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Documentation of cultural heritage by photogrammetric methods: a case study of Aba's Monumental Tomb

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ABSTRACT

Because of its geographical location, Turkey has hosted various civilizations. As a result, our country has a diverse cultural heritage inventory derived from the civilizations it hosts and the civilizations that it interacts. In terms of cultural heritage protection, preserving these assets and transmitting them to the future generations is critical. Ground and weather conditions, material degradation, natural disasters, fire, war, and misuse can all cause significant damage to these objects over time. It is vital to document the artifacts in such circumstances in order to conserve them and transfer them to the future generations. In order to transfer the cultural heritage to future generations, technological instruments and procedures are utilized to document existing artifacts and structures. Within the scope of this study, the UAV photogrammetry method was used to create the 3D point data and solid model of the Monumental Tomb of Aba built in the 2nd century AD, located in the Kanlıdivane region of Mersin province in Turkey. Images were taken with Parrot Anafi HDR unmanned aerial vehicle and a 3D model was produced. Combination errors of the photographs were also calculated and it was shown in the results that they were at an acceptable level.

1. Introduction

Aba's Monumental Tomb, which is an ancient artifact, built in the 2nd century AD and located in the Kanlıdivane region of the Mersin province of Turkey, has coordinates 36° 31' 38.5" north, 34° 10' 37.4" east. The location of the tomb is shown in Fig. 1.

Figure 1. Location of the Aba's Monumental Tomb

It is the most magnificent mausoleum of Kanytella. According to the inscription on the door of this monumental tomb, which was built in the type of Roman temples. It was built by a woman named Aba for herself and her husband Arios. The tomb monument was built on a low podium. There is a vaulted entrance on the front facade. There are Corinthian plaster caps on the four corners of the tomb. The tomb is dated to the 2nd century AD based on the inscription on it and other tombs (Turkey Culture Portal 2021).

The Monumental Tomb of Aba can be found north of the geological pit in the region. It is one of Kanlıdivane's most well-known landmarks. The building's principal construction method is cut stone masonry, with mortar as the binding material. The roof of the superstructure is shaped like a gable and is coated in stone. It's supported by a cut-stone barrel vault, which is subsequently filled

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with rubble stone to create a flat roof surface. The vault marks the main chamber's entrance on the south facade, which is topped by a pediment at roof level (Naycı 2020).

The last row of cut-stones in masonry walls was built in architrave style, with Corinth capital styling on the corner stones. Although the architectural integrity of the building has been retained, there are serious issues with the scale of the structure. The west and north walls, in particular, have material deterioration and structural deformations. On the north wall, there are serious fissures that have split the stone components in half. This graphic depicts the likelihood of a high impulse being triggered by lateral pressures or settlement issues. The structural degradation danger has been confirmed by external forces because the monument is placed extremely close to one of the site's geological discontinuity lines. The monument should be included in an architectural conservation program as soon as possible, before it loses its structural integrity, as it is one of the few examples of architectural and structural unity that still exists (Naycı 2020).

UAV photogrammetry is one of the methods widely used within the scope of documentation of cultural heritage. Generating a three-dimensional model of Gözne Castle, a medieval castle (Çelik et al. 2020), obtaining a 3D photogrammetric model of a historical inn (Yakar and Yılmaz 2008) are some of the examples of documenting cultural heritage with photogrammetric methods.

In a study, Roman tombs were examined in detail and the features of the mausoleum of Aba at Kanytellis were comprehensively presented (Mörel 2019).

2. METHOD

This study consists of two phases, namely field and office work. The steps of controlling the study area, preparing it for photographing and taking images of the monumental tomb with an unmanned aerial vehicle constitute the field study phase. In the office work phase, the steps of transferring the data received from the unmanned aerial vehicle to the computer environment and interpreting and processing were carried out.

2.1. Field Work Phase

At this stage of the study, first of all, necessary permissions were obtained to fly in the Kanlıdivane region, which is the study area. Then, the flight altitudes at which images will be taken around the tomb were determined. Images were taken with a Parrot Anafi HDR drone by manually.

UAV based modelling technique has been widely used since last decade such as landslide site modelling (Kusak et al. 2021), rockfall site modelling (Alptekin et al. 2019), shoreline detection (Unel et al. 2020), soil erosion mapping (Yılmaz et al. 2012) and pond volume measurement (Alptekin and Yakar 2020).

Figure 2. Parrot Anafi HDR UAV

The technical specifications of the unmanned aerial vehicle used are shown in Table 1:

Table 1. Technical specifications of the UAV (Parrot 2021)

Feature	Value
Drone	
Size folded	244x67x65 mm
Size unfolded	175x240x65 mm
Weight	320 g
Max transmission range	4km with controller
Max flight time	25 min
Max horizontal speed	15 m/s
Max vertical speed	4 m/s
Max wind resistance	50 km/h
Service ceiling	4500m above sea level
Operating temperature	-10°C to 40°C
Lens	
Sensor	1/2.4'' CMOS
Aperture	f/2.4
Focal length (35 mm eq.)	23-69 mm (photo)
Depth of field	1.5 m - ∞
ISO range	100-3200
Digital zoom	up to 3x (4K Cinema, 4K UHD, FHD)
Photo resolution	21MP (5344x4016) / 4:3 / 84° HFOV

The circumference of the mausoleum, which is approximately 50 km away from Mersin, is roughly 31.5 meters, and its sitting area is around 61 square meters. Every detail of the structure was tried to be captured by flying first at low altitude and then at high altitude. A total of 101 images were taken. Some of the images of the monumental tomb taken are shown in Fig. 3.

Figure 3. Images of Aba's Monumental Tomb

Camera calibration was done beforehand in photo shoots and no changes were made to the parameters. A smartphone was used together with the remote control during photo acquisitions. FreeFlight 6 and Pix4dcapture applications have been installed in order for the smartphone and the remote to work integrated.

2.2. Camera calibration

The camera used must be calibrated beforehand so that the merging and overlay operations of the images can be of high accuracy. It was mentioned in the previous section that there is a 5.92 mm sensor in the unmanned aerial vehicle used in this study. Images have a size of 4608x3456 pixels. Camera calibration was done in ContextCapture software. "Fig. 4" shows the distortion parameters obtained as a result of camera calibration:

	Focal Length [mm]	Focal Length Equivalent 35 mm [mm]	Principal Point X [pixels]	Principal Point Y [pixels]	K1	K2	K3	P1	P2
Previous Values	4.00	24.32							
Optimized Values	3.83	23.30	2323.59	1729.81	-0.0019	0.0078	-0.0069	0.0034	0.0003
Difference Previous / Optimized	-0.17	-1.02							

Figure 4. Camera calibration parameters

2.3. Office work phase

After the completion of the image acquisition within the scope of the field work, the office work phase was started. First of all, the data obtained from the field were transferred to the computer environment. The image file obtained after the flight took up 457 MB in total. Data processing was done in Bentley's ContextCapture software. The office work, which was started after half a day of field work, was completed in one day. The positions of the images taken relative to the mausoleum are shown in Fig. 5.

All the photos taken were used in the processes. Generic block type was chosen for the aerotriangulation process of the images based on experience from previous studies. No control point was used in this study. Positioning metadata of the images were utilized for rigid registration. High key points density option was selected. This step took only 5 minutes and 17 seconds. In the aerotriangulation process, 45125 tie points were formed. 31719 keypoints per image were detected by the software. Overlay error values of the photos are presented in the results section.

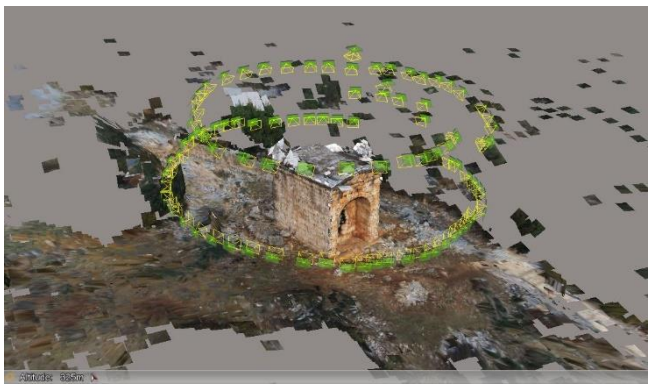

Figure 5. The positions of the images taken

After aerotriangulation step, reconstruction process was initiated by generic selection of matching pairs. Extra geometric precision (tolerance of 0.5 pixel in input photos) option was applied. In order not to deviate from the original geometry of the tomb, small hole-filling option was implemented. Finally, in this step, the spatial frame is reduced, avoiding the modeling of unnecessary regions and the use of excessive computer power. After the aerotriangulation process, it took 37 minutes and 31 seconds to obtain the 3D solid model. Computer used in processes has Intel(R) Core(TM) i7-7700HQ CPU @2.81GHz processor, 16 GB of RAM capacity and GeForce Nvidia 1050 Ti 4 GB graphics card.

3. Results and discussion

After the camera calibration, field studies and office work phases were completed, a 3D solid model of the Aba's Monumental Tomb was obtained. The surface texture was created by using photographs to add visuality to the obtained 3D solid model. Texture compression quality was selected as 100% quality and texture sharpening option was enabled. The three-dimensional model of Aba's Monumental Tomb is presented in Fig. 6.

The resulting 3D model is in one-to-one scale with the real work. While length measurements can be taken on the model, area and volume calculations can be made at the same time.

As a continuation of this study, it is planned to compare photogrammetric data with terrestrial laser scanner data. As a result of the comparison, which method is more suitable for such works will be evaluated in terms of cost, time, efficiency and applicability.

4. Conclusion

In this study, Aba's Monumental Tomb, which is an ancient artifact built in the 2nd century AD and located in the Kanlıdivane region of the Mersin province of Turkey was modeled in 3D using UAV photogrammetry. As a result of obtaining a real-scale model of this artifact, which is of great importance in terms of cultural heritage, the documentation process has been carried out. The

data obtained in this study can be used in possible studies by anthropologists, archaeologists and historians. The real-scale 3D model obtained can be utilized in the restoration and repair studies. The 3D model obtained within the scope of this study will also allow the promotion of the work within the scope of tourism activities.

Figure 6. 3D solid model of Aba's Monumental Tomb

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