Turkish Journal of Engineering

Turkish Journal of Engineering (TUJE)
Vol. 4, Issue 3, pp. 104-112, July 2020
ISSN 2587-1366, Turkey
DOI: 10.31127/tuje.637050
Research Article

IMPORTANCE OF UNMANNED AERIAL VEHICLES (UAVs) IN THE DOCUMENTATION OF CULTURAL HERITAGE

Ali Ulvi *[1]

[1] Selcuk University, Hadim Vocational High School, Konya, Turkey
ORCID ID 0000-0003-3005-8011
aliulvi@selcuk.edu.tr

* Corresponding Author

Received: 23/10/2019 Accepted: 27/11/2019

ABSTRACT

Cultural heritage is the most important resource providing communication between the past and future. The societies utilizing this resource in the best way, have had an inventory of cultural heritage and contributed to world culture. The efforts made for being able to the accurate and healthy data in the documentation of cultural heritage led the new techniques to emerge other than documentation and, together with the developing technology, documentation with traditional method replaced with modern documentation techniques using new technological devices. One of these documentation techniques is the use of Unmanned Aerial Vehicles (UAVs) in the documentation studies. In this study, the usability of unmanned aerial vehicles in the studies of cultural heritage was studied.

Keywords: *Cultural Heritage, UAV, Documentation*

1. INTRODUCTION

Cultural heritage is one of the most important bridges between the past and future of the people. It has an important place in the individual and social development of human being. Originally leaving these heritages to the next generations is an important issue on the name of humanity.

Historical artifacts that stand as cultural heritage are buildings that connect the past and future of the world(Şasi &Yakar,2018).

Many international organizations such as UNESCO (United Nations Educational, Scientific and Cultural Organization), ICOMOS (International Council for Monuments and Sites), ISPRS (International Society for Photogrammetry &Remote Sensing), ICOM (International Council for Museums), ICCROM (International Centre for the Conservation and Restoration of Monuments) and UIA (International Union of Architects) have undertaken some missions to conserve world cultural heritages (Callegari , 2003) .

Besides producing information regarding the various physical, social, economic, cultural, and historical aspects of cultural heritage in the various quality and scale, processing much amount of information produced and transforming it into the usable information is an indispensable requirement in terms of conserving (URL-1, 2007).

1.1. Cultural Heritage and Conservation

Just as cultural entities can be divided as movable and immovable entities, they are also classified as the intangible and tangible entities. While the tangible monumental ruins and archeological antiques used to be included in the scope of cultural heritage, today, the scope of this term enlarged and has begun to cover intangible ethnographic, industrial, and intellectual heritage (e.g. language, beliefs, traditions) (Can, 2009).

Cultural heritages are the history of the nations, and history forms the identities of the nations. Therefore, protection of cultural heritages means protection of the history and identity of the nations(Yakar&Doğan,2018).

Cultural heritages due to have their different natural characteristics, different sizes, and complicated structure they require more sophisticated measurement tools and techniques to documentation (Ulvi & Toprak, 2016)

Among the values UNESCO includes in tangible cultural heritage, the historical cities are also cultural landscapes, natural and holy sites, underwater cultural heritages, and museums. Cultural heritage revealing itself as historical spaces of a city is the most valuable part of social welfare. Therefore, “adopting conservation of heritage not only provides the possibility of healthy life for a city but also it helps recognition of cultural identity of that city” (Tweed & Shutherland,2007).

1.2. The importance of documenting Cultural Heritage

Documenting a structure covers the studies carried out on the purpose of measuring it as well as identifying its quality and variation process (Kuban , 2000).

Nowadays, with the development of data acquisition technologies, digital works of architectural works are documented and restoration projects are being used in many fields (Ulvi et al.,2020).

The importance of documenting cultural heritage has been more recognized in the recent years, and an increasing pressure about conserving and documenting this heritage has formed. The existing technologies and methodologies related to this issue give 2D and 3D results, in order to be used with the archeological, digital conservation, restoration, and conservation purposes and many purposes such as VR applications, catalogues, web, geographical systems, and visualization (Remondino, F. & Rizzi, A. 2009).

In addition, in documenting cultural heritage, the accuracy of relievo should also compatible with the scale of the project to be carried out (English Heritage, 2003).

Table 1.The relationship between project scale and error margin (English Heritage.,2003).

Scale	Acceptable Error Margin
1/10	**+/- 5 mm**
1/20	**+/- 6 mm**
1/50	**+/- 15 mm**
1/100	**+/- 30 mm**
1/200	**+/- 60 mm**
1/500	**+/- 150 mm**

In documenting our cultural heritage, the efforts made to be able to obtain the accurate and healthy data led new techniques to emerge in the documentation area and, together with developing technology, documentation with traditional method has replaced with modern documentation techniques, and this enabled contemporary documentation techniques to rapidly improve. The current technology enables the historical works and structures to be conserved to any longer to be documented more rapidly and transferred to the next generations (Korumaz., Dülgerler & Yakar .2011).

One of modern documentation techniques is also documentation with unmanned aerial vehicles (UAVs).

2. UAV OVERVIEW

According to the international definition of UVs (Unmanned Vehicle System), an unmanned aerial vehicle (UAV) is a generic aircraft design that does not accommodate humans in it. (URL-25).

The use of UAVs has become a recently adopted method in acquiring needed spatial data(Ulvi,2018).

“UAVs should be understood as uninhabited and reusable motorized air vehicles.” states van Blyenburgh, 1999 (Van Blyenburgh,1999). These vehicles are remote-controlled, semi-autonomous, autonomous or have some combination of these capabilities.

When comparing the UAV to human aircraft, it is clear that the main difference between the two systems is that no pilot in the UAV is physically present in the aircraft. This does not necessarily mean that a UAV flies autonomously by itself. In many cases, the crew responsible for the UAV (operator, backup pilot, etc.) Is larger than a conventional aircraft (Everaerts, 2008).

The term UAV is commonly used in Computer

Science, Robotics, and artificial intelligence, as well as in the photogrammetry and Remote Sensing communities.

Additionally, synonyms such as remote-controlled vehicle (RPV), remote-controlled Air Transport (ROA) or remote-controlled Air Transport (RPA) and Unmanned Vehicle Systems (UVS) can also be rarely found in the literature.

RPV is a term used to describe a robotic aircraft flown by the pilot using a ground control station. The first use of the term may have been directed at the United States (U.S.) Department of Defense in the 1970s and 1980s. The terms ROA and RPA have been used by the National Aeronautics and Space Administration (NASA) and Federal Aviation Administration (FAA) in the United States instead of the UAV. The term Unmanned Aircraft System (UAS) is also used. (Colomina et al., 2008).

The FAA adopted the general class UAS, originally introduced by the U.S. Navy. The common understanding is that UAS terminology represents the entire system, including unmanned aerial vehicle (UA) and Ground Control Station (GCS). (Eisenbeiss, Stempfhuber & Kolb. 2009).

2.1. Classification of UAVs

When the literature is examined, Unmanned Aerial Vehicles are classified in various ways. However, it is much more accurate to divide the UAVs into two classes as fixed-wing and rotary-wing UAVs. In addition, kite, balloon and zeppelins were used in the study of cultural heritage under the name of UAV.

2.1.1. Rotary -Wing UAV Systems

4-wing Quadrotor, 6-wing Hexacopter and 8-wing Octocopter systems are included in this group. These systems have the features such as balanced flight feature by means of pilot even if complete manual flights; return feature with GPS, altitude fixing, carefree (orientation freedom) feature, routing flight through map, and full autonomous flight. This system is seen n in Fig. 1.

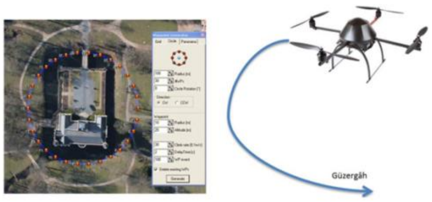

Fig. 1. Autonomous Routing Flight through Map (URL-2).

2.1.2. Fixed Wing UAV Systems

Fixed wing UAVs have more flight time compared to rotary wings. In addition, they have some advantages from the aspect of durability and flight height. Fixed wing systems, with the properties of high attitude they have and long durability, are ideal for photogrammetric and remote control applications. Also in these systems, flight routing can be defined. Entering column values to the system, autonomous flight can be realized. The disadvantage of fixed wing systems compared to rotary wing systems is that they cannot be hung in the air. In figure 2, a fixed wing UAV is seen.

Fig. 2. Ebee UAV(URL-3)

2.1.3. Kite, Balloon and Zeppelin

-Kites

Kite was used in the various scientific studies based on aerial photography in 1997. It was used in discovering fossil bed in a forest (Bigras. 1997) and in documentation of mapping archeological site in Russia (Gawronski & Boyarsky. 1997). There are some sorts of the kites used in kite systems used as photogrammetric-aimed. These are:

****Delta Kite**

Fig. 3. Delta Kite (URL-22)

**** Fled Kite**

Fig. 4. Fled Kite (URL-22)

**** Soft Kite**

Fig. 5. Soft Kite (URL-22)

- Balloon

Today, zeppelins are divided into two as motorized and non-motorized. Non-motorized zeppelins are driven by means of ground –controlled ropes the same as balloons. Zeppelins include helium gas according to carrying capacity. If the load you will carry is heavy, you have to use bigger zeppelin and, thus, there is need for more helium gas. This certainly increases cost. In addition, motorized systems have generally two wings and carry 2-3 electric motors.

Fig. 6. General Appearance of Zeppelin (URL-24).

2.2. The Platforms Used

There are also photo taking platforms, mounted to kite systems as photographic –aimed and operated by remote control, Photos taking platforms are shown in Fig. 7 and Fig. 8.

Fig. 7. Photos Taking Platforms (URL-22)

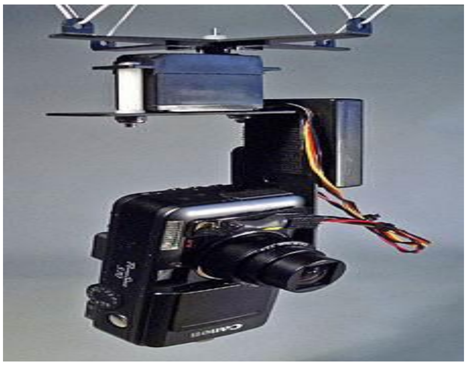

Fig. 8. Photos Taking Platforms (URL-22)

Fig. 9. Kite Aerial photography can be used to obtain more analyses and data. It is a low cost and effective method that is suitable for working in small regions (URL-23).

Fig. 10. General Appearance of Zeppelin (URL-24)

2.3. Its Benefits

The biggest advantages of UAV against manned flight systems: UAV is used in risky states, unreachable regions, low attitudes, and places, in which flight profile is near the object and manned flight system cannot be used, without jeopardizing human life.In these regions, for example, in the sites of natural disasters, mountainous and volcanic areas, flood plains, earthquake areas and deserts, accident scenes, regions that is difficult to going into, and in the places, in which airplane can be used as unmanned or flight permission is not given, the only option is sometimes UAV. In addition, cloudy and drizzling weather conditions, it is possible to collect by means of UAV

2.4. UAV Applications

Some UAVs civilian applications are mentioned in (Nıranjan, Gupta, Sharma, Mangal & Sıngh 2007) while(Everaerts, 2007) reports on UAV projects, regulations, classifications and application in the mapping domain. The application fields where UAVs images and photogrammetrically derived DSM or orthoimages are generally employed include: Agriculture, Forestry, Archaeology and architecture, Environment, cadastral mapping, thermal analyses, excavation volume computation, volcano monitoring or natural resources documentations for geological analyses are also feasible, Emergency management, Traffic monitoring: surveillance, travel time estimation, trajectories, lane occupancies and incidence response are the most required information.

3. UAV PHOTOGRAMMETRY

Terminology UAV photogrammetry (Eisenbeiss. 2008c) defines a photogrammetric measurement platform, which operates remote controllably and is semi- independent or independent, and in which there is not any pilot. Platform was equipped by photogrammetric measurement systems. This also includes small or medium sized fixed video or video camera, thermic or infrared camera systems, and aerial LIDAR systems. The existent standard UAV enables to monitor the record and position and the direction of sensors applied in a local or local coordinate system. Hence, UAV photogrammetry can be understood as a technique that makes photogrammetric measurements with the help of an unmanned aerial vehicle.

UAV photogrammetry, combining aerial and terrestrial photogrammetry, leads to the new applications in close distance effective area but also it introduces traditional aerial photogrammetry with the new (close) real time applications and low cost options..

4. STUDIES WITH UAV

4.1. UAVs for The Documentatıon of Archaeologıcal Excavatıons

This study made by M. Sauerbier and H. Eisenbeiss.

In this study, Sauerbier and Eisenbeis, the deployment of drones for the certification of such sites, or 3D digital Surface models, Ortho images provide a basis for further processing and the derivation of different products such as high quality offers 3 different case studies that are caused in the image data.

The second is the documentation of a Maya site in Copán, Honduras, and the second is the quick and simple documentation of an excavation site in Palpa, Peru. Different types of UAVs were used in these projects: in Honduras and Peru we worked with Surveycopter 1B (Aeroscout, Switzerland) driven by a two-stroke engine, in Bhutan we used a quadrocopter MD 4-100 supplied by Microdrones. by the company omnisight (Switzerland). The experiences gathered by the projects described above and the test site surveys allowed them to come to different conclusions regarding the actual state of the UAVs, especially in terms of their applicability in photogrammetric projects for the cultural heritage site. Compared to the Falcon 8 and MD4-200 systems, the positional accuracy of Copter 1B (1m) is quite high compared to 2-5m for multi-rotor systems (Sauerbier & Eisenbeiss.2010).

4.2. Uav Platforms For Cultural Heritage Survey: First Results

This study made by M. Lo Brutto, A. Garraffa,P. Meli.

In this study, the two systems were tested in two different regions: the site of the Temple of Isis at the temples Valley Archaeological Park in Agrigento was examined by the md4-200 microdron, the site of the “Gibellina Cretto Cretto”. "Near the town of Trapani with Swinglet glass. The first is one of the least-known areas of the entire archaeological park, followed by being released by tourists. The temple is located only in a partially excavated area and is formed with a podium and triportico identifying a square.

This study shows the potential of the UAV survey in the area of Cultural Heritage. Although it requires earlier and more detailed research, some initial results can already be deduced. In particular, initial tests on orientation phases do not highlight any reduction in the increments of CPS using more stable block configurations. 2000-4000 points per image and the percentage of overlap of the images, respectively, due to the number of binding points for each image High, A lot of measurements (on average, at every point there is at least 8-10 ledge) , may make unnecessary the use of photogrammetric blocks with a more stable configuration.

The final products (3D models and Ortho-images) show a very high level of detail, allowing you to do very accurate work and analysis. Due to the high level of automation achieved through the software used, the processes followed were very fast.

In the assessment of 3D point clouds, the vertical residues obtained both for all the data sets of the Temple of Isis and for two of the three data sets of “Cretto of Gibellina” appear to be quite high. Apart from the distribution of residues, 3D models show some slight deformations. In order to better understand the reasons for these latest results, certainly more extensive testing needs to be done (Eisenbeiss. 2008c)

4.3. Balloon photogrammetry for cultural heritage

Altan *et al*. (2004) took aerial photographs in Patara antique city by means of Helium gas balloon system. Balloon is in 25 m of diameter and filled with 8 m^3 of Helium gas. This system consists of flight unit and ground control unit. Flight unit consist of helium balloon, camera platform, and Olympus Camedia C-40404 Camera of Mega-Pixel. Ground control unit consists of monitor remote control for camera, and control ropes.

Fig. 11. Camera platform, camera, and balancing ropes under balloon (Altan.2004)

Fig. 12. Ground control unit with monitor (Altan.2004)

4.4. Studying the usability of non-metric digital camera, mounted to kite platform, in archeological documentation studies

This study was conducted by Ali Ulvi in Uzuncaburç Diocaesarea Antique Theater, located in Silifke district of Mersin province. in the scope of doctorate study.

Fig. 13. Digital Camera and its carrying platform

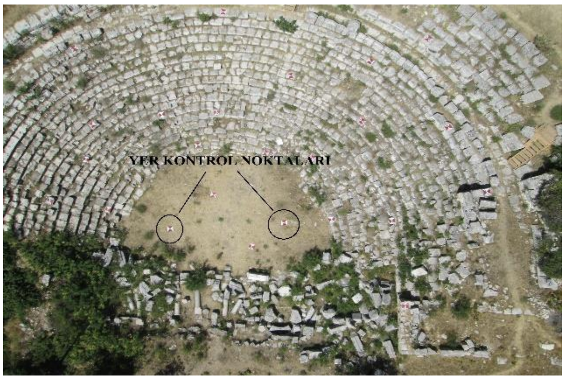

Fig. 14. Ground Control Points used in aerial photographs

Fig. 15. Mounting the camera and platform to a kite

Fig. 16. Operation of taking aerial photos with kite

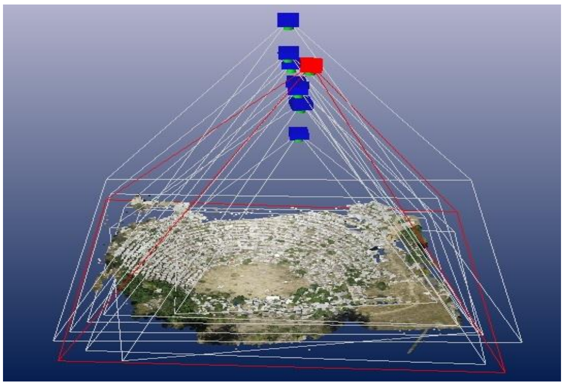

Fig. 17. Appearance of the stations of taking photos

After this stage, accuracy study of archeological documentation application, carried out by means of UAV kite by using photogrammetric techniques, was carried out. 30 pieces of ground control points were used for this study. The coordinates of ground control points were measured by total station device and were accepted as definite coordinates in accurate study. After this operation, coordinate values of ground control points were identified through archeological documentation carried out by using photogrammetric techniques

Table 2. Average position error

	Vy (cm)	Vx (cm)	Vz (cm)
m	±3.1	±3.1	±2.9
m_{yxz}	±5.3		

In the light of these data, in the accuracy study of archeological documentation carried out by means of UAV kite, the average position error in y, x, and z coordinates was found ± 5.3 cm. According to the results calculated, using photogrammetric techniques, archeological documentations carried out by UAV provides sufficient position accuracy.

In this way, excavation work in the production of litter, modeling before and after excavation, monitoring the development of the excavation phases, has the qualities that can be used in the study area determination and restoration projects.

4.5. Neptune Temple in the Archeolojical area in Italy

An example of such a practice is given in Figure 18, where the Temple of Neptune at the archaeological site of Paestum (Italy) is shown. Given the shape, complexity and dimensions of the monument, a combination of terrestrial and UAV (vertical and oblique) images was used to guarantee the integrity of the 3D surveying work. The UAV used is a 4-rotor MD4-1000 Microdrone system. It is entirely carbon fiber, capable of carrying instruments up to 1.0 kg with a duration of more than 45 minutes. For rare images. The UAV mounted an Olympus E-P1 camera (12 megapixels - 4.3 pm pixels in size) with a focal length of 17 mm, while an Olympus XZ-I (10 megapixels) with a focal length of 6 mm for oblique images. 2 pm pixel size) was used.

The average GSD of images on both flights is about 3 cm. The Autopilot system allowed it to perform two full flights in autonomous mode, but the stored coordinates of the projection centers were not sufficient for direct georeferencing. Therefore, a number of reliable GCP (measured by the total station measured by the corners and total features of the temple) was required to achieve scaled and geographically referenced 3D results. The orientation procedure processed terrestrial and UAV images (ca 190) simultaneously to bring all data in the same coordinate system. After the recovery of camera poses, a DSM was produced for the purpose of documentation and visualization (Fiorillo et al., 2015).

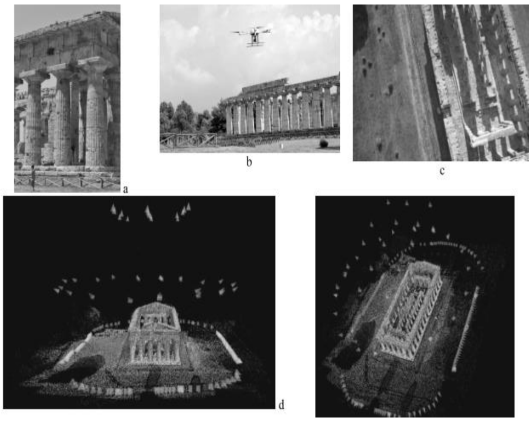

Fig. 18. Orientation results of an aerial block over a flat area of ca 10km(a). The derived camera poses are shown in red/green, while color dots are the 3D object points on the ground. The absence of ground constraint (b) can led to a wrong solution of the computed 3D shape (i.e. ground deformation). The more rigorous approach based on GCPs used as observations in the bundle solution (c),deliver the correct 3D shape of the surveyed scene, i.e. a flat terrain

4.6. Archaeological area of Pave

A second specimen was reported in Figure 19, showing the archaeological site of Pave (ca 60 x 50 m) surveyed annually at the beginning and end of the excavation period to monitor the progress of the work, calculate the volume of the flare, and produce lots. - Temporary orthographic images of the area. Flights (35 m altitude) were made with the Microdrone MD4-200 in 2010 and 2011. The Heritage site was quite windy, so the electrified platform was probably not the optimal one. For each session, a reliable set of images (ca 40), averaging one cm of GSD, were obtained using multiple shots for each waypoint. To assess the quality of the image triangulation procedure, some circular targets measured by a total station are used as Ground Control (GCP) and others as control points (CK). After the orientation step, the RMSE on the CK resulted in 0.037 m in planimetry and 0.023 in height. The resulting DSMs (figure 19b, c) were used to produce vector layers in Pava's GIS, onho images (figure 19d), and to control advances in excavation or excavation volumes (figure 19e).

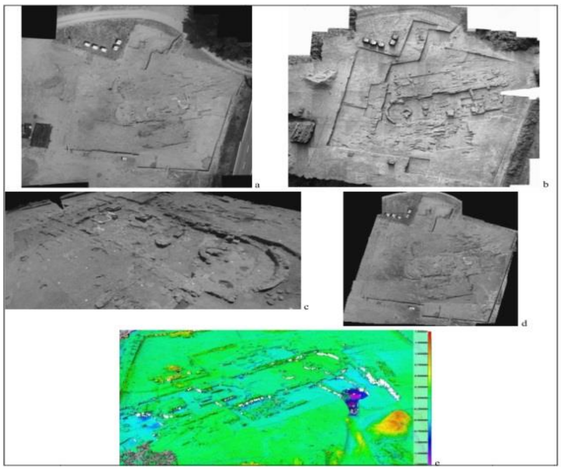

Fig. 19. A mosaic view of the excavation area in Pava (Siena, Italy) surveyed with UAV images for volume excavation computation and GIS applications(a).The derived DSM shown as shaded (b) and textured mode (c) and the produced ortho-image (d) (75). If multi-temporal images are available, DSM differences can be computed for volume exaction estimation

5. CONCLUSION

Unmanned Aerial Vehicles (UAVs) have found place for themselves in every area of life in these days. Antique cities and antique roads taking place in the areas having archeological quality and reaching today have a great importance in terms of cultural heritage. Due to the fact that unmanned aerial vehicles produce (UAVs) 3D data and ortophotos in low cost and high accuracy, they present serious advantages to measure archeological areas (Tercan.2017) .

UAV provides advantages for user in documentation of cultural works as both speed and cost and accuracy and technology in the documentation of historical and cultural works.

Thanks to UAV, it is possible to obtain orthophotos, 3D point clouds and high quality 3D models.

It is also possible to observe cultural heritage, measure, and analyze cultural heritage.

It has a great importance since it reduces the risk of time and budgetary loss and provides usability of the outputs.

Results are presented of photogrammetric projects after his drone archaeological research contexts can be evaluated as highly effective in the field, and excavation of archaeological features and structures in relation to the needs thanks to the versatility of the process.

Unmanned Aerial vehicle can be considered as a quick documentation tool for low-cost mapping.

In the meantime, 3D models will become a convenient database for placing / collecting / accumulating other reading data in a geospatial perspective, such as findings from digging activities and stratigraphic information, and for performing comparative analyses.

Today, thanks to the tilted camera contribution, which studies applications and optimizations in current geography research, 3D models achieve high descriptive performance in terms of geometric surfaces and radiometry, both on the tops and on the vertical facades of steep walls.

In complex and dense areas it can be extremely effective at both detecting details and comparing them.

REFERENCES

Altan, M. O., Celikoyan, T. M., Kemper, G. & Toz, G.(2004). Balloon photogrammetry for cultural heritage In: International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XX ISPRS Congress, Istanbul, Turkey, XXXV-B5, 964-968.

Berni, J.A.J.; Zarco-Tejada, P.J.; Suárez, L.; Fereres, E.(2009). Thermal and Narrowband Multispectral Remote Sensing for Vegetation Monitoring From an Unmanned Aerial Vehicle. Transactions on Geoscience and Remote Sensing, 2009, Vol. 47, pp. 722-738.

Bigras, C. (1997). Kite aerial photography of the Axel Heiberg Island fossil forest, In: American Society of Photogrammetry and Remote Sensing, First North American Symposium on Small Format Aerial Photography, University of Minnesota, USA, 147-153

Callegari, F. (2003). Sustainable development prospects for Italian coastal cultural heritage: a Ligurian case study, Journal of Cultural Heritage, pp. 49–56

Can, M. (2009). Kültürel Miras ve Müzecilik; Çalışma Raporu. Erişim: 12 Eylül 2009. http://www.kultur.gov.tr/teftis/Genel/BelgeGoster.aspx?F6E10F-8892433CFF530CECBE8DDD19208B89614C9154F631

Chiabrandoa F., D'Andriab F., Sammartanoa G. & Spanòa A.(2016). Uav Photogrammetry For Archaeologıcal Sıte Survey. 3d Models At The Hıerapolıs In Phrygıa (Turkey),Virtual Archaeology Review, 9(18): 28-43, 2018 http://dx.doi.org/10.4995/var.2018.5958 © UPV, SEAV, 2015 Received: June 16, 2016 Accepted: August 4, 2017, Filiberto Chiabrandoa

Colomina, I., Blázquez, M., Molina, P., Parés, M. E. & Wis, M. (2008). Towards A New Paradigm for High-Resolution Low-Cost Photogrammetryand Remote Sensing, In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Congress, Beijing, China, XXXVII. Part B1, 1201-1206.

Eisenbeiss, H., 2008c. UAV photogrammetry in plant sciences and geology, In: 6th ARIDA Workshop on "Innovations in 3D Measurement, Modeling and Visualization, Povo (Trento), Italy.

Eisenbeiss, H., (2009). Stempfhuber, W. & Kolb, M., 2009.

English Heritage. (2003). Metric Survey for Heritage Documentation, Documentation for Conservation:A Manual for Teaching Metric Survey Skills.

Everaerts, J. (2007).The Use of Unmanned Aerial Vehicles (UAVS) for Remote Sensing and Mapping. In: Int. Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Beijing, China, 2008; Vol. 37 (B1), pp. 1187-1192.

Everaerts, J. (2008). The Use of Unmanned Aerial Vehicles (UAVS) for Remote Sensing and Mapping, In: The International Archives of the Photogrammetry, Remote Sensing and Spatial

Information Sciences, ISPRS Congress, Beijing, China, XXXVII. Part B1, 1187-1192

Fiorillo F, Jimenez F.-Palacios B, Remondino F, Barba S, 2012. 3D Surveying and modeling of the archaeological area of Paestum, Italy. In: Proc. 3rd Inter. Conference Arquelogica 2.0, 2012, Sevilla, Spain.

Gawronski, J. H. G. & Boyarsky, P. V., (1997). Northbound with Barents: Russian-Dutch integrated archaeologic research on the Archipelago Novaya Zemlya, Uitgeverij Jan Mets, Amsterdam, p. 255.

Korumaz, A.G., Dülgerler O.N. & Yakar M. (2011). Digital Techniques in Cultural Heritage Documentation, Selçuk Üniversitesi Mühendislik-Bilim ve Teknoloji Dergisi.

Kuban, D. (2000). Tarihi çevre Koruma ve Onarımın Mimarlık Boyutu Kuram ve Uygulama, Yapı Endüstri Merkezi Yayınları, İstanbul.

Manyoky, M.; Theiler, P.; Steudler, D.; Eisenbeiss, H.(2011). Unmanned aerial vehicle in cadastral applications. In: Int. Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Zurich, Switzerland, 2011; Vol. 38 (1/C22).

Niranjan, S., Gupta, G. Sharma N.,Mangal, M. & Singh, V.(2007). Initial efforts toward mission-specific imaging surveys from aerial exploring platforms: UAV. In: Map World Forum, Hyderabad, India, 2007; on CD-ROM.

Remondino, F. & Rizzi, A. (2009). "Reality-Based 3D Documentation of World Heritage Sites:Methodologies, Problems and Examples", 22nd CIPA Symposium, Kyoto, Japan, October 11-15 2009.

Sauerbier M. , Eisenbeiss H.,2010. Uavs for the documentatıon of archaeologıcal excavatıons, International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVIII, Part 5 Commission V Symposium, Newcastle upon Tyne, UK. 2010

Şasi A., Yakar M.(2018). Photogrammetric modelling of hasbey dar'ülhuffaz (masjid) Using an unmanned aerial vehicle, International Journal of Engineering and Geosciences (IJEG),Vol; 3; , Issue; 1, pp. 006-011, February, 2018, ISSN 2548-0960, Turkey
DOI: 10.26833/ijeg.328919

Tercan E.(2017). İnsansız Hava Aracı Kullanılarak Antık Kent Ve Tarıhı Kervan Yolunun Fotogrametrık Belgelenmesı: Sarıhacılar Örneğı,Journal of Engineering Sciences and Design DOI: 10.21923/jesd.315232

Tweed, C., & Shutherland, M.(2007). Built cultural heritage and sustainable urban development. Landscape and Urban Planing, 83, 62-69.

Ulvi A., Yakar M., Yiğit A.Y., Kaya Y.(2020), İHA ve Yersel Fotogrametrik Teknikler Kullanarak Aksaray Kızıl Kilise'nin 3 Boyutlu Nokta Bulutu ve Modelinin Üretilmesi, Geomatik Dergisi Journal of Geomatics Araştırma Makelesi DOI: 10.29128/geomatik.560179 2020; 5(1);22-30

Ulvi A.,(2018). Analysis of the utility of the Unmanned Aerial Vehicle(uav) in volume calculation by using photogrammetric techniques, International Journal of Engineering and Geosciences (IJEG),Vol; 3; , Issue; 2, pp. 043-049, June, 2018

Ulvi, A., Toprak, A. 2016. Investigation of threedimensional modelling availability taken photograph of the unmanned aerial vehicle; sample of kanlidivane church. International Journal of Engineering and Geosciences, 1 (1), 1-7. DOI: 10.26833/ijeg.285216

Van Blyenburgh, P. (1999). UAVs: and Overview, In: Air & Space Europe, I, 5/6, 43-47

Yakar M., Doğan Y.,(2018). Gis and three-dimensional modeling for cultural heritages, International Journal of Engineering and Geosciences (IJEG), Vol; 3; Issue; 2, pp. 050-055, June, 2018, ISSN 2548-0960, Turkey, DOI: 10.26833/ijeg.378257

URL-1, 2007, ODTÜ Mimarlık Fakültesi Araştırma, Tasarım, Planlama Ve Uygulama Merkezi http://matpum.arch.metu.edu.tr/index.php?option=com_ content&task=view&id=31&Itemid=6
URL-2, http://www.robonik.com.tr
URL-3, http://www.sensefly.com/drones/ebee.html
URL-22, http://www.brooxes.com
URL-23, http://www.birdseye.nl
URL-24, http://www.rc-zeppelin.com
URL-25,http://www.uvs-international.org/(last accessed: December, 2012).