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The Journal of ***Advanced UAV*** is a peer-reviewed journal that publishes studies on UAV development, use, and earth sciences and is scanned in International Indexes and Databases. The journal Advanced UAV (AUAV), Unmanned Aerial Vehicle Systems (UAS), and Remote Piloted Aircraft Systems (RPAS), etc. focuses on the design and applications of unmanned aerial vehicles, including. Likewise, contributions based on unmanned water/underwater drones and unmanned ground vehicles are also welcomed.

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Usage of unmanned aerial vehicles on highways and application areas: a case study of Kozan Mansurlu Road

Fatih Tükenmez *[*1]

[1]*General directorate of Highways, 5th district Office, Mersin, Türkiye, f.tukenmez@hotmail.com*

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Abstract

Unmanned aerial vehicles (UAVs) are fixed or rotary wing aircrafts that can be guided by modern remote-control systems that can fly without a human being. It is important that UAVs, which have had many uses recently, are used on highway engineering services as well. It is desired that the accuracy of the numerical height model should be high in determining the horizontal and vertical geometry of the highway project and calculating the amount of cubage based on road construction costs correctly. In this context, the usage of UAVs on landslide prevention projects and the production of current maps of intersection areas is also important on highways. In this study, the usage and application areas of UAVs on the highways have been mentioned. It has been observed that the results obtained by comparing the landslide region, numerical land model obtained from Kozan Mansurlu Road Landslide Region, numerical map production model with the terrestrial classical methods and numerical land model have sufficient accuracy and sensitivity in the mountainous land region.

1. Introduction

Highway is a land strip that allows traffic flows including vehicle and pedestrian, and bridge, tunnel, viaducts, protection structures (retaining and shoring walls) which are located on it. The roads in the highway network are classified as State, Province and Highway. State roads are roads that connect provinces, provincial roads connect districts, and highways are roads with high geometric standard access control.

Base maps are large-scale maps used in road projects as well as in other engineering fields. The base maps used for highway route projects are Energy Transmission Lines and strip-like maps showing streams, hills, canals, roads, energy transmission lines covering a corridor of approximately 200 m. In addition, they are produced to be used in intersection projects and landslide prevention projects, which are local application areas on highways.

All these route maps were produced using classical methods (measurement, calculation and drawing) by the Highways survey teams, which were expressed as entrusted in previous years. As a result of developing technologies, these maps started to be produced digitally with the classical terrestrial method, by means of tenders, using GPS measurement techniques. In recent years, existing maps have been produced photogrammetrically by tender, especially on routes of 30 km and above, taking into account the topography of the land.

Digital Terrain Model (DTM), Digital Elevation Model (DEM), Digital Surface Model (DSM), City Maps, Geographic Information System (GIS), 3D modeling of areas can be given as examples of UAV usage. The creek, ditch and slope which are defined as the critical land section on the base maps for the highway projects. The precision of the DEM is important for the sections to reflect the real terrain and for the correct and calculation of soil volume calculations. The DEM produced with UAV technology gives a high accuracy result, as seen in this study.

Unmanned aerial vehicles (UAVs) are fixed or rotary wing aircraft that are the modern measurement systems, which can fly without a human on them, and can be directed by remote control. There are tools that can be used by civilian users in many sectors such as construction in the real estate sector, fields, photography, agriculture, mining archeology, agriculture, geological applications and photogrammetric studies.

Two decades ago, different surveying techniques such as total station and kite were used to model the terrain [1]. Nowadays, UAV can be controlled via a smartphone easily. UAVs are used in risky situations without endangering human life and in inaccessible areas (heavy forest areas, etc.) where there is no manned flight opportunity and flight permit cannot be given. In classical method robotic total station was used to create DEM [2]. Today, a UAV can easily produce DEM [3].

UAV has been used in many engineering projects such as landslide [4], rockfall [5], shoreline detection [6], cultural heritage studies [7-13], Energy transmission line detection [14], vegetation detection [15], and tree detection [16] and volume calculation [17-19].

UAV enables to produce maps in a short time at low cost, especially on the routes where mountainous and dense forest areas are hit on the highways. UAVs are categorized in various ways depending on their capabilities, size, or the tasks they perform. There is no specific standard for the classification of UAV systems. Since the systems are generally designed to fulfill various tasks, the limits of the classification change according to the developing technology.

Military UAVs are vehicles used during the performance of basic military missions such as reconnaissance, surveillance and intelligence that serve military purposes for our national security. Civilian UAVs are the preferred aerial image acquisition tools in various fields in recent years, and they have been frequently used in survey engineering in recent years.

Ten years ago, terrestrial photogrammetric methods were used in many engineering applications [20]. UAVs are preferred because they can make measurements in risky areas and where people have difficulty in local access thanks to the Digital Camera and GPS-GNSS systems placed on them. The data obtained is fast, economical and close to classical methods in terms of measurement accuracy [21-22]. When the measurements made with UAVs are evaluated in terms of sensitivity, it is seen that it has a place to fill the gap between classical terrestrial measurement methods and classical aerial photogrammetry.

With the Kozan Mansurlu Road landslide prevention project study, it is aimed to compare the DTM produced by the UAV with the existing DTM, which was previously produced with the classical terrestrial method, and to use it effectively on the highways.

2. Material and Method

The UAV can be used mostly in intersection projects, landslide prevention projects, the production of Digital Base Map and DEM for highway projects. In this study, the creation of a digital base map and DEM, which will be the basis for the Kozan Mansurlu Provincial Road landslide prevention project, is mentioned.

2.1. Study area

In this study, the landslide section (Adana-Kozan), Ayr.-Mansurlu Provincial Road, islocated between Km: 50 + 160- 50 + 600. The section for producing the base map using UAV is approximately 1 km, between Km: 49 + 800- 50 + 850 (Figure 1).

The aim of Kozan-Mansurlu work is to produce digital maps of the landslide area with the photogrammetric method using a UAV (drone). The relevant area is located in the Marankeçili locality, approximately 30 km northwest of Kozan district of Adana province (Figure 2).

Figure 1. Google Earth image of the project area

Figure 2. Orthophoto map of the project area

2.2. Data

Within the scope of producing the base map of the road with the terrestrial method by our Regional Directorate without leaving the land, a total of two polygon points (P33, P27), at the beginning and at the end of the Project, among the polygon points whose facilities and measurements were made beforehand, as a reference for the new Ground Control Points (GCP) to be laid within the scope of the flight (Table 1).

DJI Phantom 4 Pro model drone (Figure 3) was used for flight. The drone has an integrated 20 MP camera and axis gimbal. In this way, the camera angle always remains constant during the flight.

The flight was made from approximately 150 meters with 80% transverse and 60% longitudinal overlap, and a total of 288 aerial photographs were obtained.

Table 1. Coordinates of polygons (ITRF-96, DOM 36, 3°, Epok:2005)

Poligon	Easting (m)	Northing (m)	Elevation (m)
P.27	465360.491	4170623.615	873.500
P.33	465371.462	4171554.747	1000.408

Figure 3. DJI Phantom 4 Pro

2.3 Method

Within the scope of the project, fourteen new GCPs were established. While constructing the point facilities, attention was paid not to choose places such as the bottom of the tree, in front of the wall, in front of the building, and open areas that were easily selected from the air were preferred. While point facilities are being built, it is aimed that the distance between each other should not exceed 300-400 meters (Figure 4).

The flight plan was prepared and implemented as a single block. While preparing the flight plan, it is necessary to consider the structure of the terrain and the distribution of GCPs. For example, in this study, the flight direction was chosen as north-south. The most important reason is to reduce the possible risk by flying parallel to the mountains and hills in the field and to minimize the flight time that will arise. While constructing GCP facilities, care should be taken to distribute them as homogeneously as possible on the flight area. If there is more than one block at the beginning and end of the flight columns, GCP must be installed at their intersection.

The obtained aerial photographs were transferred to the computer and overhead triangulation, balancing and orthophoto production processes were completed using Agisoft Metashape 1.5.2 software.

The primary step on the software is to collect the point cloud, so that the common areas in the photo and column overlays are matched with each other with the help of pixels and the needed point cloud is obtained (Figure 5).

Then, by marking the real places of the GCPs on the photograph, the positioning of the photographs is ensured (Figure 6).

After GCPs were marked on the pictures, the balancing process was performed and the coordinate, height and rotation (omega, phi, kappa) values of the pictures and the camera calibration information of this balancing were obtained. With the help of this data, the pictures were introduced to Erdas Imagine software and the evaluation process was completed by the photogrammetry operators. Before starting the valuation, all GCPs were compared with their real values and their values from stereo and checked. At the same time, the model and column transitions were also checked in this way, and then they were digitized safely.

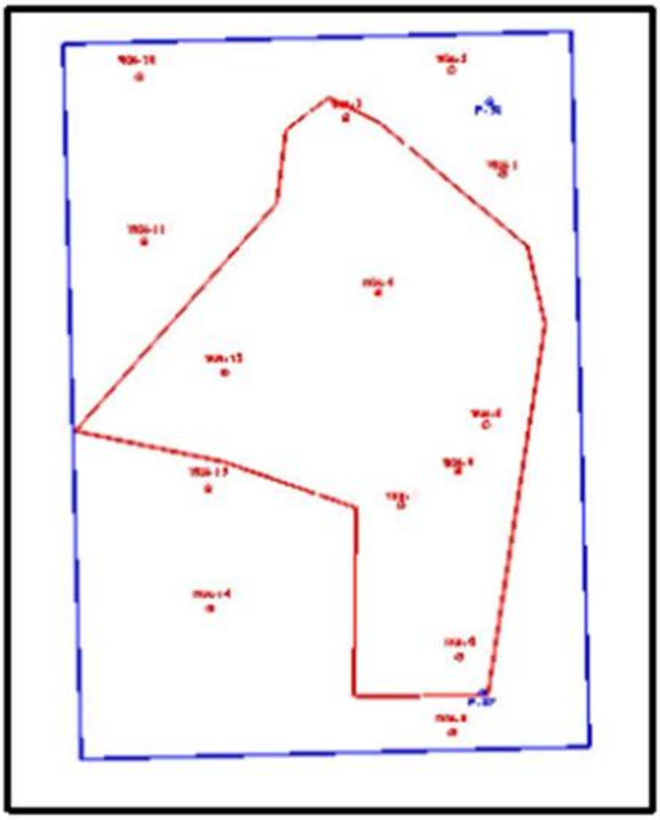

Figure 4. Ground control points

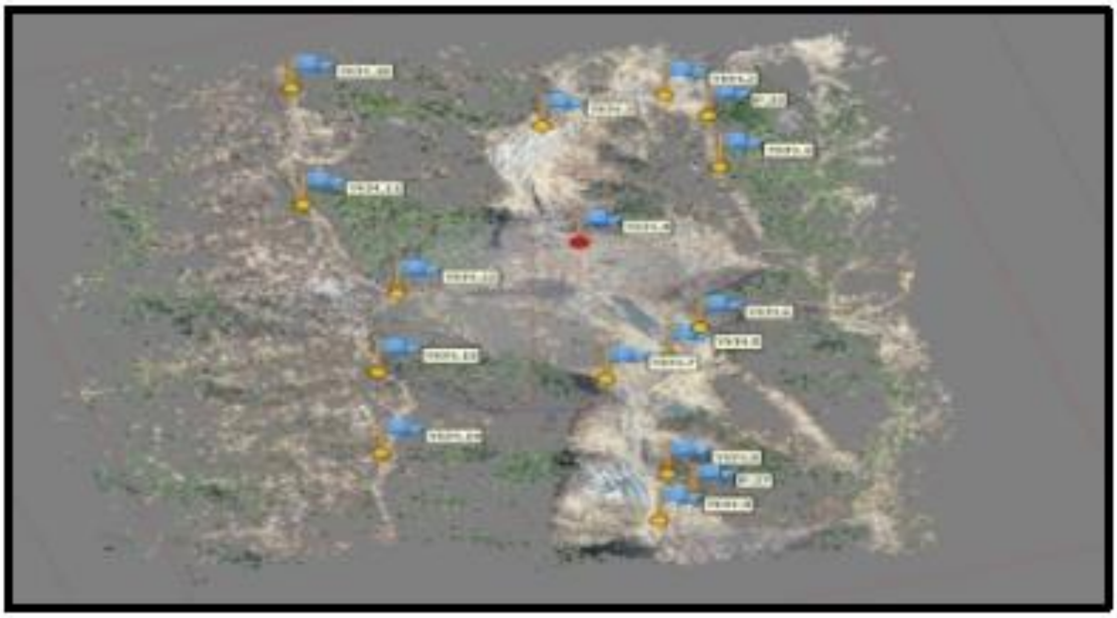

Figure 5. Point cloud of the study area

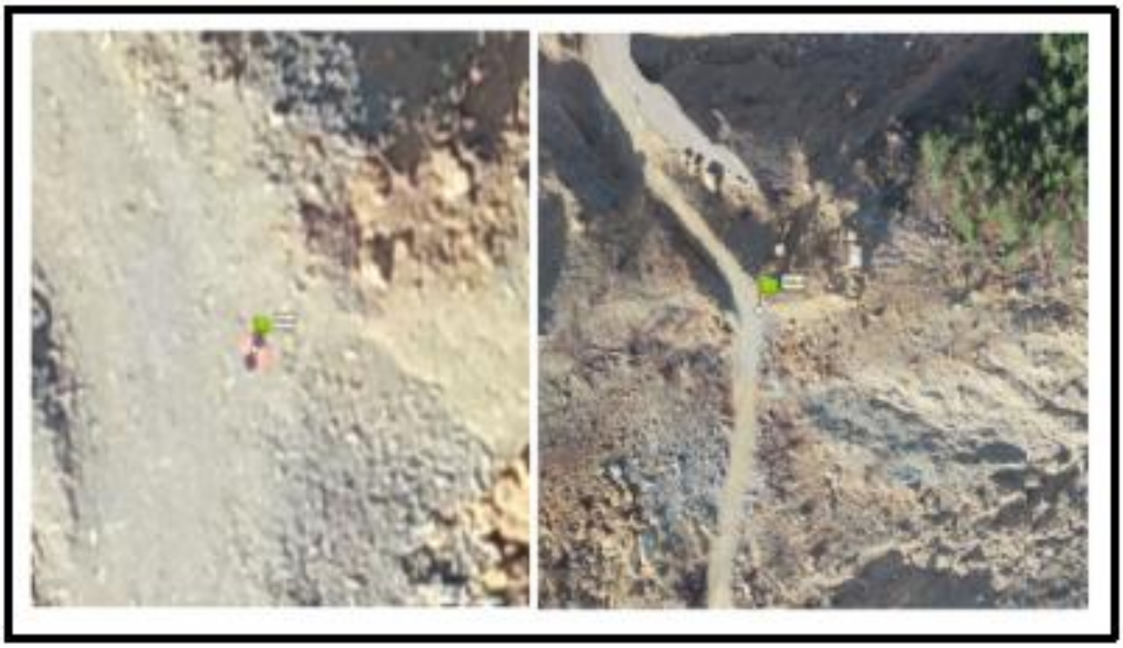

Figure 6. Ground control points in the field

3. Results and conclusion

The elevations of five points on the Digital Base map, obtained by using Microstation software, were read through the digital terrain model (DTM) (Figure 7). These points were compared with the DTM obtained in Netcad program (Figure 8) of the existing map of the region, which was previously produced with the terrestrial classical method. The differences between the heights of the points between both models were calculated and it was seen that the results were within the error limit (Table 2).

• When the results obtained considering the study area are examined, it shows that the use of UAVs on highways is a sensitive and appropriate method, especially in mountainous and inaccessible areas.

• The Kozan-Mansurlu road and the landslide area in the study area have mountainous terrain and the road standard is low. In such areas, if the base maps for highway route projects are produced using classical (traditional) terrestrial methods, it creates a danger in terms of life and property safety, especially in mountainous and inaccessible areas, and requires time loss and high cost.

• At the end of the project, UAVs can be used in the preparation of the final projects of the highway projects whose production is completed according to the project.

• It should be preferred to produce maps with UAV technology in order to ensure life safety due to the heavy traffic in the intersection areas, especially in urban intersection designs.

• Study example, in the Kozan Mansurlu Road landslide region, it is seen that the difference in the terrain elevations on which the control measurement is made on the digital terrain model produced by using the UAV technology and the classical terrestrial method is in the range of ±5-10 cm on average, and it is an acceptable high-accuracy result according to the highway map technical specifications.

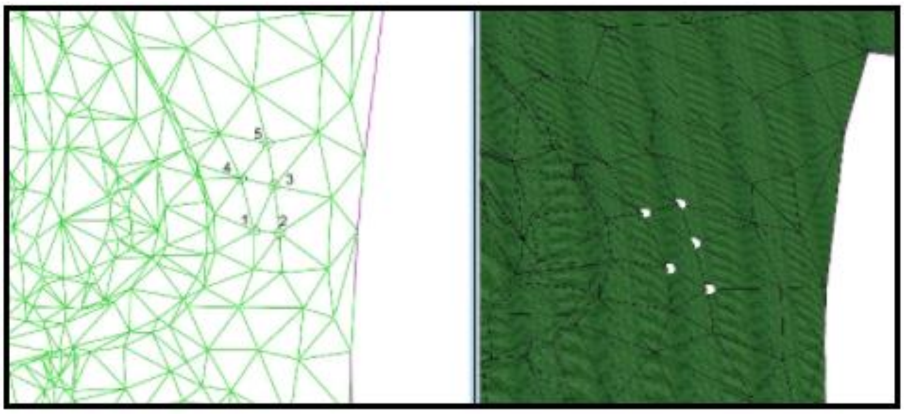

Figure 7. Digital elevation model obtained from MicroStation

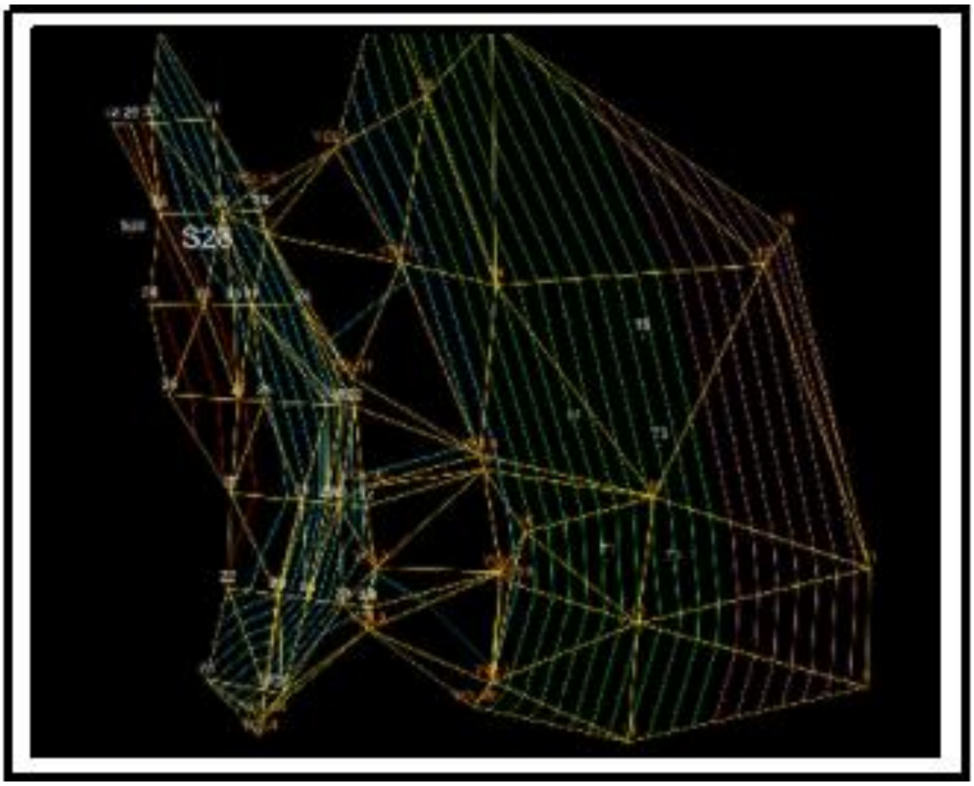

Figure 8. Digital elevation model obtained from Netcad

Table 2. Comparison of digital elevation models

Point	Y (m)	X (m)	H (avg) Terrestrial	H (avg) UAV	Difference (m)
1	465415.65	4170980.11	920.44	920.34	0.1
2	465420.45	4170979.59	917.063	917	0.063
3	465419.42	4170988.44	916.74	916.74	0.06
4	465413.2	4170989.84	920.94	920.94	0.08
5	465418.15	4170996.36	916.13	916.13	0.09

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Conflicts of interest

The authors declare no conflicts of interest.

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Unmanned aerial vehicle usage in rough areas and photogrammetric data generation

Adem Kabadayı *[1]

[1] *Yozgat Bozok University, Department of Architecture and Urban Planning, Yozgat, Türkiye, ademkabadayi@gmail.com*

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Abstract

The data produced with the help of remote sensing and photogrammetry technique is used in every field. With the development of technology, data has started to be produced with unmanned aerial vehicles (UAVs) as a different platform. It is especially preferred for small areas due to its repetitive flight capability, speed, high resolution and low cost. In addition, UAVs are used effectively in areas where human transportation is difficult and in rocky and uneven areas such as mine fields. Autophoto image is 3-dimensional, coordinated numerical data by eliminating optical errors (such as curvature, rotation and height difference) with the photogrammetry technique and making them vertical projection. In this study, the advantages of UAV-based mapping applications in rough areas are included. In this context, mapping of rough areas was carried out with the help of orthophoto maps produced by UAV photogrammetry and Digital Elevation Models (DEM) data.

1. Introduction

The technology, which is developing every day and knows no borders, has allowed the rapid change of human-made aircraft and related industries. The aviation adventure, which started with the dream of seeing the world from a bird's eye view and continued for the purpose of transporting passengers and goods, gained a different meaning with the First World War. Because in this great war, airplanes were included in military service for the first time and served for attack, defense and reconnaissance purposes throughout the war [1].

For the first time in history, an unmanned vehicle was used in a military incident, which was recorded as the first unmanned aerial attack. This event happened in 1849, when the Austrians sent explosive-filled unmanned balloons to Venice, Italy. The development and production of aircraft with the aim of flying truly remotely, that is, unmanned, coincides with the First World War for the first time. Here, Unmanned Aerial Vehicles, which are defined as flying vehicles that do not contain humans and can be controlled from the ground thanks to a communication system, in short, UAVs, came into active use especially after the Second World War [2].

The simplest examples of UAVs used today are drones. Drones, which are frequently used for civilian purposes other than military purposes, and especially by today's young generation born in the 2000s, are preferred because they outperform humans in many areas. Civil aviation drones provide great benefits in fields such as journalism, show business, marketing, agriculture, cargo, health, emergency aid, communication, cartography and fire response [3].

Developing technology and demands have accelerated the development of UAVs and many studies have been carried out especially in recent years to achieve different missions and purposes. These aircraft, which were discovered to be used for military purposes rather than civil aviation, serve the defense sector due to the numerous advantages they provide today. Unmanned Aerial Vehicles in the field of military aviation is used as target designation and bait, in conflicts for reconnaissance and surveillance, and in high-risk missions.

UAVs provides a great advantage over normal aircraft due to its low production, purchasing, fuel and flight costs [4-5]. More importantly, these vehicles do not pose a risk of injury or loss of life during the mission, as they are uncrewed. For the same reason, they are lighter than conventional aircraft and can stay in the air longer with the same amount of fuel [6].

On the other hand, the disadvantages for UAVs are that their danger perception ability is not as strong as a human, that they can pose a danger if the ground control connection is broken, and that they are vulnerable to air attacks by manned aircraft. However, these disadvantages are tried to be minimized with R&D activities in data transfer and artificial intelligence technologies. On the other hand, further increasing the flight times will allow these vehicles to be used widely in the near future [7].

Today, our country has managed to become a country that produces its own software and technology in the defense industry. In addition to the defense industry, UAVs are used in applications such as virtual reality and three-dimensional (3D) model production. In addition, UAVs are used effectively and efficiently in pre-disaster and post-disaster investigations, tourism, architectural areas and 3D city planning, 3D modeling of structures [8].

Images obtained with high sensitivity at very low flight using UAVs can be produced at a lower cost than images obtained from conventional aerial photogrammetry [9-10].

Unlike airplanes used in conventional aerial photogrammetry, UAVs offer the opportunity to fly close to the object and at low altitudes. In some cases where transportation is difficult and manned aircraft cannot be used, UAVs are preferred as an alternative method. In addition, in small-scale conventional aerial photogrammetry applications, a great deal of savings can be achieved by using UAVs despite unnecessary data volume and high cost. Studies carried out with the help of UAVs approach the sensitivity of terrestrial photogrammetry and have the opportunity to be applied in many different areas because the data processing process can be completed in a short time [11]. Two decades ago, robotic total station was used frequently [12]. However, UAV technology recently widely used by many disciplines for different purposes, such as map making, volume calculations, 3D model making, documentation of cultural heritage and hobby purposes.

Uysal et al [13] aimed to produce the Digital Terrain Model (DTM) of the Şahitler Kayası Höyük using UAV photogrammetric techniques and to perform an accuracy analysis on an area of approximately 5 ha in the Şahitler Kayası location in the center of Afyonkarahisar. In their study, they established a total of 27 GCPs in the application area, 5 homogeneously, and obtained the coordinates of GCPs in ITRF96 datum by RTK method with Stonex S9 GNSS (Global Navigation Satellite Systems - Global Positioning Satellite Systems) device. Images were captured from an average height of 60 m with the Canon EOS digital camera on the UAV. As a result of their study, they evaluated the accuracy of the DTM with 30 control points and determined a vertical sensitivity of 6.62 cm. They stated that the usage of UAVs and photogrammetric techniques together will make significant contributions to the work done in this field in terms of accuracy, speed, cost and product diversity.

UAVs are one of the most important technologies in many aviation applications, especially for civil and military purposes and applications, due to their low cost and high performance. UAVs have a short wing span (fixed or rotary wing) and a light structure, as well as a sensitive structure during flight [14-15].

Şenol and Kaya [16] stated that in order to create a 3D model, a field study of the model should be done. In order to create a 3D model of a structure, they added data collection with UAV to their data collection methods. They wanted to minimize the field work with the data collection methods, and for this purpose, they were able to collect data without the need for field work. In addition, they informed that models can be created with various software from images of UAV, terrestrial and rough areas.

Today, this is usually done with classical terrestrial measurement methods, but measuring with terrestrial methods is difficult, expensive, takes a lot of time compared to the photogrammetric method, and sometimes it is not possible due to the terrain structure. It has become a necessity to use alternative methods in such mountainous, rocky and rough terrains that people have difficulty in reaching. Sometimes it is not possible to approach dangerous places such as swamps, stream beds, and sometimes the edge of a cliff with classical measurement methods. Reaching these areas, which people cannot reach, with UAVs and taking images provides great convenience today. With the overlay images to be taken from the land, the land structure can be modeled in a 3D and coordinated manner [17].

In the light of the information given above, expanding the use of UAVs in mapping rough areas will provide many advantages. Especially in very rough areas, mapping operations should be carried out in a short time, mapping work is required in stock movements and incubation calculations in the field. Conducting this study with terrestrial methods leads to risks, high costs and time losses in terms of occupational safety. On the other hand, the production of periodic orthophoto maps using UAVs is very low cost and incomparably advantageous in terms of time and personnel. In addition, periodic maps of the entire field, not just the area where the study is carried out, can be produced instead of partial mapping with the UAV. In this way, it will be possible to make optimum planning by making healthy decisions for the future, where possible threats can be foreseen in the work area.

Nowadays, UAV has been frequently used in cultural heritage studies [18-23]. Photogrammetry and UAVs have been used in many engineering projects such as land cover classification [24], landslide modelling [25-26], rockfall modelling [27], pond site volume [28], measure the position of inaccessible geological features [29], shoreline detection [30], volume calculation [31-32].

2. Material

2.1. Study area

The mining quarry in the town of Burdur was chosen as the study area (Figure 1). The coordinates of the study area are 37° 35' 54'' North latitude, 30° 41' 40' East longitude.

Figure 1. Study Area

2.2. Data

The supply of images in the orthophoto production was captured with the DJI Phanton 4 Pro (Figure 2a). With the help of the GNSS receiver, the GCPs shown in Figure 2b were measured.

(a) (b)

Figure 2a. Phantom 4 Pro, **2b.** Ground control point

2.3. Method

Orthophoto, digital terrain model (SAM) and digital surface model were produced from the pictures taken from the study area using the Object Creation-Structure from Motion (SFM) technique.

3. Application

The application consists of two parts as field and office work.

3.1. Field work

In order to balance the photographs taken with the UAV more precisely, coordinates and height values were measured from certain points in the field. GNSS receiver was used in this process. 5 GCPs were installed on the land. The GCPs were distributed homogeneously, not exceeding 300 meters, paying attention to the places where the slope and height change. YKNs were measured twice with a sensitive GNSS receiver. Care was taken to ensure that there was at least one hour between two measurements.

After the GCP installation and measurement was carried out, the process of photographing the land with the UAV was started. For photographic image acquisition; Ground Sampling Range (YÖA-GSD) 5-7 cm. A flight plan has been prepared at a height of 80 meters, with a longitudinal overlap rate of 80% and a transverse overlap rate of 60%.

3.2. Office work

3.2.1. Preliminary

First of all, coordinate and height balancing of 5 GCPs that were installed in the field and read with a GNSS receiver were made (Table 1). Then, the conversion of the HCPs, whose ellipsoidal heights were measured with a GNSS receiver, to Helmert orthometric heights was performed.

Table 1. Balancing of ground control points

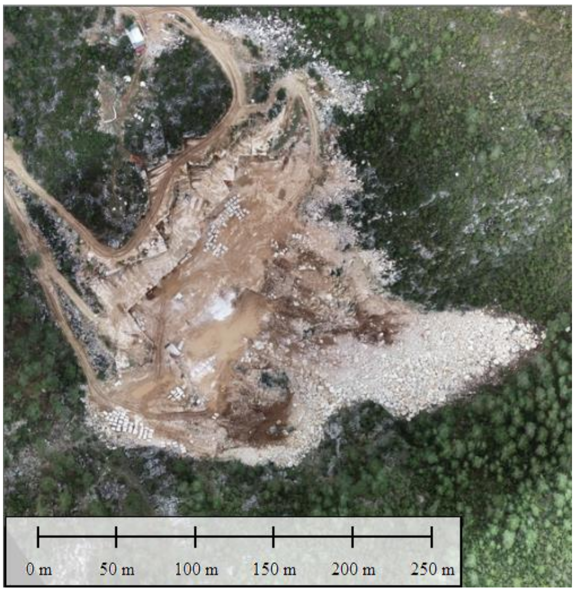
Point No	Observation number	Raw GNSS Data			Adjusted coordinates		
		Easting (Y) (m)	Northing (X) (m)	Elipsoid Height (h) (m)	Easting (Y) (m)	Northing (X) (m)	Elipsoid Height (h) (m)
P.1	1	561591.059	4163461.010	1109.003	561591.041	4163461.017	1109.002
	2	561591.023	4163461.024	1109.000			
P.2	1	561561.594	4163318.596	1095.011	561561.598	4163318.608	1094.992
	2	561561.601	4163318.619	1094.973			
P.3	1	561608.150	4163209.944	1073.103	561608.148	4163209.947	1073.094
	2	561608.145	4163209.949	1073.085			
P.4	1	561691.823	4163370.547	1074.474	561691.828	4163370.560	1074.448
	2	561691.833	4163370.572	1074.421			
P.5	1	561622.467	4163352.997	1084.599	561622.457	4163353.000	1084.569
	2	561622.450	4163353.003	1084.539			

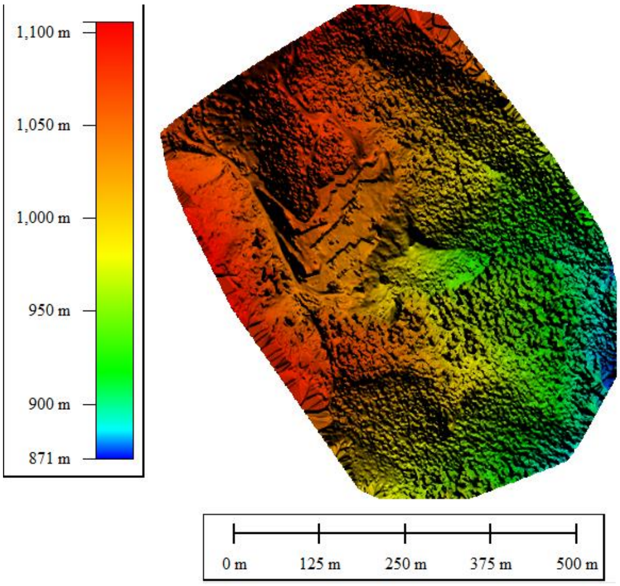
3.2.2. Photogrammetric processing of UAV images

Photogrammetry is a branch of science that creates information about physical objects and their surroundings as a result of recording, measuring and interpreting photographic images and electromagnetic energy and analyzing this information.

SFM method is used to create 3D models with photogrammetric method. SFM has been translated into Turkish as Motion Based Structural Detection. Structure from motion (SFM) photogrammetry technique has emerged as a cost-effective and practical modeling tool that has become increasingly popular in recent years in parallel with the development of computer hardware and software capabilities.

The pictures obtained by the UAV belonging to the study area were evaluated in the Pix4D software. At the end of the valuation, orthophoto image (Figure 4) and DEM (Figure 5) data were obtained for the study area.





(a) (b)

Figure 3. a) Orthophoto map produced in Pix4D software, **b)** DEM data generated in Pix4D software

3.2.3. Drawings

The map of the study area was made from the 3D model produced by combining the orthophoto and the digital elevation model (DEM) produced as a result of photogrammetric balancing (Figure 4).

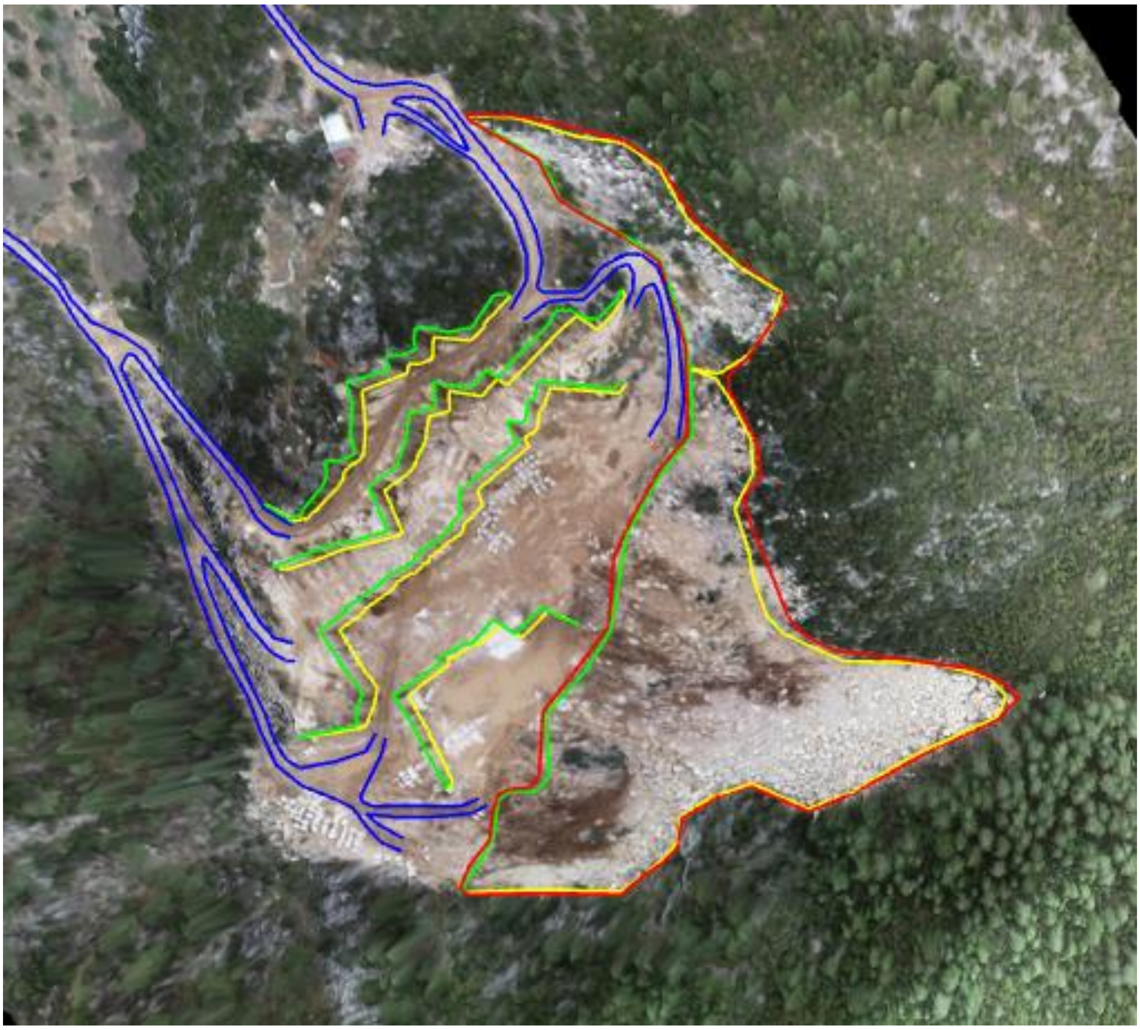


Figure 4. Map data of the land

4. Results

Working in mountainous and rough areas with terrestrial methods requires a long time and effort, and production may be interrupted during measurements. However, risky situations may arise in terms of business, and all these studies are quite burdensome in terms of cost. Numerical data to be produced by the UAV can be revealed in a much shorter timeframe, with a minimum operational team and with less cost compared to the classical terrestrial measurement methods (Total Station, GPS). In addition, digital elevation model, orthophoto and 3D model can be obtained in the study, so these products also provide multidisciplinary solutions. The production of periodic orthophoto maps using UAVs and especially the calculation of the stock amount is very low cost and incomparably advantageous in terms of time-personnel. In addition, instead of partial mapping using UAVs, periodic mapping of the entire area, not a part of the area, is in question.

5. Conclusion

In this study, mapping of a land has been shown in a practical way. Low-cost UAV can be easily used in such a terrain. With the UAV, easy, fast, high-precision and economical measurements can be made in difficult terrain conditions. 3D models produced in a short time; It offers extremely easy solutions in terms of monitoring progress in the field, identifying inconsistencies, making healthy future decisions, and planning.

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Conflicts of interest

The authors declare no conflicts of interest.

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The possibilities of data usage obtained from UAV

Mücahit Emre Oruç *1

[1]Mersin University, Department of Remote Sensing & GIS, Mersin, Türkiye, mucahitemre27@gmail.com

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Abstract

Unmanned aerial vehicles are used in many areas with the developing technology. These areas are increasing day by day and have met with intense interest due to these increases. The systems called drone, which is one of the systems that can be controlled by unmanned aerial vehicles, were first used as both weapons and surveillance equipment in military areas where there is risk. Along with the developing technology, it has also been used by many disciplines in civilian areas. It has started to be used in various application areas with its labor capacity and low cost compared to the classical photogrammetry method in obtaining high spatial and temporal resolution images in a short time. UAVs are used in various fields such as the creation of three-dimensional earth models, high-resolution orthophoto production, transportation network planning, land monitoring, determination and monitoring of forest, mine and agricultural areas. Geometric accuracy in orthophoto maps is of great importance in cartography applications. It provides the opportunity to obtain many data that can form a basis for various disciplines. In this study, point cloud, orthophoto, digital elevation model (DEM) was produced from the images obtained by the unmanned aerial vehicle. Dilution processes due to point cloud density were carried out.

1. Introduction

With the development of technology and the increase in the demand for unmanned aerial vehicles (UAVs), the usage areas have expanded and started to attract attention from researchers and scientists. Later, as this interest attracted the attention of the civilian population, it was able to get rid of its use only in military fields and find the opportunity to be used in civilian life as well. With the development of technology, it has been realized by producing more suitable sizes and equipment for civilian users, at low costs. As it has become more affordable and widely available to civilian users, it has also found wide application for civilian and commercial purposes such as aerial photography, mapping, and scientific data collection. This has shown the effectiveness of unmanned aerial vehicles to a great extent in todays and future studies.

UAV is an aircraft that provide manual flight or act autonomously on a predetermined flight plan and return to the take-off point after completing the mission [1]. Unmanned Aerial Vehicles, also called drones, are classified as fixed wing and rotary wing according to their flight capabilities. Fixed wing UAVs are generally used for scanning large areas, and rotary-wing UAVs are used for scanning smaller areas [2].

UAVs, namely drones, help many different disciplines such as forestry, archaeology, documentation and protection of cultural heritage, wildlife surveys, environmental monitoring, traffic control and regulation, mapping, transportation, construction, energy fields and pipelines, geological fields, coastal monitoring, landscape planning, mining, disaster monitoring and prevention, rescue work, agriculture and spraying, deformation monitoring [3].

While technical academic studies were carried out on UAVs in the past, it is now becoming a sector. Different types of studies on UAVs have also begun to take their place in the literature. Titles such as R&D, cost, social ethics, UAV aviation standards regulations can be given as examples of different titles that have started to be seen in this field in the literature. Compilation, classification, standardization of terms is important for academic and industrial studies to progress healthier and easily [4].

The photogrammetric potential of UAVs has been evaluated by applying it in various studies in the recent past. It is also used in many applications today. In addition to these studies, research continues to increase the accuracy of the orthophoto maps and DEMs [5-11].

In line with these developments in UAV photogrammetry, current map production, three-dimensional (3D) modeling, production, stock and casting area cubage calculations, rock detection, geological mapping, excavation planning and installation of hyperspectral cameras, alteration and mineral detection in open mines, vertical. The method is also used in studies such as mapping inaccessible points [12-15].

Images taken with UAVs are transformed into meaningful data by means of appropriate processing software. By combining the images taken in the software, many useful data such as 3D point cloud, solid model, orthophoto, digital elevation model (DEM) are obtained. With these data, appropriate disciplines can easily perform the operations they need. In this study, a mining area was chosen as the study area. 3D model of the mine area, point cloud, orthophoto, and digital elevation models were obtained. These data were processed in context capture software by taking photos with the help of an unmanned aerial vehicle. Photos of the working area are DJI brand Phantom 4 Pro model. With the help of the photographs obtained, data that will serve as a base for many disciplines have been produced. These data will provide significant convenience in the areas where it is desired to be used.

2. Method

2.1. Unmanned aerial vehicle (UAV)

Unmanned aerial vehicles (UAVs) are pilotless aerial vehicles equipped with digital cameras and, unlike traditional remote sensing methods, provide high resolution temporal and spatial images at low cost. UAVs, also called by different names such as unmanned aerial system, aerial robot, pilotless aircraft, are remotely controlled aerial vehicles that can carry cameras, sensors and communication equipment.

In other words, unmanned aerial vehicles can be defined as aircraft that automatically fly in the air with the help of GPS control without the need for a pilot [16]. UAVs are remotely controlled by a pilot on the ground, and they are vehicles that fly automatically with pre-made flight planning.

2.2. Classification of UAVs

According to the technical specifications of UAVs, it is possible to make two main classifications (according to their weight, fuel-energy usage source, wing structure, automatic or remote control, etc.) and usage purposes (military and civil). Classification is given in Figure 1 as a diagram.

2.2.1 According to their weight

These are the classification types based on the maximum take-off mass, the distance that the UAV can perform, the time it can stay in the air, and the maximum altitude it can reach. Classifications based on one or more of these parameters in different combinations constitute the majority of classifications on UAVs in total. The reason why these parameters are widely preferred in classification is based on UAV applications, it is observable, measurable and functional / operational features [4].

2.2.2 According to the Fuel-Energy source

The fuel system used in this classification is decisive. Pilotless, disposable UAVs, which are fueled during production at the factory, are the first head for the fuel system. Another topic is UAVs that use a fuel system suitable for refueling from the ground station, ship deck or any other place.

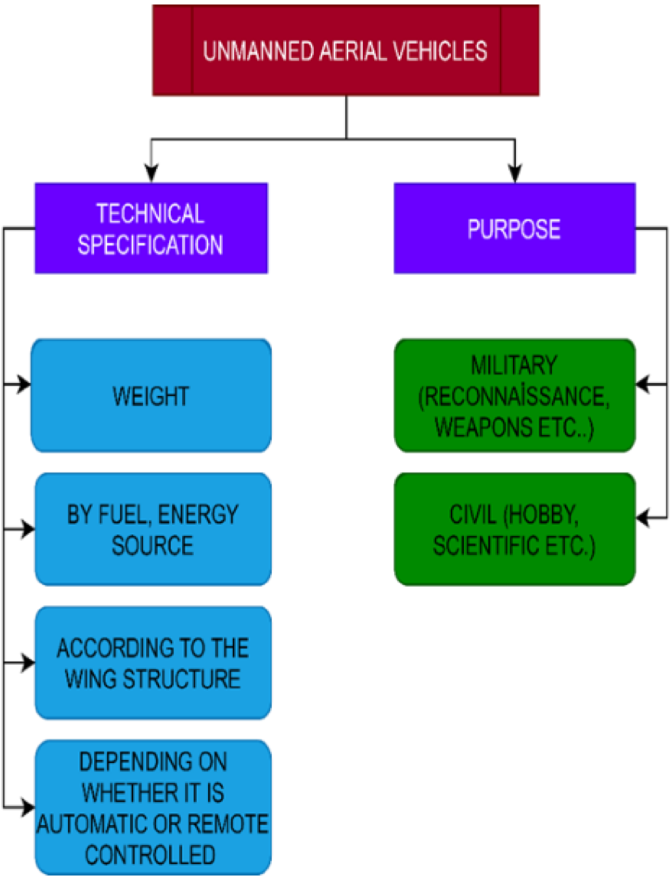

Figure 1. UAV classification

2.2.3 According to the wing structure

It is a classification made in two parts as fixed and non-fixed / rotary wing types. In general, fixed wing is preferred in the design of aircraft and helicopter type UAVs. The variable wing cap can also be divided into three subheadings such as wing size, wing position and wing form that can change during flight [4].

2.2.4 According to the automatic-remote control

It is an important parameter that distinguishes UAVs from other aircrafts. Considering that pilotless flight is aimed, the importance of the control system is understood more. When we look at the classifications made according to this parameter, we can list various control systems in accordance with the technological development of UAVs: Applications controlled by an operator up to a certain distance from a ground control center are called "direct control". Another classification is “observed control”. Here, the UAV can act autonomously, may be partially or completely intervened by a pilot, or observable movement can be achieved with a number of commands. Third, the incompatible - autonomous control head can be examined. Pilotless and autonomous, that is, independent movement is provided by pre-programming. What is meant by incompatibility is the inability to go beyond this pre-programming during the flight. After the programmed flight has started, no strategic change can be made in the movement or adaptation to external factors occurring during the flight. In the autonomous control system, which is examined as the fourth title, control is provided by a fully integrated UAV control system without any operator intervention. Thus, compatibility with external factors or new applications becomes possible [4].

2.2.5. Military

When considered in the broadest sense, military applications can be examined in 3 parts as land, air and sea applications. Used in military applications; Vehicles that can reach an altitude of 3000-8000 meters, have a take-off weight of 150-1500 kg, and can stay in the air between 2-48 hours are seen. Military activities are mostly in the form of control, surveillance and intelligence activities. Apart from these, another field of use in the military field is work in dangerous groups such as chemical, biological, nuclear and radiological activities.

2.2.6 Civil

UAVs have started to be used in civil-commercial applications as well as military aviation activities, so they are easily adapted to daily life and become a current topic for academic studies. It also offers very advantageous solutions for civilian users. In addition, UAVs are used in many areas such as oil lines, railway lines, control of tall buildings, agricultural spraying, product yield detection, post-earthquake imaging and many similar areas.

3. Application

3.1. Fieldwork

In this study, DJI Phantom 4 Pro (Figure 2) has been selected in a mountainous, rugged area with a mine. Before the flight in the application area, pre-flight plans were made by going to the land for exploration purposes.

Within these plans, the establishment of the ground control points (GCPs) to be placed on the land has been done. GCPs are homogeneously distributed over the land. The dimensions of the GCPs are square and 50x50 cm long points are used. After the ground control points were determined, the geodetic coordinates of these points were determined with the Topcon Hiper SR brand GNSS measuring device. A total of 12 GCPs have been established in the entire area.

Figure 2. DJI Phantom 4 Pro

The flight altitude was determined as 80 m, at the end of the flight, a total of 620 photographs were taken. Photographs can achieve more accurate image matching with 80% longitudinal and 60% transverse coverage. For this reason, all flights in the study area were carried out by considering the mentioned cover rate. In addition, all flights in the study area were completed on the same day and as soon as possible, minimizing the effect of sunlight. And the photos were uploaded to digital media for processing [17].

3.2. Office work

After the land operations were completed, the images taken were transferred to the computer environment and made ready for processing. Before transferring to the appropriate modeling software, the captured images should be checked for points to be considered. If there are corrupted photos, they should be removed in order not to affect the quality of the model to be created. After the photos were checked, they were transferred to the context capture software, which is a 3D modeling software.

The software models photos according to the Structure from Motion (SfM) principle. Structure From Motion (SfM) photogrammetric image matching algorithm, which was developed to predict three-dimensional 3D structures from the combination of local motion signals and two-dimensional image sequences, is the basic principle of new generation and widely used cloud-based image matching software [18-20].

The 3D model of the land was obtained by processing the photographs with the software. In addition to this, point cloud, orthophoto of the supply, digital elevation model and map were drawn. These data form significant bases for many studies. Thanks to these data, coordinate values can be obtained from the desired location of the land thanks to the land slope height information, 3D model and point cloud, and thanks to the coordinated model. Considering the mining area in the field, many data such as volume calculation can be obtained based on the excavations carried out in this area.

3.3. Product information

3.3.1. Point cloud

The point cloud cluster (Point Cloud Library) has a data structure that contains multidimensional data. Point clouds are generally used to represent three-dimensional data, which consists of x, y, and z coordinates. In particular, the z-coordinate only records the distance of the camera from the object surface according to the depth. Point data is mostly used to show the outer surface of some objects. Each point in the point cloud can contain normal direction or color data as well as geometric coordinates. As this data is added to points, cloud sizes increase. When RGB color data is added to a three-dimensional point cloud, this cloud can now be six-dimensional [21].

3.3.2. Orthophoto

It can be defined as the name given to orthophoto images on which map edge information, grids, contour lines, place and position names and similar cartographic information are added. It is a photo map produced in standard or random scales by combining orthophoto image particles, obtained by adding contour curves, height information, map edge information on the orthophoto images obtained by eliminating the errors caused by the curvature effects and height differences (relief shift) in the images. In the production of orthophoto maps, combined operations such as photographic edge enhancement, color separation or a combination of these can also be applied as special cartographic operations. Orthophoto maps; It is widely used by the relevant institutions in national security projects as well as in the renewal/updating of the cadastre, urban transformation/zoning project base, agriculture, forest, disaster management information systems such as geographic information system and decision support projects.

3.3.3. Digital elevation model (DEM)

Digital surface model is a surface where all objects are included, besides the plain land surface, obtained from the location and height information of the earth, vegetation, trees, buildings [22-23]. When the flight height is less, the DEM will be obtained with more resolution [24]. Until now, too many scholars used UAV technology to obtain DEM. Many engineering projects such as landslide site [25-26], rockfall site [27], shoreline detection [28], cultural heritage modelling [29-30] and pond volume measurement [31] have been solved with this technology.

4. Results

Before the flight operation with an unmanned aerial vehicle in the field studies, land exploration and establishment of ground control points of the area to be flown were carried out. Then, the geodetic coordinates of the ground control points were measured with the GPS/GNSS instrument. These coordinates were used in combining the photos obtained from the unmanned aerial vehicle via software and converting them to the country coordinate system. These data allowed to take measurements with real coordinates on the supply. Photos were processed in context capture software. The photographs were taken from 80 m height and the overlay ratios were determined as 80-60%.

As a result, point cloud (Figure 3 and Figure 4), orthophoto (Figure 5) and digital elevation model (Figure 6) were created in the country coordinate system from the photographs, which were completed by means of software in the office environment. The data obtained will provide convenience when there is a desired measurement in the future due to the land roughness and from the mine located in the land. With the point cloud, many studies such as volume calculation of the area to be excavated on the mine site and elevation differences can be easily performed.

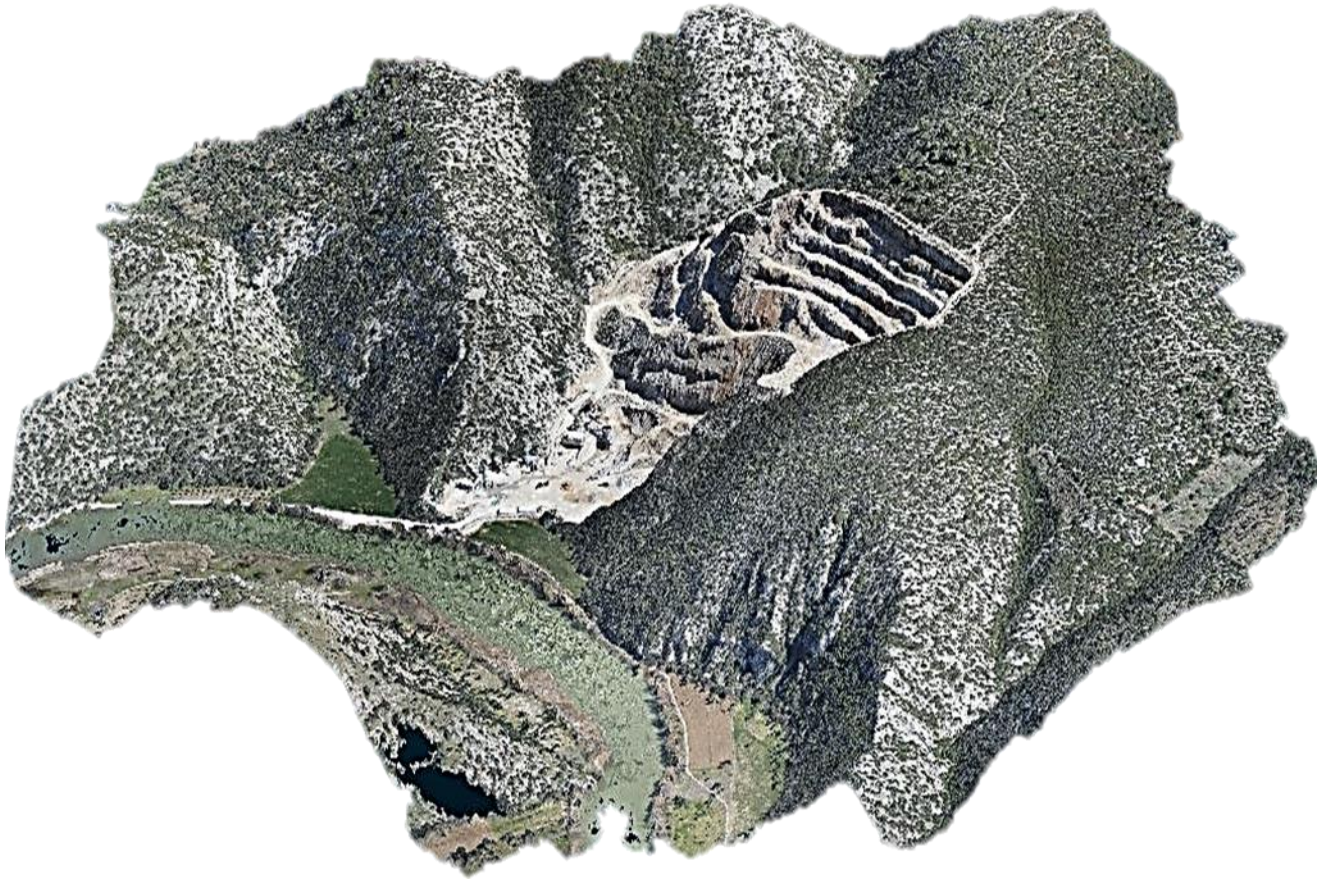

Figure 3. Entire workspace point cloud

Figure 4. Mine excavation site point cloud

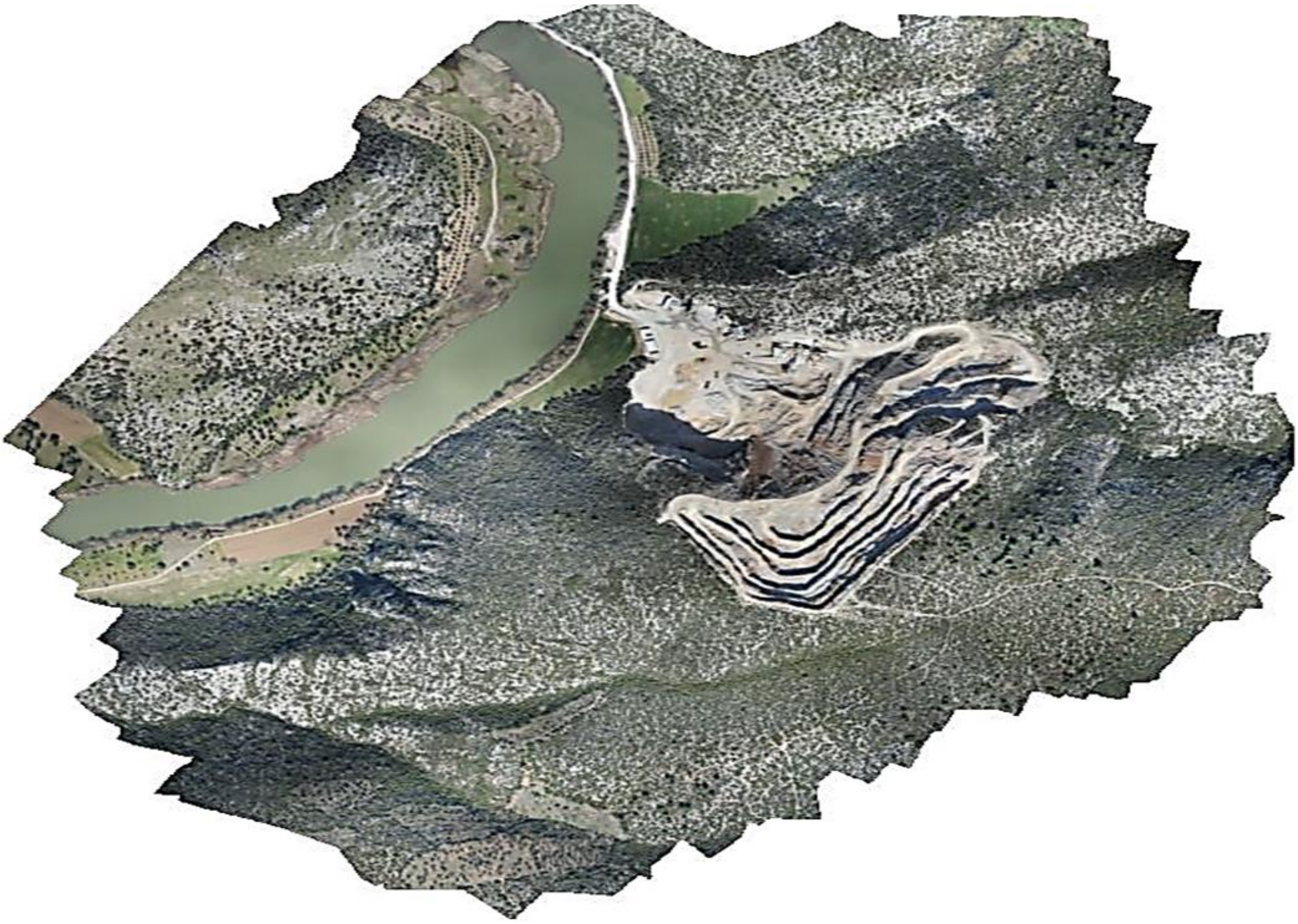

Figure 5. Workspace orthophoto view

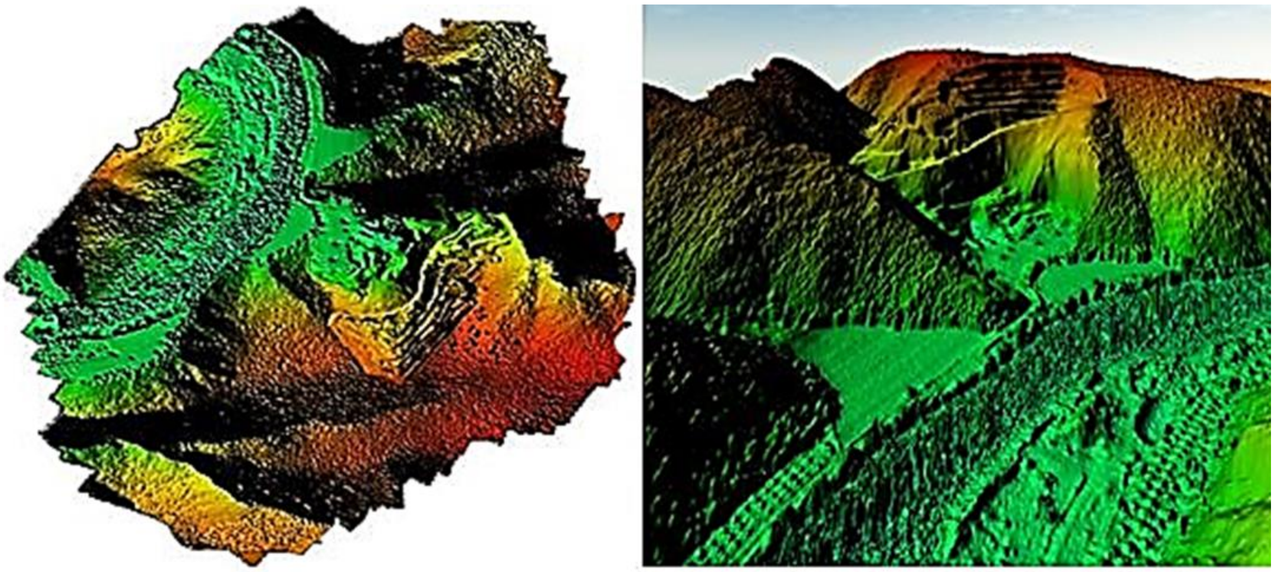

Figure 6. 2D and 3D Digital elevation model

7. Conclusion

The possibility of reaching inaccessible or dangerous areas without putting anyone in dangerous situations or dangerous areas with low cost and risk has led researchers to unmanned aerial vehicles as an alternative to classical aerial photogrammetry. In this study, three-dimensional modeling and orthophoto maps were obtained from the study of unmanned aerial vehicles. The position error of the products obtained as a result of the study was calculated as ± 3.1 cm on average, and the height error was calculated as ± 8.6 cm on average.

In obtaining three-dimensional models, it is important to take vertical pictures as well as oblique pictures. Height accuracy was therefore higher than position accuracy. It has been concluded that compared to conventional aerial photogrammetry, baseline maps of small areas, digital terrain models, digital elevation models and orthophoto maps used by many disciplines can be produced in a shorter time and more economically, with appropriate position and altitude errors, by using Unmanned Aerial Vehicles.

Thanks to the aerial imaging and measurement systems with the unmanned aerial vehicle, the desired data can be collected in all kinds of terrain conditions, both sensitively and in a short time. While drones can generate data that takes a few hours, people using traditional methods need days, weeks, or months depending on their workload. In addition to these advantages of the use of UAVs in mining, the data generated by the UAV is comprehensive, sensitive and can be analyzed in many ways as it provides digital transmission.

The obtained point cloud, orthophoto and digital elevation models will have many working bases. In addition to geodetic measurements, it has been seen that it can be done in difficult terrain conditions more easily and in a short time without requiring much labor.

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Conflicts of interest

The authors declare no conflicts of interest.

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Cultural heritage modelling using UAV photogrammetric methods: a case study of Kanlıdivane archeological site

Engin Kanun*[1], Aydın Alptekin [2], Murat Yakar [3]

[1]*Mersin University, Department of Mechanical Engineering, Mersin, Türkiye, ekanun@mersin.edu.tr*
[2]*Mersin University, Department of Geological Engineering, Mersin, Türkiye, aydinalptekin@mersin.edu.tr*
[3]*Mersin University, Department of Geomatics Engineering, Mersin, Türkiye, myakar@mersin.edu.tr*

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Abstract

Turkey has hosted many civilizations throughout history. Therefore, it has a diverse cultural heritage inventory. Atmospheric conditions, natural disasters and unconscious people constantly damage the structures. It is vital to document the artifacts in such circumstances in order to conserve them and transfer them to the future generations. Cultural heritage protection, preserving these assets and transmitting them to the future generations are the human duty. Remote sensing techniques such as unmanned aerial vehicle is a very beneficial tool to obtain information without touching the object. Kanlıdivane archeological site hosts many ancient buildings. Within the scope of this study, the UAV photogrammetry method was used to create the 3D point data and solid model of the Monumental Tomb of Aba built in the 2nd century AD, located in the Kanlıdivane region of Mersin province in Turkey. Images were taken with Parrot Anafi HDR unmanned aerial vehicle and a 3D model was produced. Detailed length, area, volume and coordinate measurements were made on the model obtained and verified with Agisoft Metashape and Context capture. Floor perimeter, floor area and volume of the monumental tomb are also presented in the results section. These findings can be used in restoration in future.

1. Introduction

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

It is the most magnificent mausoleum of Kanytella. According to the inscription on the door of this monumental tomb, which was built in the type of Roman temples, it was built by a woman named Aba for herself and her husband Arios. The tomb monument was built on a low podium. There is a vaulted entrance on the front facade. There are Corinthian plaster caps on the four corners of the tomb. The tomb is dated to the 2nd century AD based on the inscription on it and other tombs [1].

The Monumental Tomb of Aba can be found north of the geological pit in the region. It is one of Kanlıdivane's most well-known landmarks. The building's principal construction method is cut stone masonry, with mortar as the binding material. The roof of the superstructure is shaped like a gable and is coated in stone. It's supported by a cut-stone barrel vault, which is subsequently filled with rubble stone to create a flat roof surface. The vault marks the main chamber's entrance on the south facade, which is topped by a pediment at roof level [2].

Figure 1. Location of the Aba's Monumental Tomb on the map of Turkey

The last row of cut-stones in masonry walls was built in architrave style, with Corinth capital styling on the corner stones. Although the architectural integrity of the building has been retained, there are serious issues with the scale of the structure. The west and north walls, in particular, have material deterioration and structural deformations. On the north wall, there are serious fissures that have split the stone components in half. This graphic depicts the likelihood of a high impulse being triggered by lateral pressures or settlement issues. The structural degradation danger has been confirmed by external forces because the monument is placed extremely close to one of the site's geological discontinuity lines. The monument should be included in an architectural conservation program as soon as possible, before it loses its structural integrity, as it is one of the few examples of architectural and structural unity that still exists [2].

In a study, Roman tombs were examined in detail and the features of the mausoleum of Aba at Kanytellis were comprehensively presented [3].

UAV photogrammetry is one of the methods widely used within the scope of documentation of cultural heritage. Generating a three-dimensional model of Gözne Castle, a medieval castle [4], obtaining a 3D photogrammetric model of a historical inn [5] mausoleum [6] and a ruin [7] are some of the examples of documenting cultural heritage with photogrammetric methods.

UAV photogrammetry also can be used in most of the engineering projects. In the last decade UAV has been used in rockfall [8], landslide studies [9-10], shoreline detection [11], pond volume [12] and energy line measurement [13] are some of the examples.

2. Method

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

2.1. Field work

At this stage of the study, first of all, necessary permissions were obtained to fly in the Kanlıdivane region, which is the study area. Then, the flight altitudes at which images will be taken around the tomb were determined. Images were taken with a Parrot Anafi HDR drone (Figure 2a) by manually. The technical specifications of the unmanned aerial vehicle used are shown in Table 1.

The circumference of the mausoleum, which is approximately 50 km away from Mersin, is roughly 31.5 meters, and its sitting area is around 61 square meters. Every detail of the structure was tried to be captured by flying first at low altitude and then at high altitude. A total of 101 images were taken. Some of the images of the monumental tomb taken are shown in Figure 2b.

(a) (b)

Figure 2. a) Parrot Anafi HDR UAV **b**) Images of Aba's Monumental Tomb

Table 1. Technical specifications of the UAV [14]

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

2.2. Camera calibration

The camera used must be calibrated beforehand so that the merging and overlay operations of the images can be of high accuracy. It was mentioned in the previous section that there is a 5.92 mm sensor in the unmanned aerial vehicle used in this study. Images have a size of 4608x3456 pixels. Camera calibration was done in Context Capture software. Figure 3 shows the distortion parameters obtained as a result of camera calibration:

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

Figure 3. Camera calibration parameters

2.3 Office work

After the completion of the image acquisition within the scope of the field work, the office work phase was started. First of all, the data obtained from the field were transferred to the computer environment. The image file obtained after the flight took up 457 MB in total. Data processing was done in Bentley's Context Capture software. The office work, which was started after half a day of field work, was completed in one day. The positions of the images taken relative to the mausoleum are shown in Figure 4.

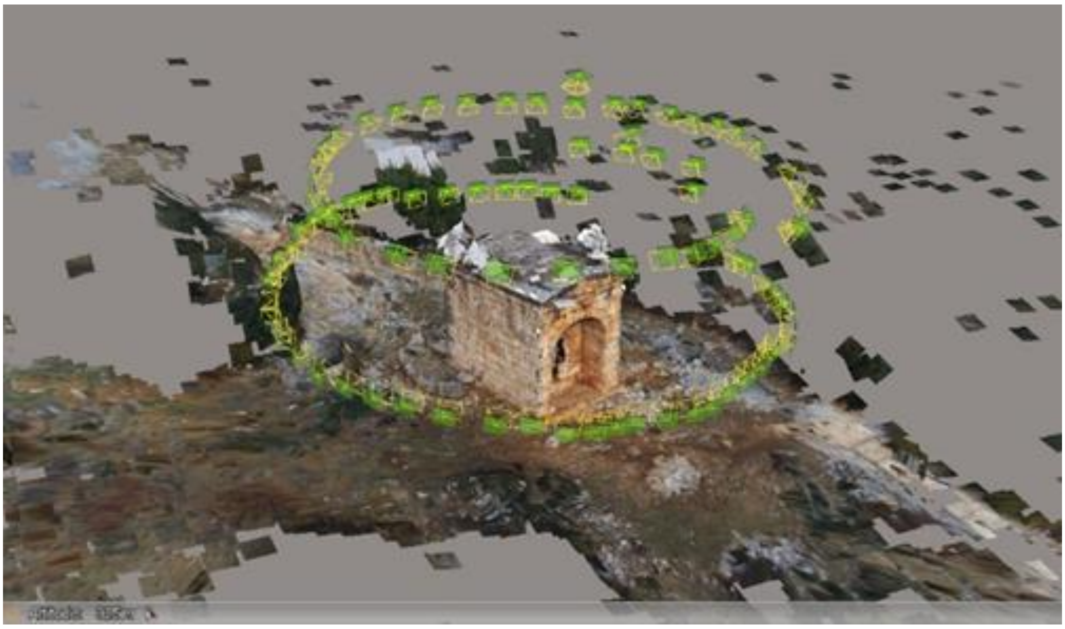


Figure 4. The positions of the images taken

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

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

3. Results and Discussion

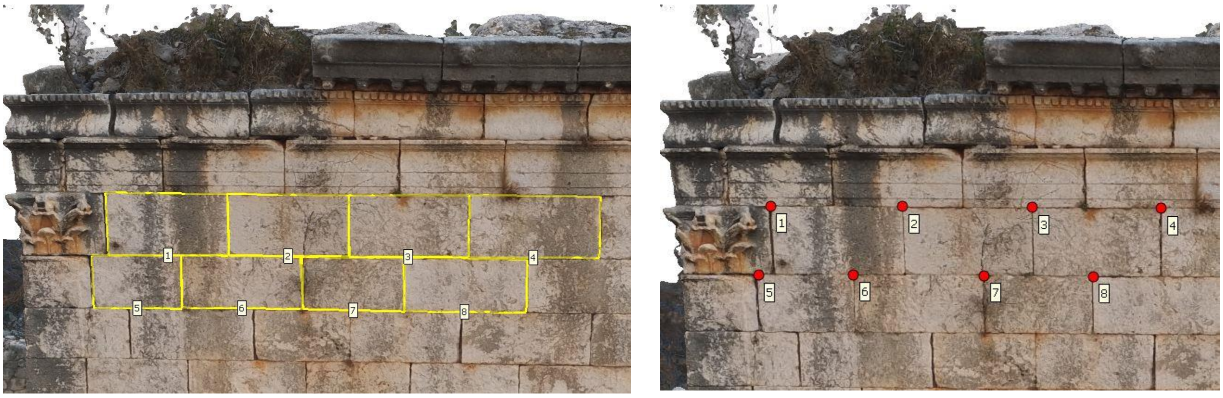
After the camera calibration, field studies and office work phases were completed, a 3D solid model of the Aba's Monumental Tomb was obtained. The surface texture was created by using photographs to add visuality to the obtained 3D solid model. Texture compression quality was selected as 100% quality and texture sharpening option was enabled. The three-dimensional model of Aba's Monumental Tomb is presented in Figure 5.

Figure 5. 3D solid model of Aba's Monumental Tomb

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

It is possible to draw shapes on the 3D model obtained. Area and volume calculations can also be made easily on the drawn curves. As can be seen in the Figure 6a, the area and volume of each stone on the structure can be calculated. Thanks to the high-quality texture of the model, deformations, cracks, gaps and abrasions on the structure can be easily observed. In a possible restoration process, all the stones of the building can be documented in a coordinated manner and the quantities such as area, volume and slope of each stone can be calculated.

Within the scope of this study, the models obtained by UAV photogrammetry were examined separately in ContextCapture and Agisoft Metashape software. Figure 6a and Figure 6b show eight different stones and eight different points selected on the building. In the light of the data obtained from the models in both software, first of all, the coordinates and height values of the points were compared and presented in Table 2-3. In the next step, as can be seen in Table 4, the perimeter and area values of the front surfaces of the selected stones were compared.



(a) (b)

Figure 6. a) Drawings on the 3D tiled model **b)** Marked points on the 3D tiled model

Table 2. Information obtained from Context Capture

Point Number	North	East	Elevation (m)
1	36.52736	34.17705	263.35
2	36.52735	34.17705	263.35
3	36.52734	34.17705	263.34
4	36.52733	34.17706	263.33
5	36.52736	34.17704	262.72
6	36.52736	34.17705	262.74
7	36.52735	34.17705	262.73
8	36.52734	34.17706	262.72

Table 3. Information obtained from Agisoft Metashape

Point Number	North	East	Elevation (m)
1	36.52736	34.17704	263.381
2	36.52735	34.17705	263.339
3	36.52734	34.17705	263.299
4	36.52733	34.17705	263.258
5	36.52736	34.17704	262.744
6	36.52735	34.17704	262.725
7	36.52734	34.17705	262.684
8	36.52734	34.17705	262.652

Table 4. The perimeter and area values of the front surfaces

Stone	Context Capture		Agisoft Metashape	
Number	Area [m²]	Perimeter [m]	Area [m²]	Perimeter [m]
1	0.72	3.60	0.73	3.66
2	0.66	3.47	0.70	3.58
3	0.67	3.47	0.70	3.55
4	0.73	3.64	0.75	3.68
5	0.45	2.71	0.47	2.83
6	0.60	3.38	0.63	3.45
7	0.50	2.98	0.53	3.03
8	0.58	3.34	0.60	3.43

Table 5-7 show the root mean square deviation (RMSD) between the coordinate values of both programs. RMSE calculation was made according to Eq. 1.

$$RMSE = \sqrt{\frac{\sum(y_1 - y_2)^2}{n}} \tag{1}$$

Table 5. RMSD calculation of north coordinates (degree)

North Coordinates			
Context	Agisoft	(y_1-y_2)	$(y_1-y_2)^2$
36.52736	36.52736	2.5E-06	6.25E-12
36.52735	36.52735	2.3E-06	5.29E-12
36.52734	36.52734	2.5E-06	6.25E-12
36.52733	36.52733	2.6E-06	6.76E-12
36.52736	36.52736	1.9E-06	3.61E-12
36.52736	36.52735	2.5E-06	6.25E-12
36.52735	36.52734	2.4E-06	5.76E-12
36.52734	36.52734	2.9E-06	8.41E-12
		RMSE	2.46424E-06

Table 6. RMSD calculation of east coordinates (degree)

East Coordinates			
Context	Agisoft	(y_1-y_2)	$(y_1-y_2)^2$
34.17705	34.17704	4.3E-06	1.849E-11
34.17705	34.17705	5E-06	2.5E-11
34.17705	34.17705	4.4E-06	1.936E-11
34.17706	34.17705	4.7E-06	2.209E-11
34.17704	34.17704	4.9E-06	2.401E-11
34.17705	34.17704	5.1E-06	2.601E-11
34.17705	34.17705	4.8E-06	2.304E-11
34.17706	34.17705	4.4E-06	1.936E-11
		RMSE	4.7085E-06

Table 7. RMSE calculation of elevation values (meters)

Elevation Values			
Context	Agisoft	(y_1-y_2)	$(y_1-y_2)^2$
263.35	263.381	-0.031	0.000961
263.35	263.339	0.011	0.000121
263.34	263.299	0.041	0.001681
263.33	263.258	0.072	0.005184
262.72	262.744	-0.024	0.000576
262.74	262.725	0.015	0.000225
262.73	262.684	0.046	0.002116
262.72	262.652	0.068	0.004624
		RMSE	0.044

The 3D models obtained in both software were transferred to Rhinoceros 7 software and overlap analysis was performed. As can be seen in the Figure 7 and Table 8, 64288 of 888963 points have a high overlap ratio. Although the model dimensions are very close, the algorithms of both programs cannot produce one-to-one overlapping models. Small deviations in the coordinate values greatly affect the overlap of the models.

In addition to all these results obtained within the scope of the study, the floor perimeter, floor area and volume of the mausoleum were also calculated and presented in the Fig. 8. The floor perimeter was calculated as 28.51 meters when measured from the outside. The floor area is 50.04 square meters. The volume value of the mausoleum was calculated as 240.37 m^3.

Digital Elevation Model (DEM) is the digital representation of the land surface elevation with respect to any reference datum. DEM is frequently used to refer to any digital representation of a topographic surface. DEM is the simplest form of digital representation of topography. DEMs are used to determine terrain attributes such as elevation at any point, slope and aspect. Today, GIS applications depend mainly on DEMs [15]. In addition, DEM data of the mausoleum can be seen in order to show that digital elevation models of historical buildings and their surroundings can be obtained with UAV photogrammetry. Length, area and slope calculations can be made using DEM data. An exemplary length measurement is made in the Figure 9. Slope calculation can be made by using the height difference and horizontal distance value between two points. Thus, detailed measurements of the historical building and its surroundings can be made easily. In addition, at the marked points seen in the Figure 10, stones that were separated from the building over time are seen. Measurements can also be made on these stones and can be used in possible restoration projects.

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

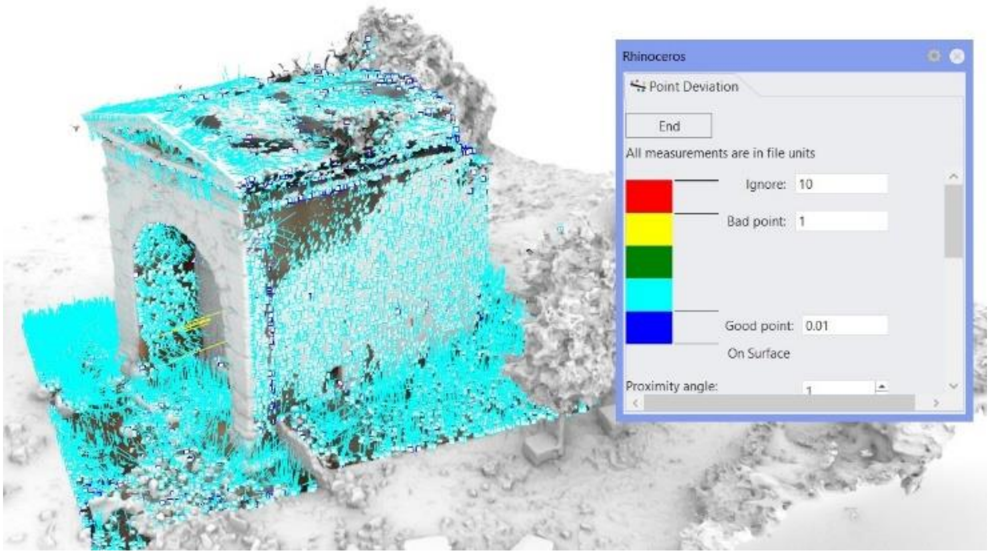


Figure 7. Overlap analysis of the 3D models

Table 8. Point test statistics (m)

Total points	888963
Close point count	64288
Average distance	0.04423805
Median distance	0.03791145
Standard deviation	0.05168753
Maximum distance	1.240013
Minimum distance	2.311686E-06

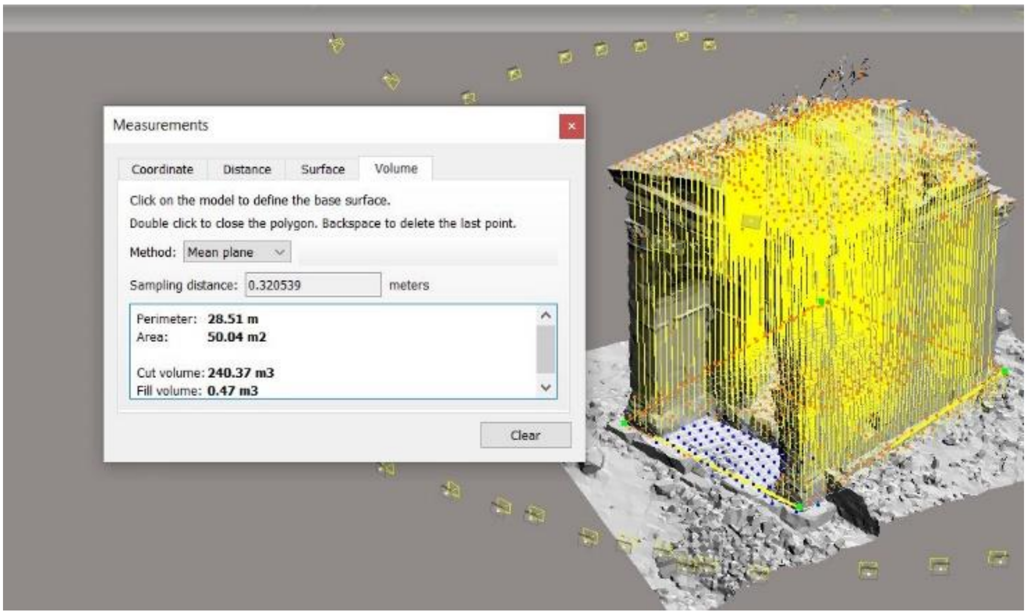


Figure 8. Area and volume calculations of the tomb

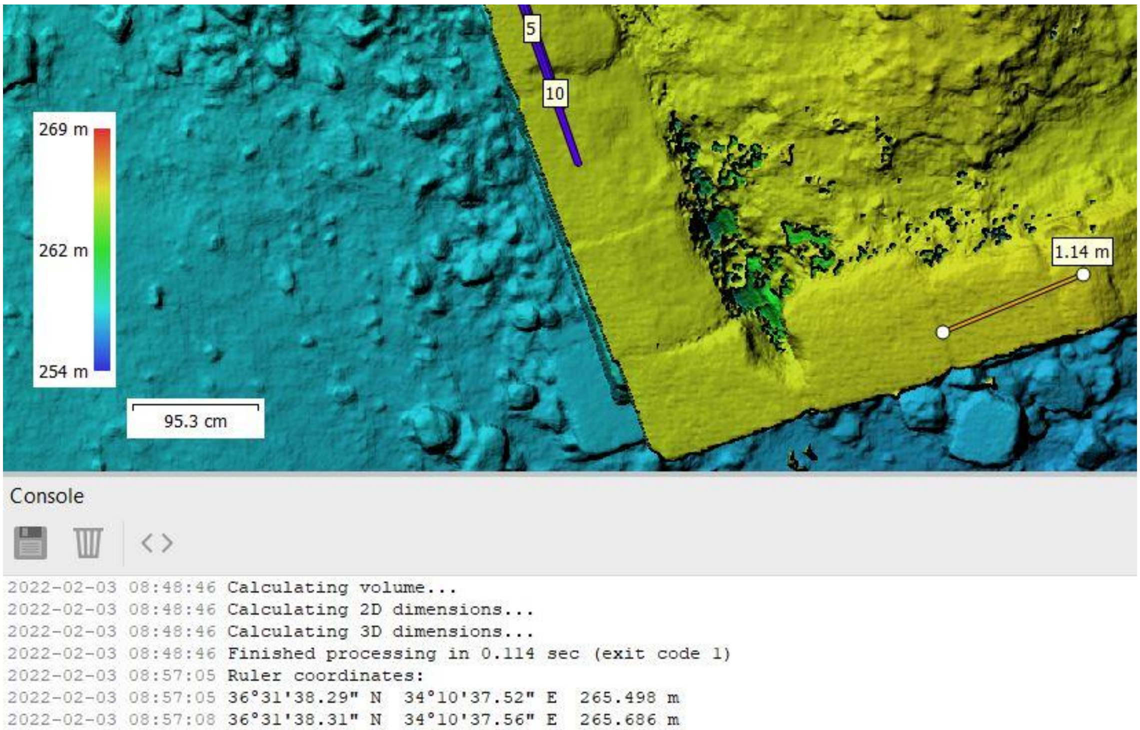


Figure 9. Measurements on DEM data

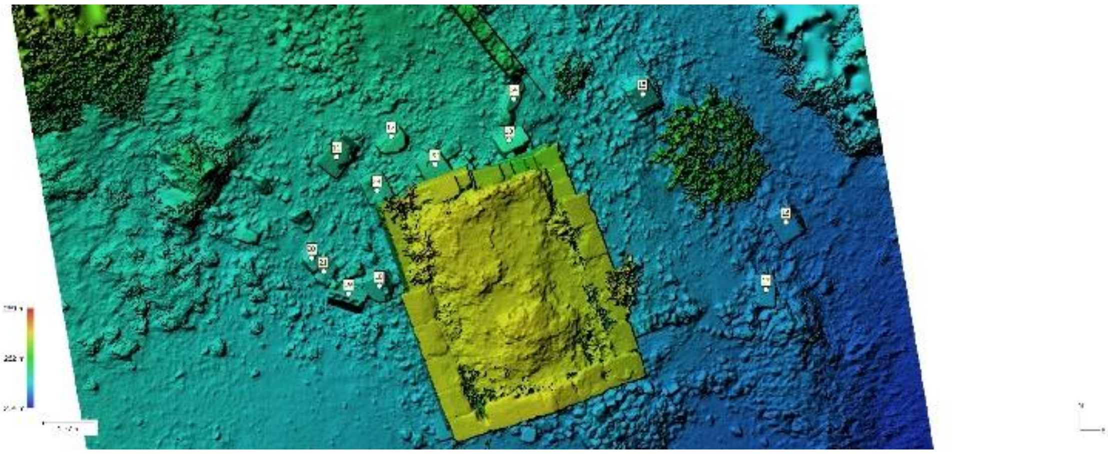


Figure 10. Digital elevation model (DEM) of the tomb

4. Conclusion

In this study, Aba's Monumental Tomb, which is an ancient artifact built in the 2nd century AD and located in the Kanlıdivane region of the Mersin province of Turkey was modeled in 3D using UAV photogrammetry. As a result of obtaining a real-scale model of this artifact, which is of great importance in terms of cultural heritage, the documentation process has been carried out. The data obtained in this study can be used in possible studies by anthropologists, archaeologists and historians. The real-scale 3D model obtained can be utilized in the restoration and repair studies. The 3D model obtained within the scope of this study will also allow the promotion of the work within the scope of tourism activities.

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Author contributions

Engin Kanun: Conceptualization, Methodology, Software **Aydın Alptekin:** Data curation, Writing-Original draft preparation, Software, Validation. **Murat Yakar:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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Numerical data generation using unmanned aerial vehicle: a case study of Aksaray Güzelyurt District

Efdal Kaya*[1], Müjdet Güngör[2]

[1] *İskenderun Technical University, Department of Architecture and Urban Planning, Hatay, Türkiye, efdal.kaya@iste.edu.tr*
[2] *Nevşehir Hacıbektaş Veli University, Department of Mathematics, Nevşehir, Türkiye, mujdetgungor@nevsehir.edu.tr*

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Abstract

Base maps can be produced using terrestrial methods, also known as classical methods. In recent years, with the technological developments, remote sensing methods have been started to be used in the production of base maps. These methods are satellite images, LIDAR systems and aerial photogrammetry. Although these systems are innovative systems brought by technology, they have their own advantages and disadvantages. The presence of atmospheric-radiometric errors in photographing satellite images and the correction of these errors in these satellite images increase the cost. Although LIDAR systems can produce dense point cloud data representing the land topography and are an active sensing system that is not dependent on weather conditions, they are still quite burdensome in terms of cost. Unmanned Aerial Vehicles (UAV) have started to be used in many areas due to their low cost and decreasing size. Especially in recent years, UAVs have started to be used for technical data production. These technical data in the field of geomatics can be used in orthophoto map production, in the production of ready-made maps to scale, digital terrain model (DTM), digital elevation model (DEM), route creation in road projects, excavation-fill calculations, area-volume calculations and observation of environmental change. The aim of this study is to produce a base map using up-to-date technological equipment and methods. Güzelyurt District, an area of approximately 110 hectares in Aksaray Province, was chosen as the application area. The eBee Rtk model was used for taking terrain photographs. Sony camera is mounted on the UAV. The 166 field pictures were taken from a height of 150 meters, with a transverse overlap of 70% and a longitudinal overlap of 80%. These pictures were evaluated in the Pix4D program. As a result of the evaluation, orthophoto map, DEM and point cloud data were obtained.

1. Introduction

Urbanization that came with the industrial revolution in the world has caused ground rent. Therefore, the correct use of land and planning on the basis of cities and countries contribute to the development of countries [1].

The good planning of the cities of a country shows the level of development of that country. It is possible by planning all the facilities that should be in a city, such as the construction of main and intermediate roads in a city, the selection of park areas and forest areas, the selection of university places, the selection of shopping centers, the selection of nursery-primary school, secondary school areas, the selection of parking lots suitable for the population of the city and the surface of the land. In order to plan this in a comprehensive way, we need to produce the base maps, which are the basis for the planning studies at the highest level of accuracy of all the details on the earth.

The topography of the land must be accurately represented in the production of base maps. This requirement for existing maps arises from its use as a base in urban planning, in the construction of all infrastructure and superstructures, in all projects that require technical equipment. The existing maps, which are the basis for technical projects, need to be updated at regular intervals in order to be digital and the changes in the land surface to be recorded on the maps. Updating the rapidly changing topography of the earth on the existing maps can be detected faster and at a reasonable cost using remote sensing techniques.

Unmanned Aerial Vehicle (UAV), which has become more and more common in recent years are the aircrafts that do not physically have a pilot or a passenger, but can carry measuring equipment such as a camera, laser scanning device, video camera, Global Navigation Satellite System (GNSS), remotely or automatically fulfill and complete their flight. It means an aircraft that can fly without a pilot in UAVs. UAV is a vehicle that can move automatically or semi-automatically in accordance with the flight plan, or it is a remotely controlled vehicle from the station by a pilot [2].

UAV system constitutes GPS receivers, microprocessors, gyroscopes used in direction finding and measuring processes, micro-scale sensors and electronic communication equipment. Low cost, high spatial and temporal resolution data can be produced using a UAV [3].

Today, although UAVs continue to be used for military, security and intelligence purposes, they are also used for civilian purposes. These areas are orthophoto map production, base map production to scale, digital terrain model (DTM), digital elevation model (DEM), creating routes from road projects, excavation-filling calculations, area-volume calculations, observing environmental change, monitoring of weather conditions, observation of coast and coastline, detection of mining areas, agricultural applications (land classification, soil analysis, determination of product productivity) urban transformation projects, monitoring of natural disasters, archaeological studies, architecture and landscape studies, 3D city modeling, city silhouettes It is used in many technical and hobby areas such as creating movies, filming and sports activities [4].

UAVs are very beneficial tools in DEM construction. In oldest times robotic total station has been used in these studies [5]. Terrestrial photogrammetry is time consuming and expensive [6].

UAV has been used frequently in the last decade. Many engineering projects such as rockfall modelling [7], landslide site modelling [8-9], pond site volume calculation [10], shoreline detection [11], cultural heritage modelling [12-16], land cover classification [17], energy line detection [18], tree extraction [19] have been performed using UAV.

2. Material and Method

2.1. Study area

Güzelyurt district of Aksaray City has been selected as study area (Figure 1).

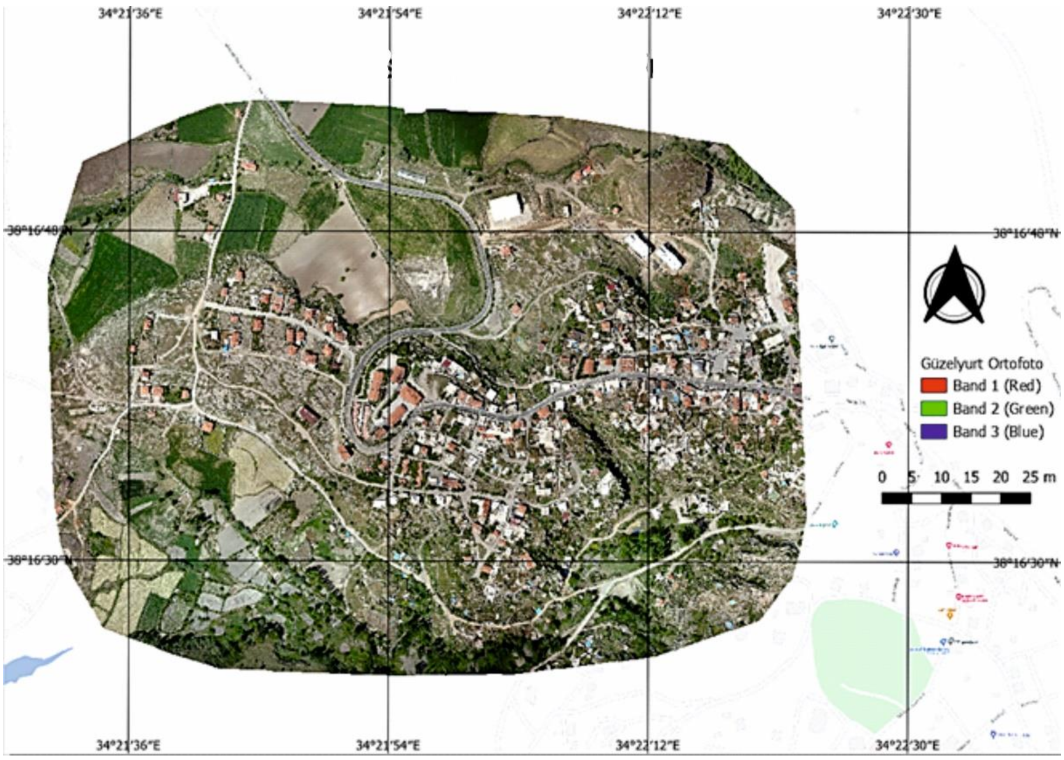

Figure 1. Study area

2.2. Materials

The eBee Rtk model was used as an unmanned aerial vehicle in the field studies. The technical specifications of the UAV used in this study are given in Table 1. The general processing steps used in the Pix4D program are given in Figure 3. GCP values collected on the land, aerial photographs recorded with the UAV, and UAV flight orientation parameters were transferred to the computer environment.

Table 1. Properties of eBee Rtk

Property	Value
Wieght with camera	Nearly 0,73 kg
Wing span	96 cm
Equipment	Composite material
Motor	160 W DC motor
GNSS/RTK receiver	L1/L2, GPS & GLONASS
Battery	11.1 V, 2150 mAh
Maksimum flight time	40 minutes
Flight speed	40-90 km/s
Radyo link distance	3 km
Maksimum wind speed	45 km/h
Landing accuracy	5 m
3D software	Menci, Pix4D Mapper

3. Results and discussion

In this study, the flight plan was carried out in the east-west direction as four lines. Approximately 30 minutes of flight were performed from an altitude of 150 meters along these four lines. Pictures of the terrain were taken with the help of a multispectral camera mounted on the UAV and 166 terrain images were recorded on this flight.

After the field studies were completed, the obtained images were transferred into the computer environment. First of all, 166 pictures representing the land were calibrated in the Pix4D program. Ground control point (GCP) was introduced into the program and the balance of the pictures was ensured using this GCP. In the Pix4D program, these 166 pictures were used for stabilization. As a result of the calibrating processes, the pictures were balanced by 100%. In the second process step, point cloud data with LAS extension was obtained from the stabilized pictures and Digital Terrain Model (DTM) data was obtained. Orthophotos were produced using point cloud data and DTM data. GCP and detail points taken by GPS were compared with the dense point cloud data produced in the Pix4D program. Coordinate differences taken from the dense point cloud with GCP were calculated as my=1.2 cm position error in Y direction, position error in X direction mx=2.4 cm and position error in Z direction as mz=4 cm.

The images taken with the help of UAV in the study area were transferred into the Pix4D program. Combining the photos, balancing the photos according to the GCPs, generating the dense point cloud data, creating the digital terrain model and producing the orthophoto data using these data were performed in the Pix4D program.

After the photos are matched, the result of the balancing process is shown in Figure 2. As a result of photo stabilization, DTM, DEM and orthophoto were produced.

The fact that the roof of the buildings is perceived as the floor of the building while producing the base map from the photographs is among the disadvantages of the photogrammetric method. "Unmanned Aerial Vehicle Instruction-SHT-UAV" flight permit procedures should be done in residential areas where there is a settlement, and pilot capabilities should be developed in order to prevent possible accidents. Camera selection should be made in accordance with the purpose of the study. Since rainy and foggy weather will not allow photographing, the flight should be planned considering the weather conditions. In addition, investigating the presence of signal cutting devices in the work area will prevent financial losses that may occur as a result of a possible UAV accident.

4. Conclusion

In this study, the flight was carried out in an area of approximately 110 hectares in the Güzelyurt District of Aksaray Province. The eBee Rtk model was used as an unmanned aerial vehicle. In this flight plan, a flight was carried out from a height of 150 meters for 30 minutes and as a result of the flight, 166 pictures of the terrain were taken.

The pictures taken with the camera mounted on the UAV were combined using the Pix4D software and the pictures were stabilized with the help of GCP. Dense point clouds with LAS extension and DEM were generated in the Pix4D program. By using dense point cloud data DEM data and orthophoto were obtained. On the other hand, the production of the base map with the UAV allows the production of the base map with high spatial accuracy at a lower cost compared to the collection of other data. CCP designing in the field and flight operations took less time than terrestrial methods. In areas that are difficult to reach by local methods, the base map production with the use of UAV in regions such as mountainous regions or coastlines shows the advantage of the system.

Considering the spatial accuracy of the data produced by the UAV, it is predicted that it can be used as an alternative to the litters produced by terrestrial methods in the coming years.

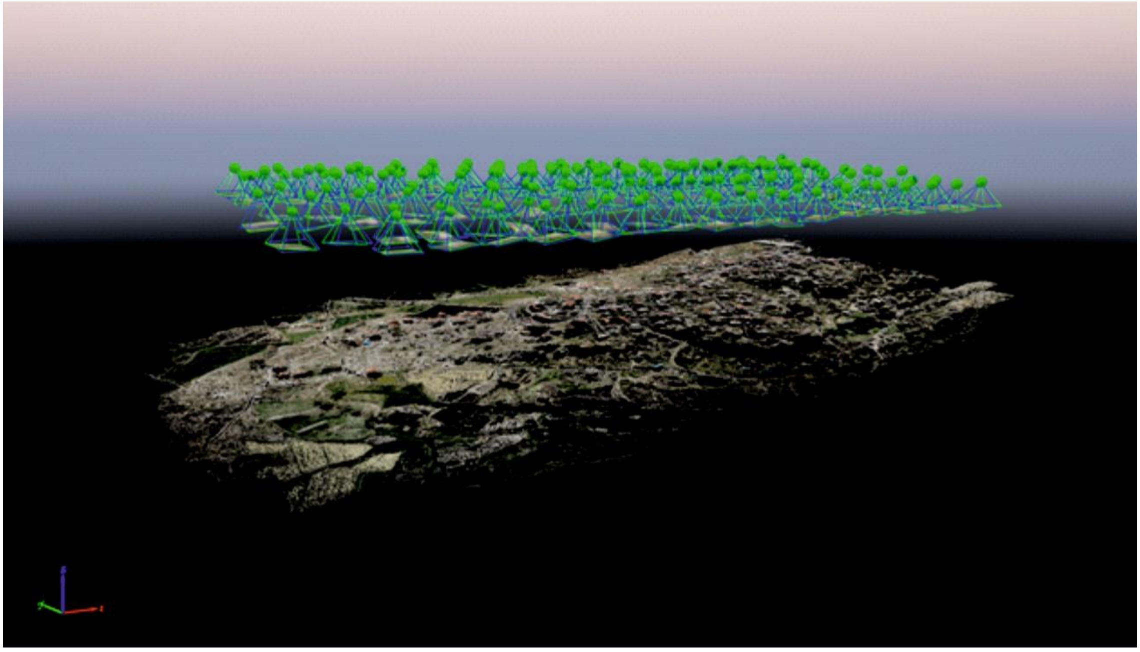

Figure 2. Balance operation in Pix4D

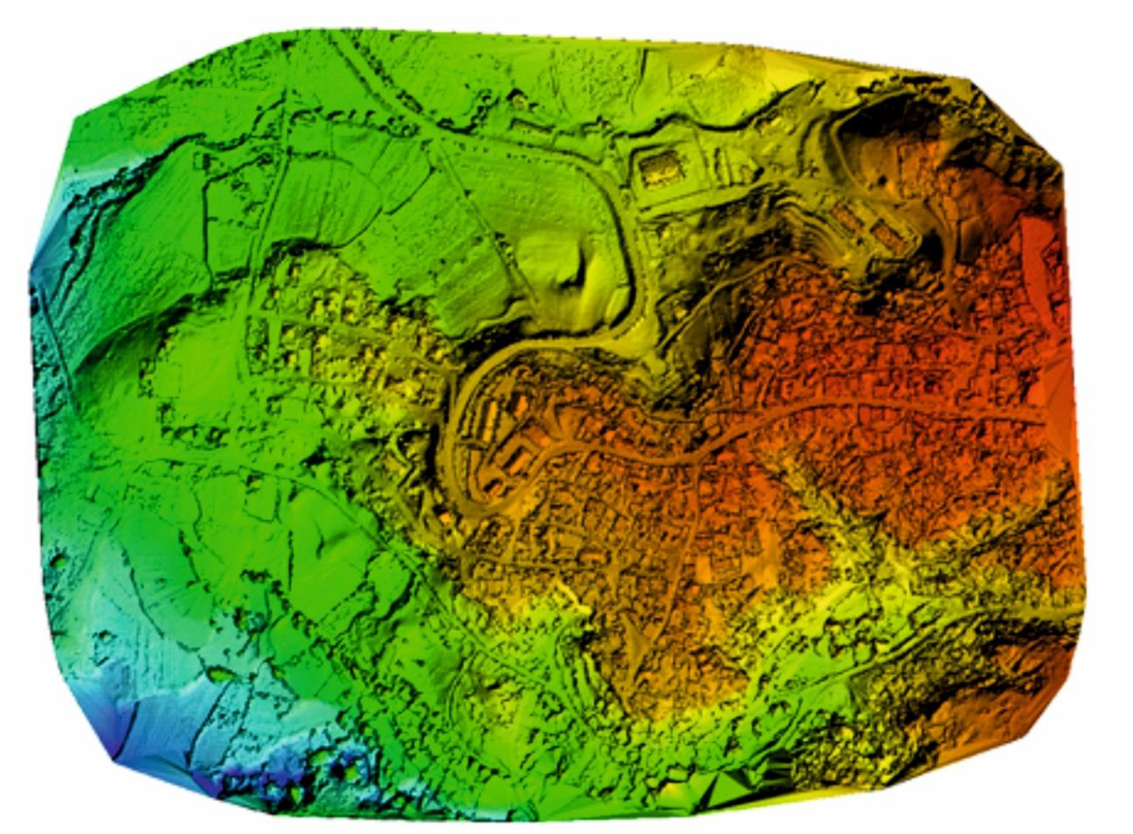

Figure 3. Digital elevation map

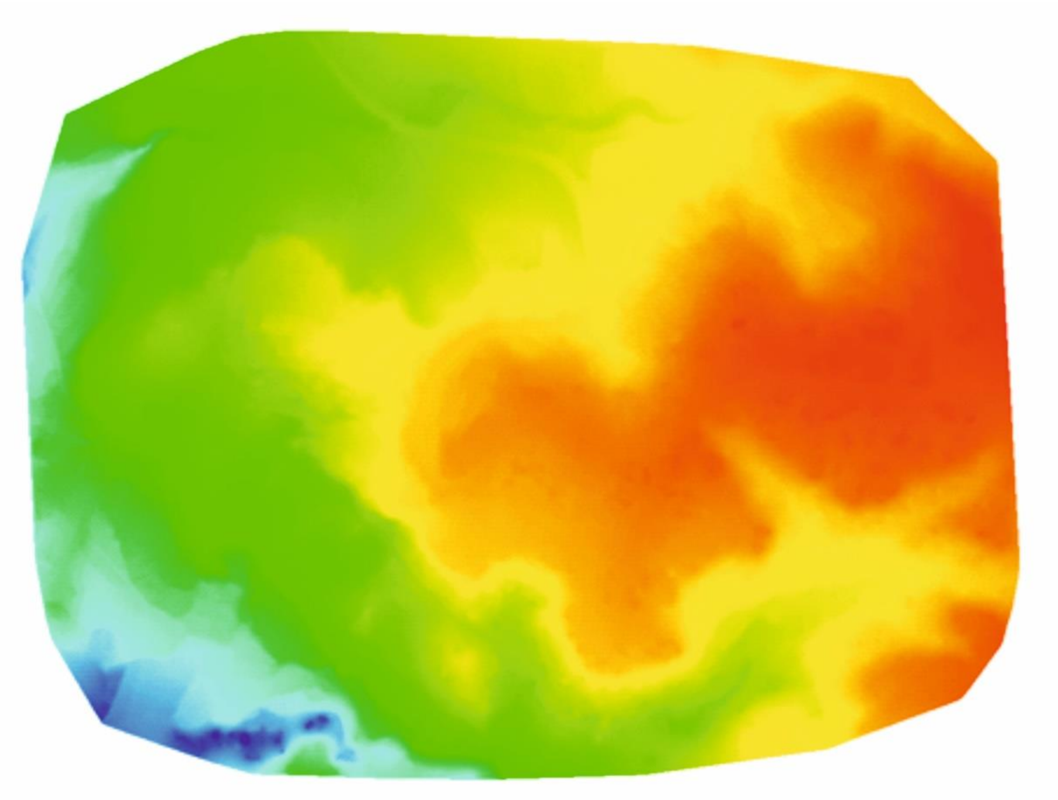

Figure 4. Digital surface map

Figure 5. Orthophoto

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This research received no external funding.

Author contributions

Efdal Kaya: Conceptualization, Methodology, Software, Data curation, Writing-Original draft preparation, Software. **Müjdet Güngör:** Visualization, Investigation, Validation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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