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CONTENTS

Volume 1 - Issue 1

RESEARCH ARTICLES

** Modeling of Historical Fountains by Using Close-Range Photogrammetric Techniques

Ali ULVİ, Abdurahman Yasin YİĞİT, Murat YAKAR 1

**3D Modelling of Bridges by UAV Photogrammetry Method

Yusuf Doğan 7

** Mapping of A Rockfall Site with An Unmanned Aerial Vehicle

Aydın Alptekin, Mehmet Özgür Çelik, Yusuf Doğan, Murat Yakar 12

** The Use of UAV and Photogrammetry in Digital Documentation

Mustafa Ulukavak, Abdulkadir Memduhoğlu, Halil İbrahim Şenol, Nizar Polat 17

** Excavation Monitoring with UAV in Şanliurfa Castle Archaeological Site

Mustafa Ulukavak, Abdulkadir Memduhoğlu, Halil İbrahim Şenol, Nizar Polat 23

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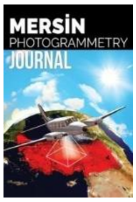
https://dergipark.org.tr/tr/pub/mephoj

e-ISSN 2687-654X



Modeling of historical fountains by using close-range photogrammetric techniques

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Keywords
Historical artifacts
Photogrammetry
Close-Range photogrammetry
Documentation
3D Model

ABSTRACT

It is inevitable to see historical monuments in every geography where man exists. Most of the architectural monuments that have witnessed history have been completely or partially destroyed for different reasons. Especially natural disasters such as earthquakes, floods, and fires, as well as wars, misuse and unconscious use cause these damages. Architectural monuments bearing the traces of history are one of the most important means of transferring history to future generations. The preservation and transfer of this cultural heritage to new generations are one of the common tasks of all peoples in the world. In this context, with the developing technology, efforts to document the cultural heritage in the digital platform in 3D have accelerated. There are many 3D modeling methods in the literature. Photogrammetry technique, which is one of the 3D modeling methods, enables us to create photo-realistic models. The photogrammetry technique gives more meaningful results in terms of speed and accuracy compared to traditional methods. This study involves the production and documentation of a 3D model of historical fountains by using close-range photogrammetry.

1. INTRODUCTION

Historical artifacts are a cultural heritage that includes all experiences from past to present. Cultural heritage is a historical monument with certain criteria (witnessing a different tradition, the product of creative human genius, representing one or more, etc.), that are protected and transmitted for the benefit of future generations (URL1). Cultural heritages represent the bond between people from the past to the present and to the future. Cultural heritage reflects the history and essence of humanity and ensures the continuity of traditions and diversity. Cultural heritage can contain many concepts. A cultural heritage that reflects the dusty pages of history can be grouped under three main headings: concrete, abstract and natural cultural heritage.

Tangible Cultural Assets: It is divided into two groups as movable and immovable heritage. Monuments, sculptures, paintings, archaeological works, inscriptions, books, landscapes and so on.

Intangible Cultural Assets: Folklore, traditions, language, oral history, etc.

Natural Heritage: Culturally important landscapes and biodiversity (URL2).

2. THE IMPORTANCE OF DOCUMENTATİON OF HİSTORİCAL ARTEFACTS

Ever since humanity began to play a role in the history scene, artifacts that trace of history in every geography has emerged. There are more historical monuments, especially in areas where access to minimum living requirements and opportunities (food, housing, education, etc.) is easy. Therefore, as the cradle of civilizations, there are many cultural and historical heritages on Anatolian lands. Documentation and preservation of cultural assets that have hundreds of years of knowledge of many peoples and which must be hand down the next generations are indispensable (Uslu et al, 2016).

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Throughout history, due to the, and natural richness it has housed, different communities have existed in Anatolia. In Today's in the Republic of Turkey (Anatolia Region) at the end of the year 2018, by The Ministry of Culture and Tourism 108813 units, the immovable asset was registered as a cultural asset.

Table 1. 2018 year-end distribution of immovable cultural assets located in Turkey (URL3)

The registered immovable cultural property in Turkey	Real estate count
Example of Civil Architecture	69.104
Religious Structures	10.147
Cultural Structures	12.53
Administrative Structures	2.985
Military Structures	1.252
Industrial and Commercial Structures	4.171
Cemeteries	5.169
Martyrdoms	307
Monuments And Landmarks	375
Ruins	2.702
Streets Protected	71

Destruction of cultural heritage due to natural disasters or human factors, making recompenses as a result of damage, knowing where they belong to the missed works, preserving their original features and keeping them back in their original places is very important (Demirkesen et al, 2005). It is possible to transfer historical works including all phases of history and giving us any clues about history to future generations through healthy documentation. Documentation of historical or cultural structure covers the entire steps which are necessary for determining the current state of the structure (shape and position) in three-dimensional space that are surveys, process, storage and presentation (Georgopoulos and Ioannidis, 2004).

3. DOCUMENTATION METHODS

Documentation can be defined as the determination of the current status of cultural assets in different scales and qualities (drawings, plans or other graphic narration, photographs, digitized documents, etc.). Information about the state of the structure or area at the time of study and the documentation stage at which the document is produced form the basis of the whole process. Today, different techniques are used in the documentation of cultural heritage and this issue is developing rapidly in parallel with technological developments. In addition to producing information on various physical, social, economic, cultural and historical aspects of cultural assets in different qualities and scales, processing and converting the produced data into usable information is an indispensable requirement for protection. General documentation techniques are shown in figure 1 (Pakben, 2013).

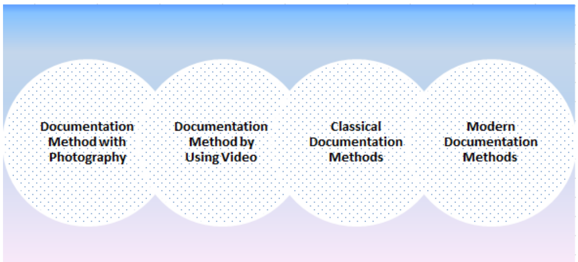

Figure 1. General documentation techniques

3.1. Documentation Method with Photography

Photography is a means of communication. The rules for detecting messages also apply to the detection of a photo. It is natural for people living in different cultures to perceive the same message differently. Especially the indicators with symbolic meanings have different meanings according to cultural characteristics (Bodur, 2006).

As a visual text, the product photo should be able to identify the product correctly and effectively. The effective use of photography forms the basis of visual communication (Grill and Scanlon, 2003). The purpose of documentation with the photograph is completed by taking a large number of photographs from general photographs of buildings (facades, building environment, etc.) to detailed photographs (interior and exterior photographs).

3.2. Documentation Method by Using Video

It is possible to document structures with video shooting. The surroundings, facades, and interiors of the building are visited and recorded. During this recording, shooting should be performed with an as little shake and heavy motion as possible. Thus, the details of the structure can be seen clearly in the video.

3.3. Classical Documentation Methods

The idea of protecting cultural heritage has emerged for the measures taken for the protection, renovation, and restoration of historical monuments. With the development of technology, the techniques used to document historical artifacts for many years started to be known under the name of classical techniques.

- Linear Documentation
- Written Documentation
- Graphic Documentation
- Information Sheet

Classical documentation techniques are can be collected under the above headings.

3.4. Modern Documentation Methods

Modern documentation techniques are frequently preferred by different disciplines when traditional methods are inadequate in the documentation of historical monuments. Particularly facade silhouettes, building decorations, 3D documentation on digital platform and so on. It would be more accurate to use modern methods for their work.

Modern documentation methods are divided into photogrammetry and laser scanning. In our study, the close-range photogrammetry method, which is one of the photogrammetric methods, was preferred.

3.4.1. Documentation with close-range photogrammetry method

Photogrammetry is a successful documentation method that especially has accuracy, flexibility, and practicality. As an indispensable part of restoration projects, drawings related to the current situation (detection drawings) can be obtained by the photogrammetric method accurately and reliably in a short time. Also, with this method, analytical documentation (materials, distortions, authenticity, etc.) can also be used for studies.

The close-range photogrammetry technique has been used for archaeological surveys and documentation of historical monuments for many years. With the development of digital techniques, photogrammetry has become a more efficient and economical method for the documentation and preservation of architectural works. In recent years, as a result of developments in digital photogrammetry and computer technology, the creation of a 3D model of buildings has been among the current research topics. 3D building models are becoming increasingly compulsory for urban planning and tourism. (Suveg and Vosselman, 2000).

The 3D photo modeling used in this study is very effective in understanding terrestrial objects that are actually inaccessible. The use of photo models from existing objects facilitates the understanding of complex terrestrial structures (Dorffner and Forkert, 1998).

4. MATERIALS AND METHODS

Nikon D3100 camera (fig. 3), Cygnus Topcon KS-102 non-reflector total-station (fig. 2), and PhotoModeler UAS software, which enables 3D drawing and point cloud production from photographs, are used as the hardware.

Figure 2. Cygnus topcon ks-102 total-station

Table 2. Nikon D3100 Technical Specifications

Sensor size	23,1 x 15,4 mm
Total megapixels	14.80
Max. image resolution	4608 x 3072
Weight	505 g
Dimensions	124 x 96 x 75 mm
Pixel density	3,99 MP / cm^2

Figure 3. Nikon D3100 photograph cameras (URL4)

Planned geodetic measurement and photographing should be performed in order to make 3D modeling with the digital photogrammetric method. For geodetic measurement of the control points on ancient artifacts to be used in the photogrammetric evaluation, a geodetic network that covers the object completely in all aspects should be established primarily in such terrestrial photogrammetric and modeling studies.

In this context, a geodetic network has been established in the local coordinate system to cover the historical structure completely from all directions. In selecting the control points where the measuring device will be installed, the locations that will see the structure fully are preferred. Considering the physical properties of the surface of the structure, attention was paid to the selection of sharp lines and clear control points (Uysal et al, 2015).

The stage of taking photographs of the historical fountain was made from different angles according to the convergent shooting principles, taking into account that at least four photographs were included for each detail point. The photographs were taken from different angles on the days and times when the structure and weather were suitable. With the double-image photogrammetry method, each photograph is overlapped with other photographs with common target points and is referenced to each other. There were no situations in front of the building that would prevent the building or any part of the building.

5. STUDY AREA

Figure 4. Study area and Sultan Water Fountain

Taşkent is a small town situated on the Göksu valley canyons on the Taşeli Plateau in the Middle Taurus Mountains. 135 km of Konya province about 100 km south of the Mediterranean coast away, located in the Mediterranean region. Sultan Water Fountain N 36 ° 55'17.5 "E 32 ° 29'25.7" is located in the coordinates (URL5).

Information on Sultan Suyu Fountain from the 110th page of the journal “Mecmuatül Tevarî-Ül Mevleviye”, which was published in 1203 in the form of the official newspaper of the time, found in the Directorate of Konya Antiquities Museum (URL 6) is available. Also information from local residents is available. According to this information, the first state of the fountain was made during the Anatolian Seljuk Sultan Alaeddin Keykubad (1192-1237). Later, in 1982, it was learned that the single-arched section in the middle of the fountain was built and in 1998 the present state was made.

6. APPLICATION of PHOTOGRAMMETRY in ARCHITECTURAL STUDIES

Data processing in the photogrametry consists of coordinate calculations and generating a 3D model. Coordinates of points are calculated in a local system with surveying and leveling. Basically, all detail points of the structure measured with Total Station equipment are transferred to the computer. In Netcad software, the 3D coordinates of the point are calculated. In the fieldwork some surveys are made for controlling the detail points as the same detail point is observed from different polygon points. At the end of all calculations and controls, the coordinates of points are saved in .txt format. Camera calibration parameters of the Canon D3100 camera are calculated in PhotoModeler software and saved as a .cam format. For absolute orientation, the .txt and .cam files are used (Uysal et al., 2013).

Checkpoints that appear in two or more images are marked because the PhotoModeler software performs mutual and absolute orientation at the same time (Yastıklı, 2013). After marking the control points, a photograph was selected as a reference and matching of each control point was shown in the other marked photos.

After that, the orientation process was done according to the bundle method in PhotoModeler software. The orientation results using 45 photographs are shown in figure 5.

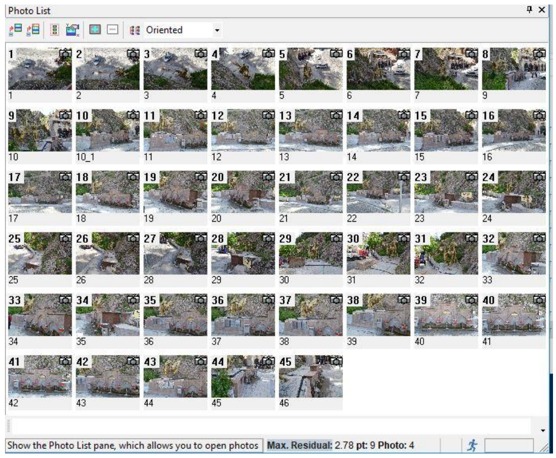

Figure 5. The result of the orientation

After the orientation process, 3D model production was started.First, the details of the pairs of the same detail were drawn (fig.6-7) and the skeleton of the fountain was completed (fig.8).

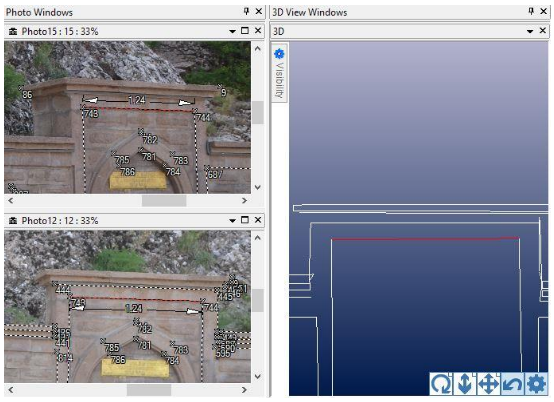

Figure 6. Detail drawing

Figure 7. Detail drawing

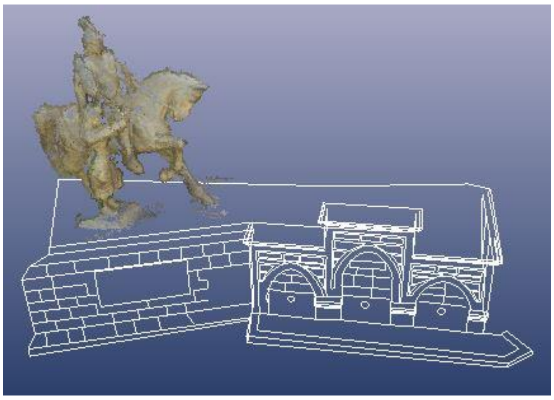

Figure 8. The basic skeleton of the Sultan Water Fountain

Afterward, texture coating was performed on the basic skeleton (fig.9).

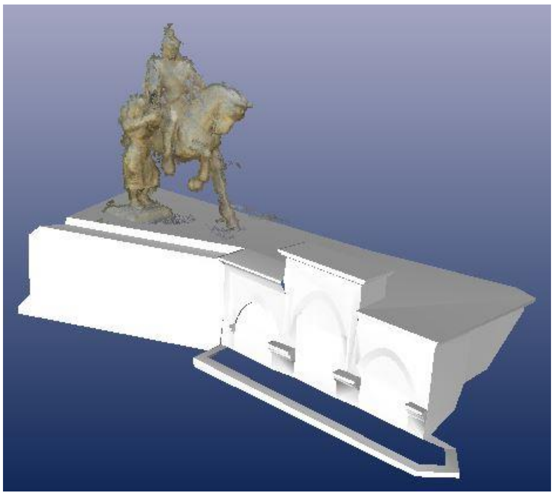

Figure 9. The 3D shaded model

As a result of all processes, a 3D model of the historical Sultan fountain was produced on the digital platform and the documentation work was completed (fig.10).

Figure 10. 3D model of the Sultan Water Fountain

7. CONCLUSION

The use of advanced technologies in the documentation of historical and cultural heritage is necessary to achieve accurate and high precision and fast and effective results. The vector study is not always sufficient to document the details of the historical monument and to collect all the details of the structure. Advanced documentation techniques allow for precise accuracy of the survey of sections of complex geometry (dome, arch, etc.) encountered in historical buildings.

It is advantageous to use photogrammetric methods instead of traditional methods that require long and laborious measurements especially in the documentation and evaluation of stone surfaces and high structure. In the photogrammetric documentation of historical buildings, all the details on the building can be handled together and as a whole. This makes it especially easy to produce the necessary bases for the hand down and documentation of historical buildings to the next generations. In addition to three-dimensional vector data by photogrammetric methods, texture data is also provided. This data is very important in terms of giving the real appearance to the objects to be re-formed in three dimensions and increasing the comprehension of the user. This texture data reflects the geometric properties of three-dimensional objects, ie the metric properties are overlapped with vector data. Since these textures are taken from the photos of the building, they create more realistic models.

It is seen that three-dimensional models produced using photogrammetric techniques can be used as a source in restoration projects and this model can also export VRML format to be used in different applications (Carry and Bell, 1997).

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3D modelling of bridges by UAV photogrammetry method

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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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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.

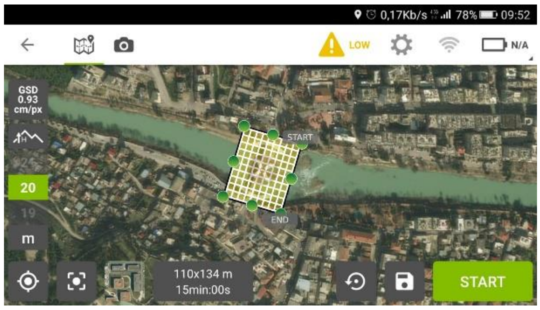

Figure 5. Flight plan made via Pix4D Capture mobile app

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).

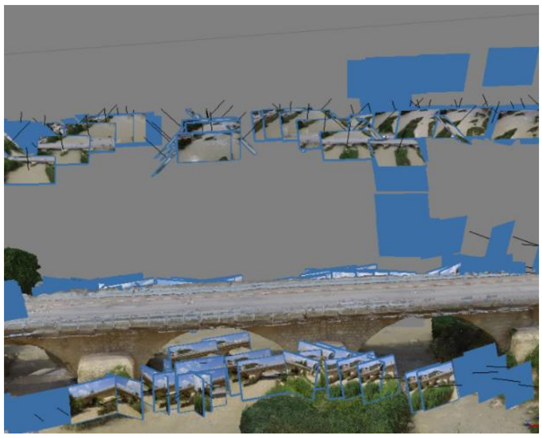

Figure 6. Double grid and manuelly taken photos

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).

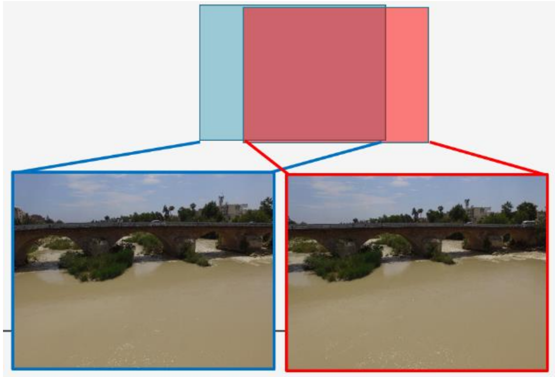

Figure 7. Overlapped images of the West side of the bridge

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).

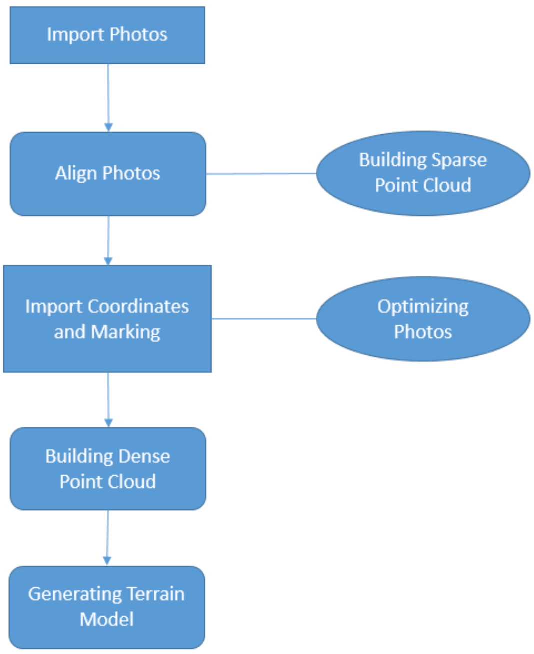

Figure 8. Workflow in the software

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).

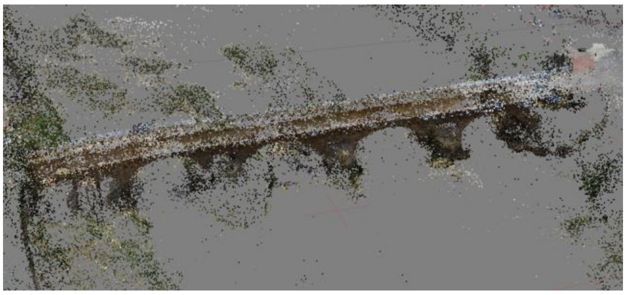

Figure 9. Sparse point cloud

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).

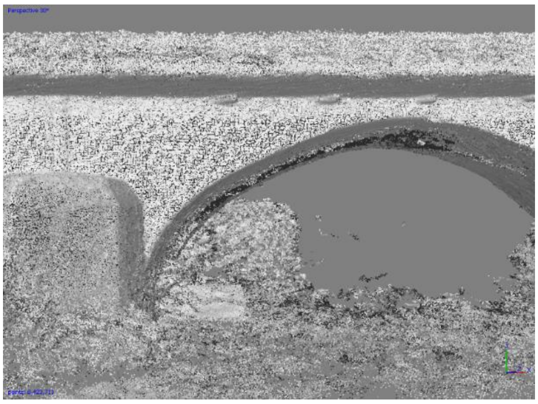

Figure 10. Dense Point Cloud

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.

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Mapping of a rockfall site with an unmanned aerial vehicle

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Keywords
Rockfall
UAV
DSM
3D Model

ABSTRACT

The combination of geological, topographical and climatic conditions causes mass movements. Rockfall, which is a frequently seen disaster at mountainous regions, gives damage to residential areas and transportation corridors. Rockfall barriers are being designed to capture falling rocks worldwide. The classical method applied in rockfall analysis is 3D modelling of the study area to determine rockfall trajectory with the help of Digital surface model (DSM). 3D rockfall simulation is performed in order to determine bounce height, maximum run-out distance and kinetic energy of rocks. DSM of the study area needs to be accurately determined to properly design barrier system. Unmanned aerial vehicle (UAV) can be used to prepare actual DSM from inaccessible areas. In this study, we prepared the DSM of the area which was affected from rockfall due to high rainfall with using a UAV.

1. INTRODUCTION

Turkey is frequently exposed to geological hazards, which can cause loss of life and property due to its geomorphological conditions. Highways, railways and settlement areas are in danger of rockfall and landslide. Mountain hazards such as rockfalls are generally seen in winter due to excessive rain and snow. Rockfall, which is a gravitational movement, occurs because of change in forces on rock masses. At last 50 years, 2956 rockfall events occurred in Turkey and 19422 people affected from rockfalls (Gökçe et al., 2008). Rockfalls that does not make significant damage usually unreported.

There are various reasons that can cause rockfalls. Earthquakes with high amplitude (Lunina et al., 2007), presence of joints (Simon et al., 2015), heavy rainfall (Wei et al., 2014), freeze-thaw cycle (Matsuoka and Sakai, 1999), undercutting of rocks by wind erosion (Admassu et al., 2012), weathering and tree root growth (Yılmaz et al., 2008) may cause rockfall.

Rockfall occurs at four different types, falling, bouncing, rolling or sliding depending on the geometric properties of rock blocks, slope angle and roughness with gravity effects. Potential energy is transformed to kinetic energy during rockfall event. Potential energy of a rock is higher when the slope height, which is defined as the vertical height, is higher.

The most commonly proposed solution is to design a barrier. In order to properly design a barrier, a digital elevation map (DEM) is needed. Unmanned aerial vehicle with GNSS can be used to create actual DEM of the study area.

2. STUDY AREA

Taurus Mountains, which are a part of Alp-Himalaya orogenic belt, are extending in an east-west direction along southern boundary of Turkey. Karahıdırlı village, which is located in central segment of Taurus Mountains, is exposed to rockfall event. Karahıdırlı village is located in Erdemli district, Mersin (Fig.1). This region has been suffering from rockfall threat and this is a concern on public safety. Upper Creteceous ophiolitic rocks have been dropping due to excessive rains.

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Figure 1. Location map of the study area

3. MATERIAL AND METHODS

Detailed evaluation of rockfall is required to select the best protection way. RocFall (Choi et al., 2009), Stone (Agliardi and Crosta, 2003), Rotomap (Papini et al., 2005), Rockyfor 3D (Corona et al., 2017), Colorado Rockfall Simulation Program (CRSP) (Moon et al., 2014), CONEFALL (Jaboyedoff and Labiouse, 2011) and Rockfall Analyst (RA) (Lan et al., 2007) are some of the software that model the rockfall trajectory.

RocFall uses a DEM, slope roughness, static friction angle and coefficient of restitution to determine velocity and bounce height at any points and run-out distance of rock blocks (Choi et al., 2009). Stone, which is a 3D GIS-based software, uses a digital terrain model, normal and tangential restitution coefficients and dynamic friction coefficient to determine the velocity, bounce height and runout distance of rock blocks (Guzzetti et al., 2002 and Agliardi and Crosta, 2003). Rotomap, which is a 3D model, uses normal and tangential coefficient of restitution, friction coefficient of rocks and limit angle to determine the run-out zone (Papini, 2005). Rockyfor 3D, uses a DEM, density, shape and dimensions of rock, mechanical properties of surface, normal and tangential coefficient of restitution and roughness of slope surface to model the rockfall trajectory (Corona et al., 2017). CRSP uses coefficient of restitution, surface roughness and slope geometries to determine impact energy, bounce height and run-out distance of falling rocks (Moon et al., 2014). CONEFALL, which uses DEM and coefficient of restitution can determine the maximum run-out distance and the velocity of rock blocks (Jaboyedoff and Labiouse, 2011). Rockfall Analyst, which is an extension of ArcGIS, uses a DEM, friction angle and coefficient of restitution to determine the velocity and run-out distance of rock blocks (Lan et al., 2007).

Detailed geological investigations; such as, types of faults, joints, rocks, rain intensity, weather conditions, weathering susceptibility and erosion potential of the region should be known to determine the possible areas that rockfall event may occur. DEM with high resolution at those areas with the help of unmanned aerial vehicle (UAV) will be created. By using a DEM, the velocity, bounce height, run-out distance and trajectory of rock blocks may be determined by using a computer software. That information will be used in rockfall barrier design.

The classical method in rockfall studies is to model the area in 3D to decide the rockfall trajectory. Runout distance, travel path, kinetic energy and bounce height of rocks will be determined by using DEM, mass of the rocks, coefficient of restitution (COR), static friction angle and surface roughness parameters.

To measure velocity rocks were rolled. Schweigl et al. 2003 used 2D simulation to suggest rockfall barrier design. Ansari et al 2018 have used 2D and 3D models to suggest rockfall barrier design. Fanos and Pradhan 2019 have used terrestrial laser scanner to obtain 3D point clouds of the area affected from rockfall.

Coefficient of restitution (COR), which is defined as the rate of velocity after collision and before collision, is the most important parameter to estimate rockfall hazard as all the computer software use that parameter. The equation of COR is given at Eq. (1).

$$COR=\frac{V_{after}}{V_{before}} \quad (1)$$

There are two components of COR, which are coefficient of normal (COR_N) and tangential (COR_T) restitutions and their equations are given in Eq. (2) and Eq. (3) respectively.

$$COR_N=\frac{V_{after\ N}}{V_{before\ N}} \quad (2)$$

$$COR_T=\frac{V_{after\ T}}{V_{before\ T}} \quad (3)$$

UAV has been used in engineering projects since last decade. Ulvi and Toprak (2016) and Şasi and Yakar (2018) have used UAV to model an archeological site. Saroglou et al (2018) have used a UAV to map the rockfall site area. UAV is a valuable tool to get information at the places where we cannot reach. Land surveying is time consuming and dangerous. Satellite images are not high resolution. Therefore, we need to use UAV to get actual information from the study area. UAV related research has been increasing over the last decade.

In this study, we used eBee-Plus integrated with real time kinematics global navigation satellite system (RTK/GNSS). GNSS device was set up in a fixed position to get high accuracy position data. The coordinates of the GNSS device was obtained by connecting the TUSAGA Active CORS network. GNSS device and UAV system were integrated to get the coordinates of the photos with high accuracy and precision. 162 photos were taken from the study area and imported into Agisoft Metashape Professional software to get Digital Surface Model (DSM) (Fig.2) and orthophoto (Fig.3) of the study area. Results are shown in table 1. Akar (2017) has stated that kriging method is the best interpolation technique in generating DEM.

Table 1. Analysis report

Item	Value
Number of images	162
Flying Altitute	373 m
Ground resolution	8.27 cm/pix
Camera location error	1.96734 cm
DSM resolution	33.1 cm/pix
DSM point density	9.15 points/m^2

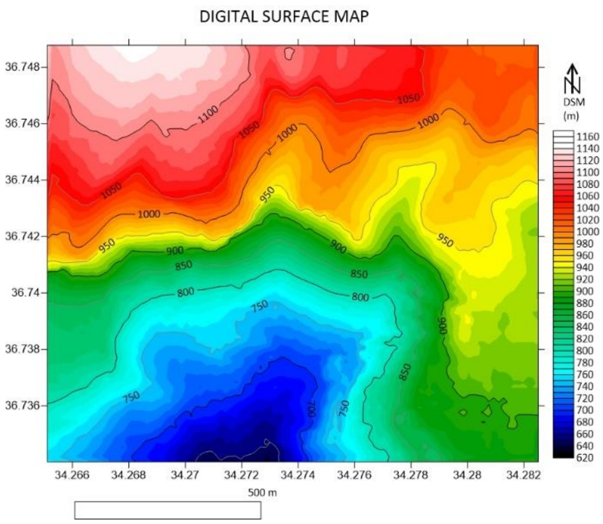

Figure 2. Digital surface map

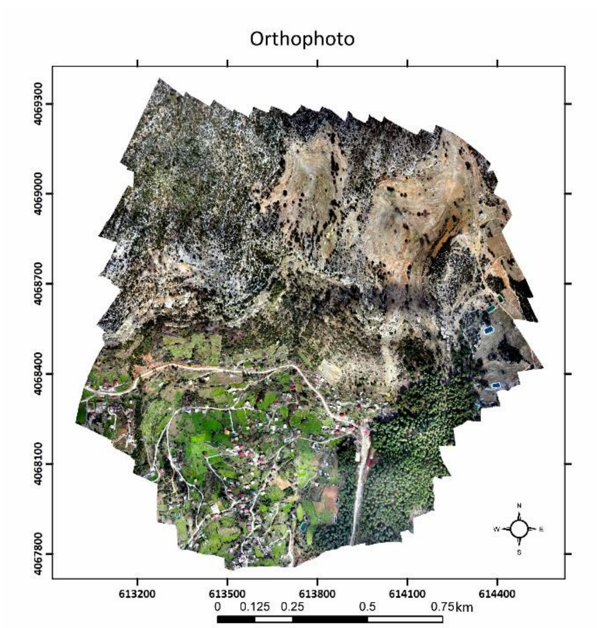

Figure 3. Orthophoto

4. ROCKFALL PROTECTION SYSTEMS

Rockfall barriers are important to protect people and buildings. They need to strong enough to stop the motion of large rock blocks, which have huge kinetic energy. Ditches, rock fences, barriers, wire-nets and ring nets with cables (Chau et al., 2002, Sasiharan et al., 2006 and Escallon et al., 2015) may be used to be protected from the harmful effects of rockfall. Geometrical arrangements of wires need to satisfy engineering standards. At historical places, they need to be constructed without disturbing the natural beauty.

5. DISCUSSION

Slope angle and the geometric properties of rock are the most important parameters at calculating the run-out distance of a rock. Predicting the volume of a rock that will fall and determining the coefficient of restitution of a rock are very challenging. When a rock hits a soft surface, it will bounce less; however, when a rock hits a hard surface, it will bounce much. Therefore, correctly modelling the rockfall trajectory is very difficult.

The knowledge of which joint and rock type may have tendency to make the rock fall more than others needs to be investigated. A database about rockfall activity including the coordinates and type of motion and cause of rockfall event should be constructed to help the researchers about understanding the rockfall phenomenon. By creating a rockfall distribution map, the danger zone will be identified. At each region, the dominant reason of rockfall event will be determined.

6. CONCLUSION

Karahıdırlı village is in danger of rockfall. Geologic properties of the rocks in the study area need to be investigated, in order to prevent from negative effects of rockfall. After modelling the study area, protection systems need to be constructed.

Topographical, geological and climatic factors play important role in rockfall event and it generally occurs due to combinations of those factors. While planning the transportation route and settlement closer to rocky slopes, rockfall hazard should be taken into account as it is an inevitable event. Rockfall protection systems should be implemented in order to prevent from death, injury and financial loss.

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The use of UAV and photogrammetry in digital documentation

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Keywords
Harran Bazilica Church
Unmanned Aerial Vehicle
Point Cloud
DEM
Orthophoto

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).

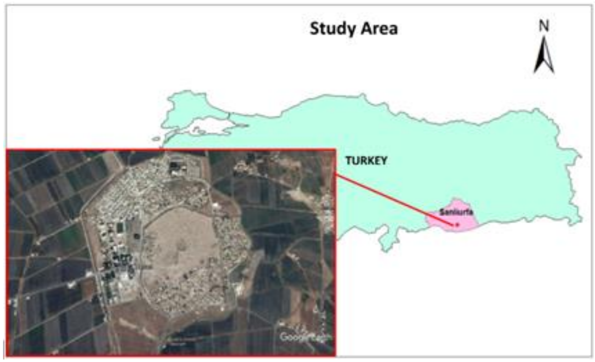

Figure 1. Satellite view of the region of Harran Ruins (Google Earth 2016).

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.

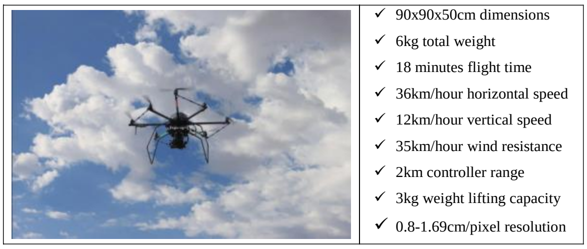

Figure 2. Technical specifications of TurkUAV Okto V3 UAV.

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.

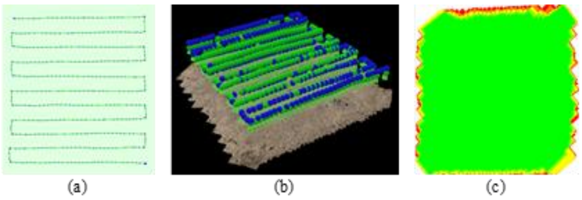

Figure 4. Adjusted coordinates of aerial photographs (a), point cloud (b) and image overlays of the land surface (c).

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).

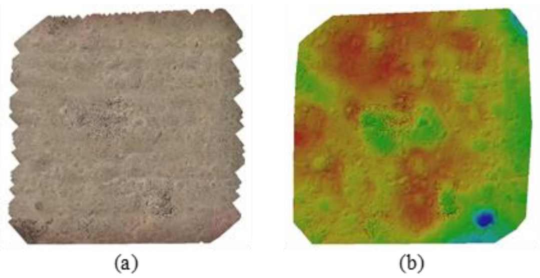

Figure 5. Low-resolution orthophoto (a) and digital terrain model obtained from initial data processing (b).

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).

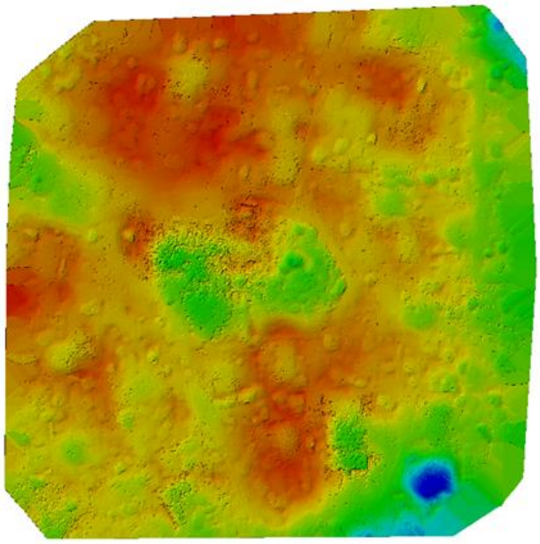

Figure 6. Digital elevation model of the ruins of Harran Basilica Church and a Small Mosque.

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.

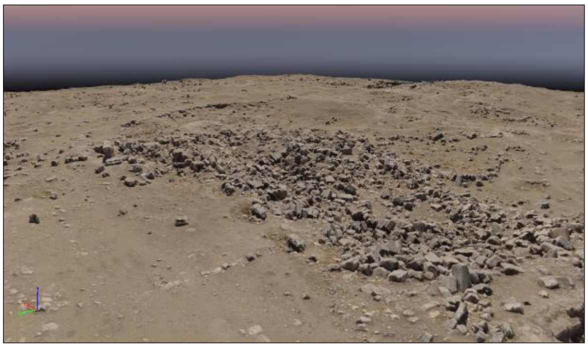

Figure 8. The mesh model of the ruins of the Harran Basilica Church.

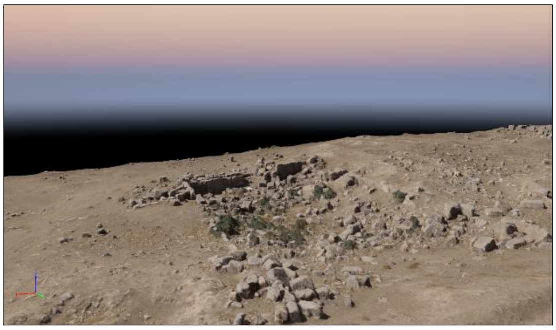

Figure 9. The mesh model of the remains of a Small Mosque.

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).

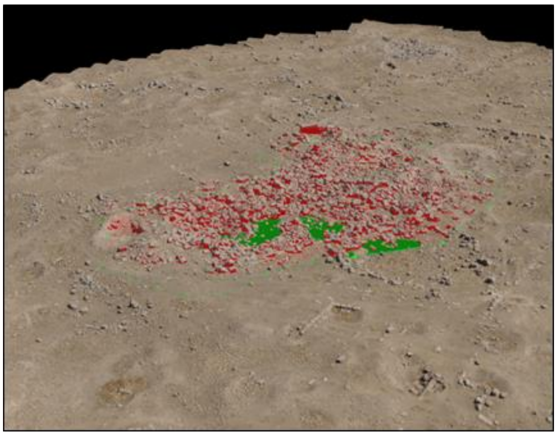

Figure 10. The area and volume of Harran Basilica Church ruin.

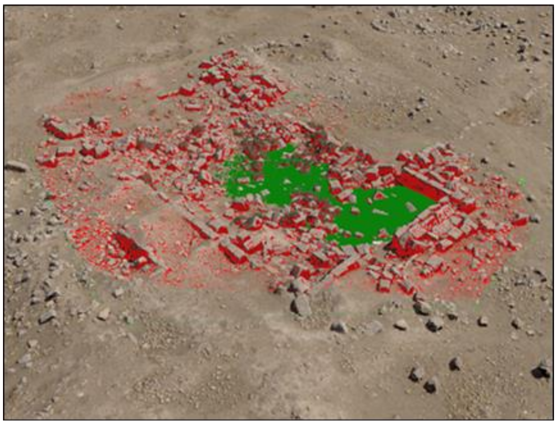

Figure 11. The area and volume of Harran Small Mosque remain in the field.

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.

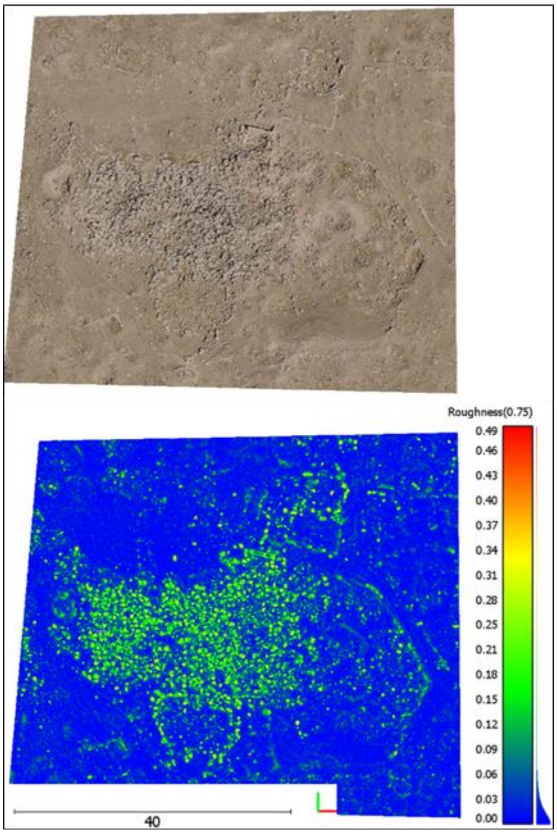

Figure 12. Surface roughness analysis of the Harran Basilica Church.

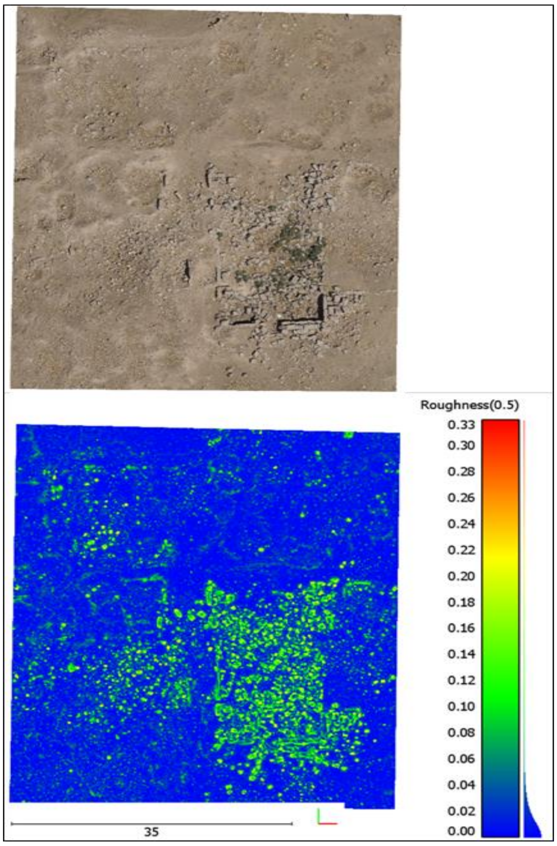

Figure 13. Surface roughness analysis of Small Mosque.

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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Excavation monitoring with UAV in Şanlıurfa Castle archaeological site

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Keywords
Photogrammetry
UAV
Archaeology
Documentation
Sanliurfa

ABSTRACT

There are many archaeological sites in the world from past civilizations. These areas, which are cultural heritage sites, have suffered severe destruction and deformation because of humanitarian interventions such as earthquakes and floods or wars. These demolitions and deformations continue today. Therefore, archaeologists try to document all objects of potential value that they uncover as a result of excavation. Documentation is also necessary for the identification and interpretation of the found objects, as well as for restoration and reconstruction, which are possible after archaeological excavation. For this reason, the documentation process is as sensitive as possible, without damaging the objects and requires the correct way. At this point, recently, fast and practical, very high-resolution images, low cost and repetitive use due to the unmanned aircraft (UAV) began to be preferred in documentation studies. In this study, UAV usage is given in the archaeological excavations of Urfa Castle.

1. INTRODUCTION

Historical artefacts are cultural legacies that hosting Many hundred years of knowledge. This knowledge must be transferred to the next generations. These historical heritages reflect the life-style and aesthetic understanding of elder civilization as well as being cultural assets that hosting all changes in time such as wars and earthquakes. The documentation and conservation of the natural tissues of historical monument without damaging is indispensable element for transferring future generations. It is a fact that cultural heritages not only in our country (Turkey) but also in many parts of the world were damaged and being damaged. Because of this reason cultural heritages are partly documented in time all over the world.

The work of documentation of historical places and cultural heritages is complex and multi-faceted process (Kulur, 2005). Documentation of historical or cultural structure covers the entire steps which is necessary for determining current state of the structure (shape and position) in three-dimensional space that are surveys, process, storage and presentation (Georgopoulos and Ioannidis, 2004). There are a few techniques for documentation of cultural heritages (Bohler and Heinz, 1999). These techniques, which are very important and necessary, are traditional surveys, topographic techniques, photogrammetric surveys and scanning technique (Bohler and Heinz, 1999, Scherer, 2002). At this point, it is a huge advantage that photogrammetry can provide reliable information in a short time (Yakar and Yılmaz, 2008; Şasi and Yakar, 2018).

Nowadays, with the remarkable advancement of Computer Vision and Photogrammetry, the image-based modelling becomes as a rival for laser scanning (Remondino et al., 2011). Some remarkable advantages of image-based modelling are that: it is low cost and contains colour information; any kind of camera (calibrated or un-calibrated) can be accepted (Colomina et al., 2008) and it may produce point cloud denser than a laser scanner. This image-based approach, named as Structure from motion (SfM) is a newly popular low-cost Photogrammetry method com-pared to its competitors.

During the last few decades, low-cost Unmanned Aerial Vehicles (UAVs) are used as an

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alternative photogrammetric platform for traditional data capture, especially while aiming at mapping application with high spatial and temporal resolution and introduces also a low-cost alternative to the classical manned aerial Photogrammetry (Colomina et al., 2008; Eisenbeiss, 2009; Ulvi and Toprak, 2016). Nowadays, the use of UAVs is increasing day by day due to its advantages at cost, inspection, surveillance, reconnaissance, marine environment, and mapping (Remondino et al., 2011; Bayirhan and Gazioğlu, 2019; Gazioğlu et al., 2017; Akar, 2017). In this study UAV platform is used to capture aerial images of Sanliurfa castle in purpose of producing a template for planning excavation by archaeologists.

2. STUDY AREA AND EQUIPMENT

The study is at inner city of Şanlıurfa (Figure 1). The castle was built by the Osroene in antiquity and the current walls were constructed by the Abbasids in 814 AD.

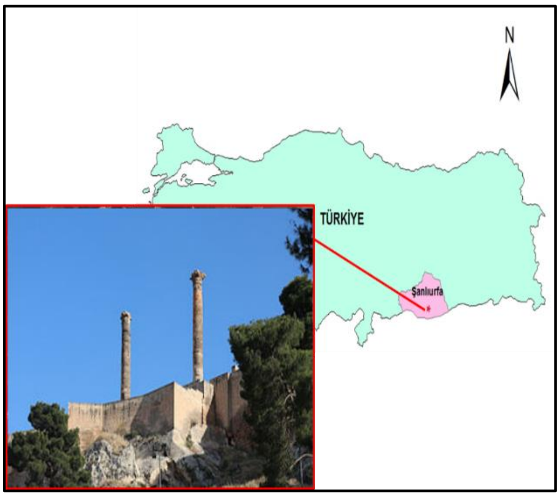

Figure 1. The Sanliurfa castle (37° 8'43.95"N, 38°47'2.45"E).

The TurkUAV Okto V3 was used to capture images (Figure 2). It uses the microcopter electronic. The weight of it is approximately 6 kg and the payload are 3 kg. Flying time essentially depends on both battery and payload weight. A lot of features of this model are available such as Waypoint Flight and Follow Me. Mikrocopter (MK Tools) software let us to view the navigation and flight status information in real time. It is possible to perform autonomous flight plan over the online maps. Moreover, some details such as horizontal and vertical speed, altitude, direction, waiting time at willing points, coordinate information, and camera angle are also can be specified. Waypoint Flight electronic is capable of autonomous flight in a 2km radius area.

The digital camera was Sony RX100II (Figure 2). It has featured with 20 Megapixel. Single, continuous, and self-timer drive abilities are among the digital camera features. The Body weight of the device is 281 g. All images are processed in Pix4D software.

Figure 2. The UAV and Digital Camera

3. METHODOLOGY

Although the SfM approach is developed by the computer vision community in order to get an automatic feature-matching algorithm, yet it operates under the same essential conditions as Stereoscopic Photogrammetry (Tanskanen et al., 2013; Snavely, 2009; Westoby, 2012; Micheletti, 2015). The overlapping images are used in order to get a 3D form of interested object.

However, there is a fundamental difference between traditional Photogrammetry and SfM. In traditional Photogrammetry, 3D position of the camera(s) or 3D position of ground control points (GCP) have to be known to determine the 3d location of points within an image. In contrast, the SfM determines the geometrical parameters (orientation, internal and external parameters) automatically without any pre-defined set of known GCP (Westoby, 2012). Instead, these parameters are solved synchronously using a highly overlapped image set with automatic identification of matching same features (Snavely, 2009).

Then, an iterative non-linear least-squares minimization process estimates the camera positions and object coordinates by tracking matched features image to image. Comparing with the traditional Photogrammetry, the determined camera positions are in the image space, which means there is no scale and orientation, considering the object space. This issue can be overcome with a 3D similarity transformation by using a small number of GCPs (Westoby, 2012). To get a useful 3D geometry of the object, the images must fully cover of the object, which means the camera captures the images from different positions by means of moving, as the named structure from motion (moving sensor) in the scientific literature.

4. APPLICATION

The study performed in two flight. The first flight covers the entire castle to get a wide view of the study area before the excavation. With the first flight, the initial base orthophoto is generated. The second flight is performed a few weeks later.

Meanwhile, the excavations started. The aim of the second flight is to observe the progress of excavation. So, the area of second flight covers only east part of castle where the excavation starts. The basic information's about flights are given in the table 1.

Table 1. The basic information's about flights

	Flight 1	Flight 2
Dataset	147 images	319 images
Covered Area	0.11 km2	0.03 km2
GSD Average	2.19cm	0.95 cm
Column	6	Grid flight
Points	17784677	30665936
Density (per m3)	226.3	3531.15

The Grid flight consists of two flight plane that are perpendicular to each other. This type of flight is very successful to create 3D models of the earth's surface. The generated point cloud for both flights is in figure 3 and 4.

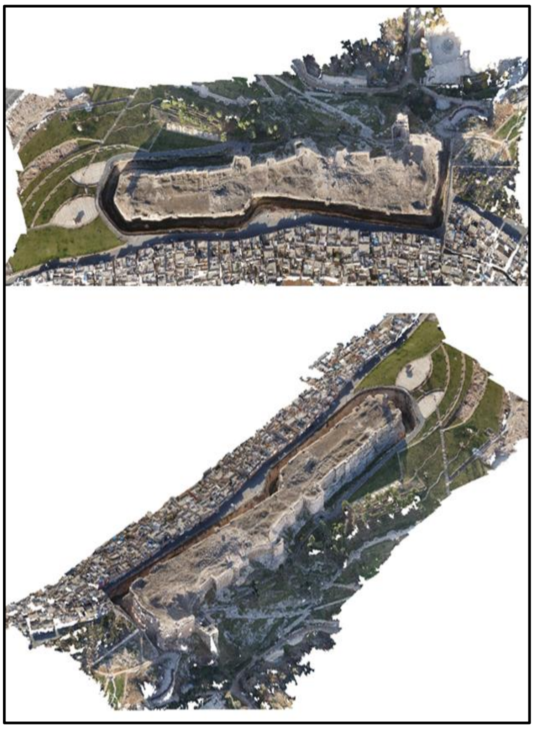

Figure 3. Point cloud of the first flight

Figure 4. Point cloud of the second flight

The excavation was started at the east side of the castle where the entrance exists. Therefore, to observe the progress of the excavation, a cloud to cloud distance calculation was performed (Figure 5).

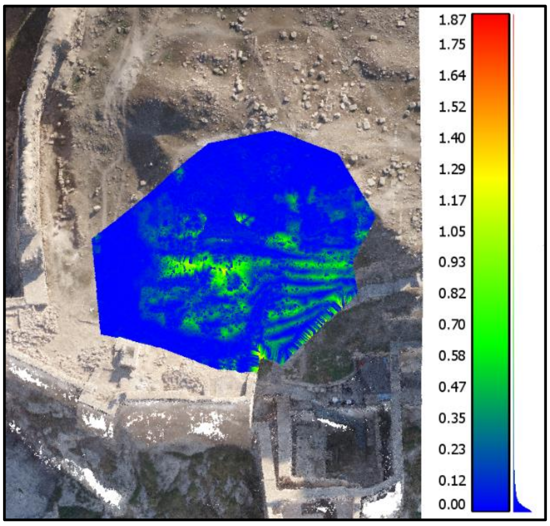

Figure 5. Cloud to cloud distance calculation

According to this calculation, there are height differences in excavation area from 10 cm to nearly 2 m. Unfortunately, the study area was closed to prevent the risk of collapsing due to heavy rainfall. Therefore, a control terrestrial measurement could not be made.

As a final analysis, an approximate volume calculation is performed. In this analysis, the first point cloud is used as base/initial state and the second point cloud used as final state of the area. In the end, the approximately added and removed volumes were calculated as 10,9 and195,4 m^3 respectively in an 816 m^2 surface area.

5. CONCLUSION

This paper depicts the possible usage of UAVs in archeological studies. The generated products of this study such as orthophoto, point cloud or digital surface models can be used in archeological studies. In our case the generated orthophoto was used in determining the current status of the castle and planning the archeological excavation. the generated Point clouds were used for approximate volume calculation. The study shows that, UAV and photogrammetry have advantages and wide capability of usage in arkeological studies in terms of cost, time and temporal usage.

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