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# The use of UAV and photogrammetry in digital documentation

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Harran Bazilica Church
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Point Cloud
DEM
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**ABSTRACT**

Today, UAVs are used in a wide range of applications. Used as a data collection platform in the scope of cartography, UAVs are used extensively in the small working areas especially due to the fast, accurate, low cost, high resolution and ease of periodic measurements. Thanks to its advantages, the UAVs used in different disciplines are being used together with different sensors day by day and enabling new application areas. In this study, application of UAV with camera mounted in the archaeological area of Harran district of Şanliurfa is explained. The study was carried out on the ruins in the excavation area of the town of Harran. The UAV flight was chosen because the Harran Bazilica Church in the North-Northeast of the region and the small mosque ruins in the southeast of the church have not yet started excavations. It is aimed to figure out the remains found in the archaeological excavation areas, modeling of the discovered remains and the topographical structure of the land. It is thought that the result products of the study may be a base for the excavation and restitution procedures to be performed in the region.

## 1. INTRODUCTION

Nowadays, the records made with the sensors mounted on an unmanned aerial vehicle (UAV) have been used in many areas. UAVs have been used to document archaeological and cultural heritage due to their easy use in obtaining fast, accurate, low cost, high resolution and periodic measurements in small work areas (Agapiou and Lysandrou, 2015; Konstantinos et al., 2017; Field et al., 2017). In addition, UAVs are more preferred in contact with archaeological sites in areas where transportation and accommodation are at risk of damage to archaeological samples, as contactless measurement can be realized. (Avdan et al., 2014). This study was carried out on the ruins of the excavation area of the Harran District of Sanliurfa Province. In the North-Northeast of the region where a single flight was performed by UAV, there are remains of the Harran Basilica Church and the Small Mosque in the southeast of this church. It has been determined that the products obtained from the study area can be used to determine the residual quantities found in archaeological excavation areas, to model the uncovered remains and to create the topographic structure of the land (Uysal et al., 2015). In addition, these products can be used to document the work done before and after the restitution studies in the region.

## 2. STUDY AREA

The study was carried out on the ruins in the excavation area of the town of Harran in Sanliurfa. Seton Lloyd and William Brice first investigated this region in Harran by Seton Lloyd and William Brice in the first volume of Anatolian Studies titled Journal of the British Institute of Archeology in Ankara. The great interest and attention are given to the ruins of Harran were not met with suspicion that the city had old connotations of the Mesopotamian lunar cult. From the past to the present, it was revealed that the fact that the ruins of Harran were excluded from the relevance of the archaeologists could have originated from the geographical location of this region. Many references to Harran, either in his own name or in Carrhae's classic outfit, emerge throughout Mesopotamia, Rome, and medieval Arabic literature, and it is argued that Harran's ruins have a strong historical personality, with virtually no

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reference. Many archaeologists have been investigated in the region, but it has not been brought to light perfectly (Lloyd and Brice, 1951). This region was visited frequently by Chesney's on his Euphrates trips and by the British missionary G. P. Badger in the middle of the last century (Chesney, 1850). In 1879, Sachau drew the shape of the ruins and made important interpretations of the architectural remains (Sachau, 1883). In 2015, by the permission of the Ministry of Culture and Tourism, Prof. Dr. Mehmet ÖNAL and his archaeology team started excavation in the Harran region on behalf of the Ministry and Harran University (Figure 1).

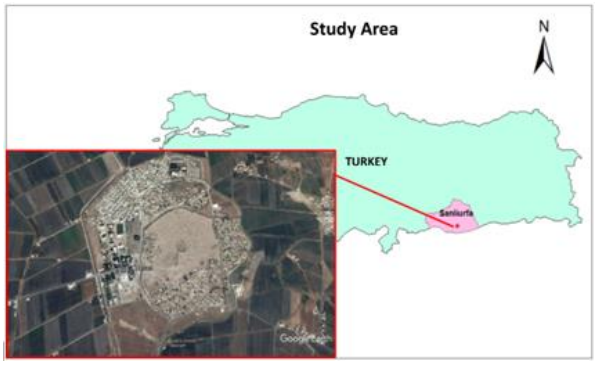


**Figure 1.** Satellite view of the region of Harran Ruins (Google Earth 2016).

Harran Basilica Church, which has not yet begun excavation works in the North-Northeast of the region where a single flight was carried out with the UAV, and the region that contains the remains of Small Mosques in the southeast of this church were selected. In this study, the reason why Harran Basilica Church and Small Mosque remains was chosen because there is no study on these remains yet and the remains are not moved from their places and the human effects are less than the other areas.

## 3. METHODOLOGY

In this study, UAV, which is fully automatic flight capable after the take-off, is used with the model named TurkUAV Okto V3 produced by Robonik Mechatronics Technologies company. According to the prepared flight plan, the UAV was manually ventilated without entering the excavation site, and according to the predetermined route, photographs of the archaeological study area were obtained automatically and downloaded manually. Photo shooting was performed using the Sony RX100II compact camera with a 20.2MP resolution placed underneath the UAV. The technical data of the unmanned aircraft and the camera are shown in Figure 2 and Figure 3, respectively.

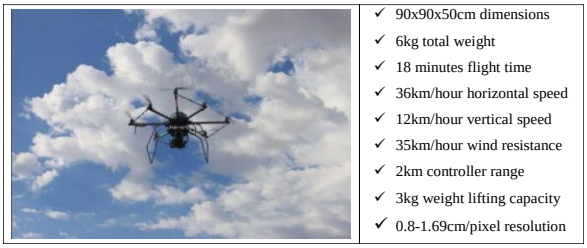


**Figure 2.** Technical specifications of TurkUAV Okto V3 UAV.


**Figure 3.** Technical specifications of the Sony RX100II compact camera.

### 3.1. Flight Plan Preparation

Multiple parameters should be taken into consideration when working with UAVs. First of all, the flight plan should be done well and the scenarios of any errors that may arise should be reviewed carefully. The weather conditions (temperature, pressure, humidity) at the time of flight of the region should be checked. In order to identify the obstacles that may be encountered in the area where the flight will take place, it is necessary to check the dangerous high objects on the land by going to the area before the flight. A flat surface should be chosen as far as possible for the UAV to be able to take off smoothly. Before starting the flight, pre-flight preparations should be checked step by step and then the flight should be started.

The flight plan of the land was prepared in the office before the data collection process with the UAV. The flight plan was prepared with TurkUAV Ground Station v2.1.0, which is the control software of the UAV. The ground sample distance (GSD) was calculated as 0.62cm/pixel for a flight height of 30m. The image overlay ratios of the images to be captured are set at 80% width and 60% longitudinal overlap. After all the controls were completed, the flight was carried out. The flight lasted 12 minutes and a total of 352 pictures were taken. At this stage, the coordinates of the midpoints of the image were first adjusted (Figure 4a), from the common pixels in the superimposed images, to the surface point cloud produced (Figure 4b) and with that the image overlays (Figure 4c) can be controlled.

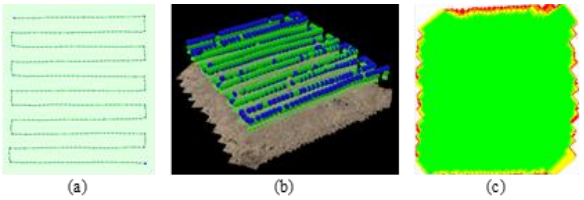


**Figure 4.** Adjusted coordinates of aerial photographs (a), point cloud (b) and image overlays of the land surface (c).

Coordinates in the pixels are minimized when the coordinate values of the aerial photographs and the pixel values of the midpoints of the pictures are adjusted. Then the point cloud produced from the point of the objects to be taken, the determination of the amount of excavation can be done with more accurate measures. Finally, the digital elevation model (DEM) and ortho-mosaic production were performed.

### 3.2. Processing the Data of UAV

After the flight, the blurred photos were taken from the data set. In order to use the images obtained as a result of flight with UAV, it is necessary to correct the errors caused by the difference in the curvature, rotation and height of the photographs and to be made into an orthogonal projection (Avdan et al., 2014). These errors are corrected, and digital images are converted into orthogonal views called orthophoto.

The coordinates obtained from the UAV and the coordinates of the shooting points of the photographs are related to the images obtained in this study using the ground control software. The data were evaluated with Pix4D software. As a result of the processing of the images with the software, Digital Surface Model (DSM), orthophoto image and point cloud data as well as the volume information of the remains can be obtained. After the ground control station and photo midpoints coordinated at the time of flight, the data processing of Pix4D was performed with 3 steps. First, initial processing was performed and a low-resolution orthophoto and digital terrain model was created (Figure 5a and 5b).

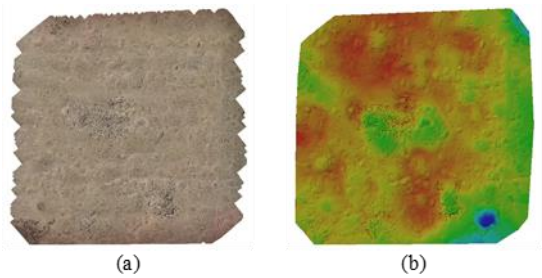


**Figure 5.** Low-resolution orthophoto (a) and digital terrain model obtained from initial data processing (b).

Since the resulting products are low-resolution in the first stage, they are only used to see the preview of the application area. Then the Point Cloud Densification phase has started.

In order to get the non-ground ruins which are stones in our case, an empirical roughness analysis was performed. The followed procedure is relatively easy. In roughness analysis, it was assumed that, the 'roughness' value for each point is equal to the distance between this point and the best fitting plane computed on its nearest neighbors (URL-1, 2019). In this way, a local height difference allows us to detect the above ground stones.

## 4. APPLICATIONS

The Digital elevation model of the area is generated as the first product of the study (Figures 6).

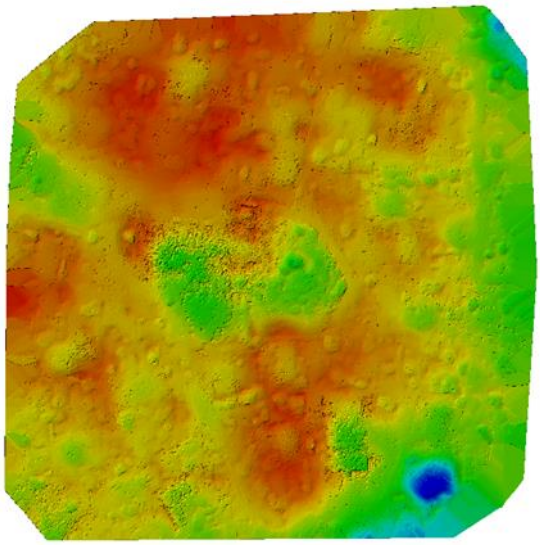

**Figure 6.** Digital elevation model of the ruins of Harran Basilica Church and a Small Mosque.

After the digital elevation model is produced, the height change of each object in the working area is determined. The regions with red areas are the highest and the blue areas are the lowest parts of this area. In the digital elevation model, the ruins of the Harran Basilica Church (Figure 6a) and the Small Mosque (Figure 6b) were enclosed in black dashed squares, respectively.

After the digital terrain model is produced, the height change of the working area is determined. The regions with red areas are the highest and the blue areas are the lowest. In the digital terrain model, the ruins of the Harran Basilica Church (Figure 7a) and the Small Mosque (Figure 7b) were enclosed in black dashed squares, respectively.

**Figure 7.** An orthophoto view of the Harran Basilica Church and the ruins of the Small Mosque.

After the orthophoto image was obtained, the heights of the land were reduced, and the measurements taken from this image were the same as the real values in the field. The positions of the ruins of the Harran Basilica Church (Figure 7a) and the Small Mosque (Figure 7b) in the orthophoto image were enclosed in black dashed lines, respectively. After the production of the digital elevation model, a digital terrain model and orthophoto image of the study area, modelling of remains in the region can be made. The modelling process is carried out by a method called surface mesh. Figure 8 and Figure 9 show the mesh models of the Harran Basilica Church and Small Mosque remains, respectively.

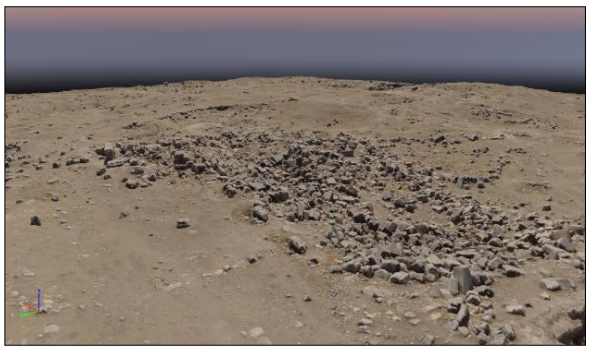

**Figure 8.** The mesh model of the ruins of the Harran Basilica Church.

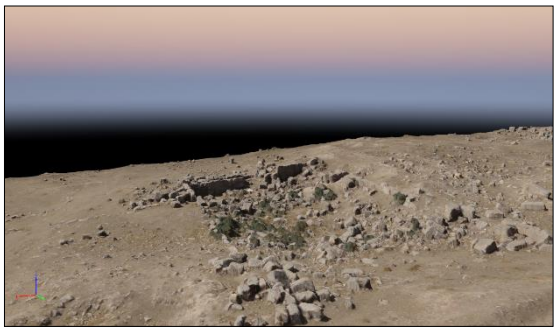

**Figure 9.** The mesh model of the remains of a Small Mosque.

After the meshing process, we can get some measurements from the Harran Basilica Church and Small Mosque ruins. The produced point cloud and surfaces contain the location information of each detail on the land and their area and volume calculations can be made easily with the Pix4D software. Finally, in our application, we determined the results of the area and the volume of the area covered by the Harran Basilica Church and the remains of Small Mosques (Figure 10 and Figure 11).

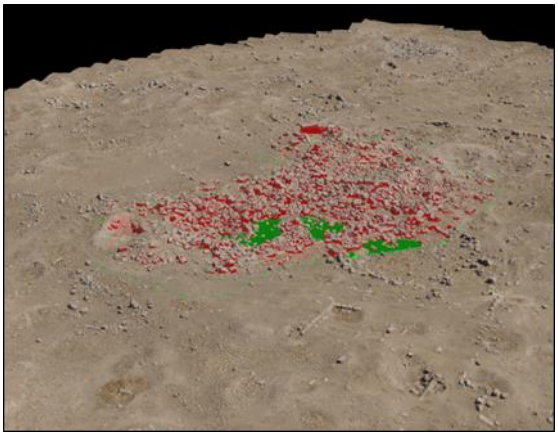

**Figure 10.** The area and volume of Harran Basilica Church ruin.

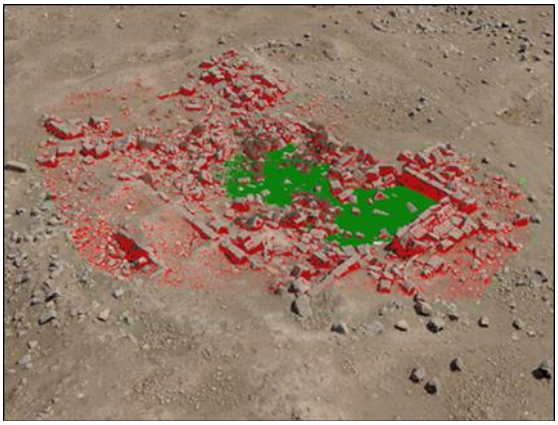

**Figure 11.** The area and volume of Harran Small Mosque remain in the field.

As seen in Figures 10 and 11, the area and volume occupied by the Harran Basilica Church and Small Mosque remain on the land surface. The surrounding area was marked by the software as green after surrounding the remains. Elevations in this green area were marked as red in the determination of the remains on the land. When the green areas are taken as a reference to the height at the lowest point of the remains, the volume of the objects remaining above this area can approximate the total amount of objects in the residue area. According to this study, the area covered by the ruins of the Harran Basilica Church is approximately 2061m2 and the approximate volume of the remains on the land is calculated as 1766m3. The area covered by the ruins of the Harran Small Mosque is approximately 916m2 and the approximate volume of the ruins is 610m3. According to these results, it is possible to calculate the approximate volume and the approximate area with UAV flights to be made on the archaeological excavation areas. Roughness analysis was performed to figure out the stone remains in the study area. Neighborhood parameters were used for analysis at different radii. In this study, the analysis made for the ruins of the Basilica Church, the radius was selected 0.75m and in the analysis for the remains of the Small Mosque, the radius was selected as 0.50m. Surface roughness analysis results for Harran Bazilika Church and Small Mosque are given in Figure 12 and Figure 13.

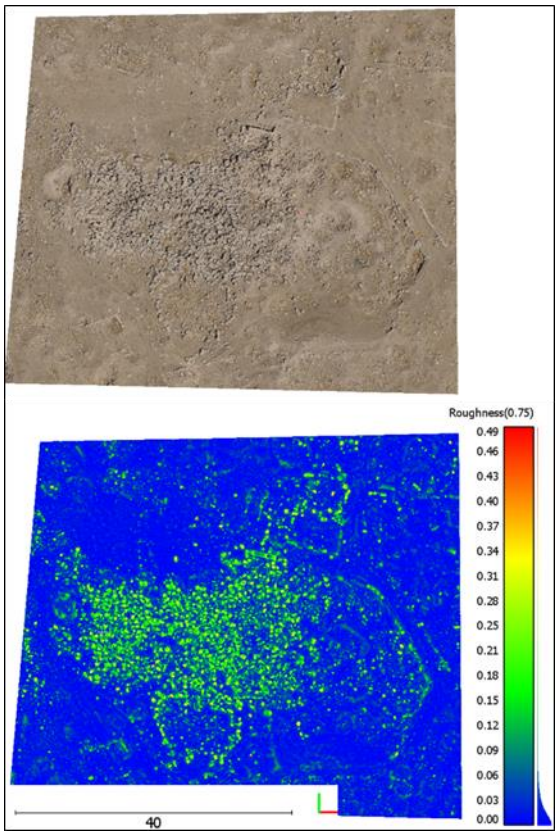


**Figure 12.** Surface roughness analysis of the Harran Basilica Church.

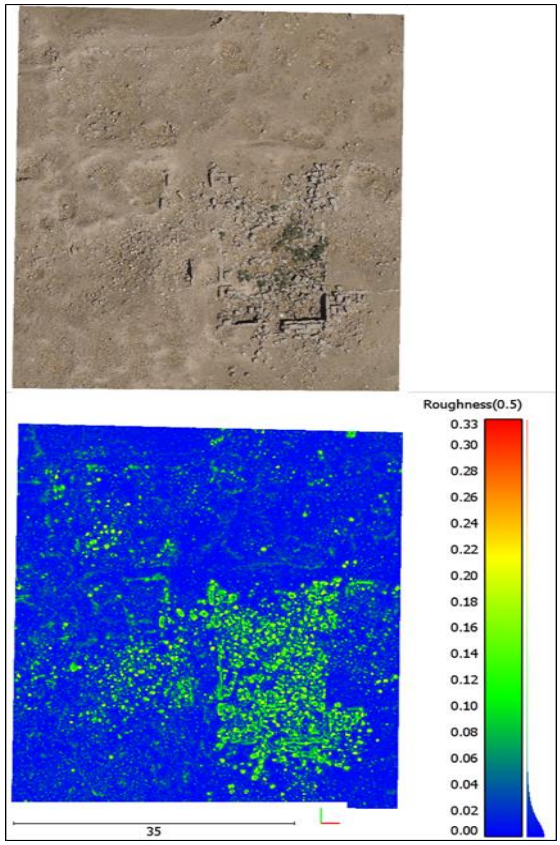


**Figure 13.** Surface roughness analysis of Small Mosque.

The roughness analysis is respectively successful to detect above ground objects. As it seen in Figure 12 and 13 roughness scale, the average size for stones are 21cm and 14cm for Harran Bazilika Church and Small Mosque respectively. But still needs an improvement to fully detect all stones.

## 5. RESULTS

As a result of the study, point cloud production, surface creation of the area, orthophoto map of the study area, digital elevation and digital terrain models were prepared. At the end of the study, the products obtained by using the images captured with UAVs; can be used in archaeological excavation areas as the determination and modelling of the amount of land, the formation of the topographic structure of the land, before and after the restitution operations. In this context, the Harran Region has archaeological importance. At the same time, the works to be carried out here will have great economic and cultural contributions to the locals. The study will shed light on the future of archaeological importance. It is of great importance to document the historical artefacts of the study and it is used as one of the most effective methods used in transferring works to future generations. As a result of such studies, the model will create a visual element and inherit realistic data in the future.

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