 16 m / s. In addition, the vehicle has an internal GPS receiver and the position accuracy range is ± 1.5 m in the horizontal and ± 0.5 m in the vertical. The camera is equipped with a 1 / 2.3" CMOS sensor and aperture f / 2.8, FOV (Field of View) 94º, focal length 20 mm (35 mm equivalent) lens (DJI-Co., 2017).

Figure 3. South S82-V GNSS

Ground Control Points were measured with the South S82-V GNSS instrument by connecting to TUSAGA-Active CORS System. The device can use all signals of 6 different GNSS systems (GPS, GLONASS, BeiDou, Galileo, QZSS and SBAS). Post-Process accuracy of the device:
Static & Fast Static

- Horizontal: 2.5 mm ± 0.5 ppm
- Vertical: 5 mm ± 0.5 ppm (GeoTeknik-San.Ltd.Şti, 2014)

2.2. Method

2.2.1. Field experiment

The points determined by land reconnaissance have been established by marking the land so that it can be easily seen in aerial photographs. Care has been taken to distribute the GCPs homogeneously across the terrain. The number of GCPs varies according to the size of the object or land, and six points were established on the bridge in our study.

Figure 4. View of GCPs in aerial photos

Images of the bridge were taken by DJI Phantom 3 Standard UAV (Figure 2 and 4). Since the camera angles can be changed between 0º and 90º degrees, so images of the object can be obtained from any angle and sharp. The device saves these images to the micro SD card on the camera and the images are instantly displayed via mobile applications compatible with the device.

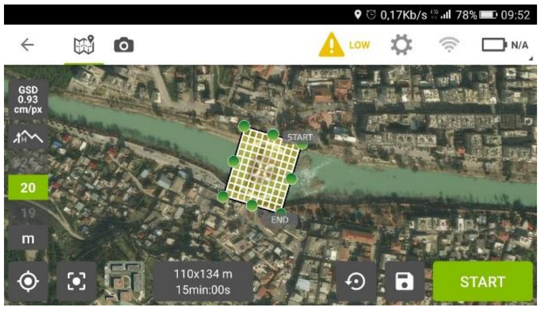

Figure 5. Flight plan made via Pix4D Capture mobile app

Object images were taken with double grid mode to produce a better 3D model (Figure 5). With this mode, the UAV performs its duty by taking oblique photographs by flying horizontally in both north-south and east-west directions. However, in order to obtain a more detailed image of the object, photographs of the side surfaces of the bridge were obtained by manual flight (Figure 6).

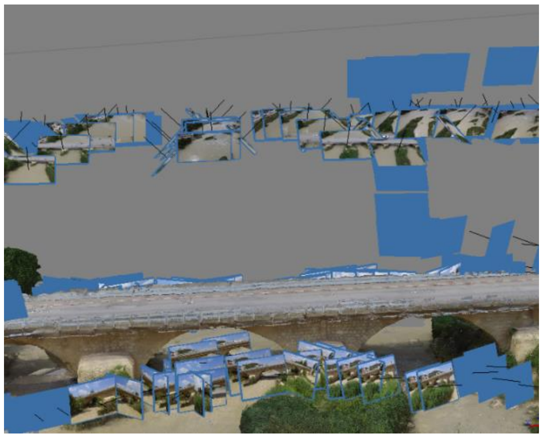

Figure 6. Double grid and manuelly taken photos

In order to obtain 3D data, two photographs must be taken minimum 60% overlap. Due to the unfavorable terrain conditions, photographs were taken with manual flight instead of automatic flight plan. Therefore, since it is not possible to manually adjust the overlap ratio, the photographs are taken at 1 m intervals in horizontal and vertical movements. This has enabled us to obtain an overlap rates of more than 60% (Fig. 7).

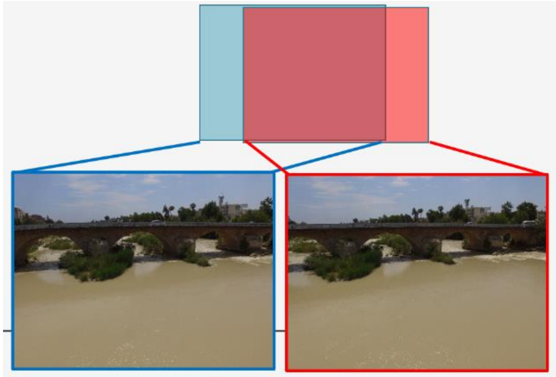

Figure 7. Overlapped images of the West side of the bridge

2.2.2. Office experiment

Agisoft PhotoScan software was used for the evaluation of the images. This program allows the creation of georeferenced point cloud, texture surface model, digital elevation model and orthophoto-mosaic using a series of overlapped photographs and location coordinates (Agisoft, 2019).

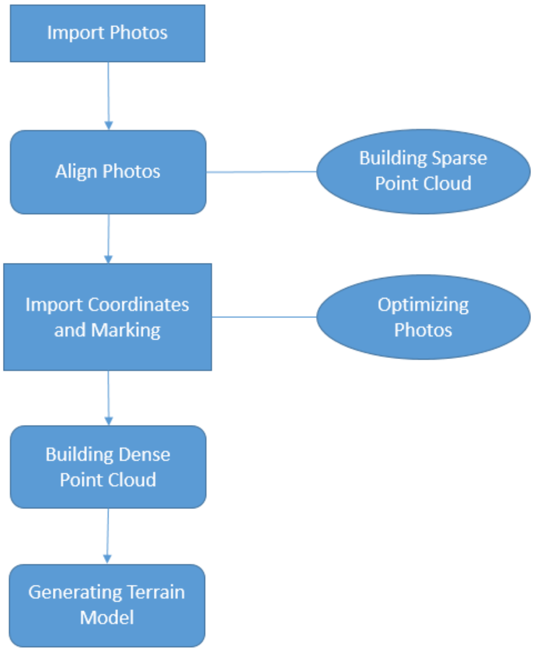

Figure 8. Workflow in the software

As seen in the workflow chart (Fig. 8), GCP coordinates and aerial photographs obtained from the field were imported to Agisoft PhotoScan. Without knowing the camera calibration parameters, the program firstly found common points from photo pairs to align the photos and create a point cloud (Fig. 9).

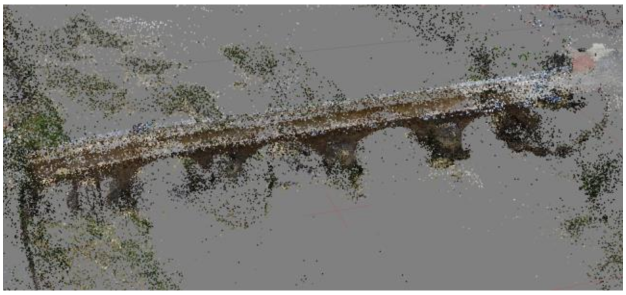

Figure 9. Sparse point cloud

The program calculated the camera calibration parameters from the images at this stage. Then, GCP coordinates were imported to the program and they were marked on the photographs. The photos were optimized to bring the point cloud to a high accuracy position. After this stage, a dense point cloud was created (Fig. 10). 3D digital model was generated by using dense point cloud (Fig. 11 and 12).

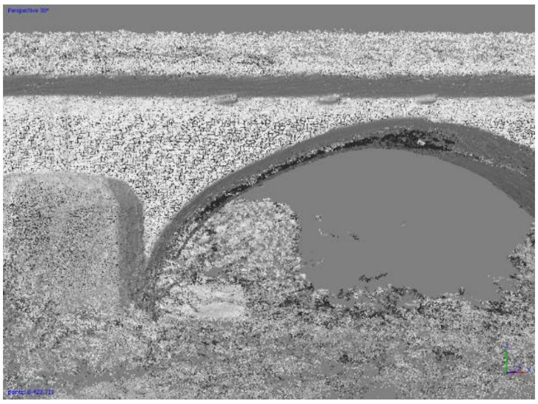

Figure 10. Dense Point Cloud

Figure 11. 3D Digital Model of the Roman Bridge

Figure 12. Textured 3D Digital Model of the Roman Bridge

3. CONCLUSION

In this study, ground control points were taken with GNSS position measurement device in order to form a three dimensional model of Silifke Roman Bridge by photogrammetric method. The most important pillar of the photogrammetric study was obtained by the rotary wing UAV. Since the UAV flights in the settlements are subject to legal permission, the flights have been carried out with the permission of the local government since the bridge is located in the city center. Since the bridge has a lot of people and vehicle traffic, it was understood that more calm times should be preferred for photographing and images were taken accordingly. Photogrammetric image processing algorithms match photographs to fixed points on them. Since objects such as people and vehicles are moving, it has been seen to cause errors in the image processing step. So images taken at quieter hours have been processed. The results show that for high-precision and accurate 3D modeling of bridges, it is necessary to take images from the most suitable location with appropriate light. UAV systems are advantageous in photogrammetry due to their flexible use and ability to capture images from any position. The appearance of the bottom of the arches of the bridges increases the value of this advantage. The view of the bridges increases the value of this advantageous position. Thus, it is advantageous to provide detailed measured drawing for restitution and restoration works.

ACKNOWLEDMENT

We would like to thank Mersin University Scientific Research Projects Unit for supporting this project with the project no. 2018-3-AP4-3036.

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