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Unmanned aerial vehicle usage in rough areas and photogrammetric data generation

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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

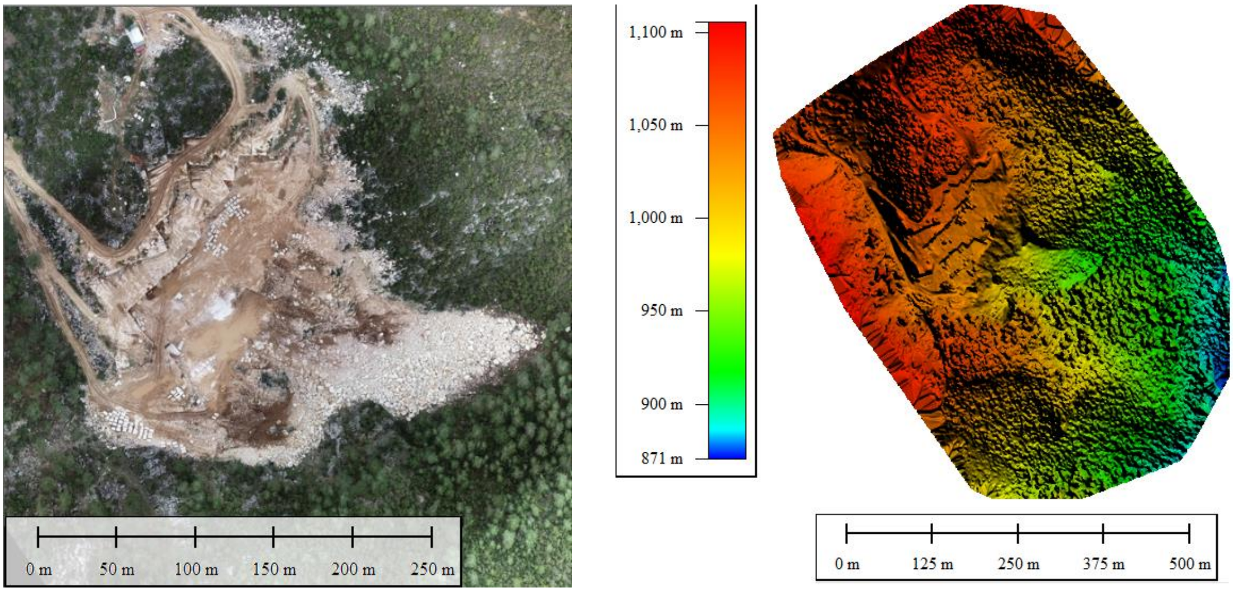
Point No	Observation number	Raw GNSS Data			Adjusted coordinates		
		Easting (Y) (m)	Northing (X) (m)	Elipsoid Height (h) (m)	Easting (Y) (m)	Northing (X) (m)	Elipsoid Height (h) (m)
P.1	1	561591.059	4163461.010	1109.003	561591.041	4163461.017	1109.002
	2	561591.023	4163461.024	1109.000			
P.2	1	561561.594	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).

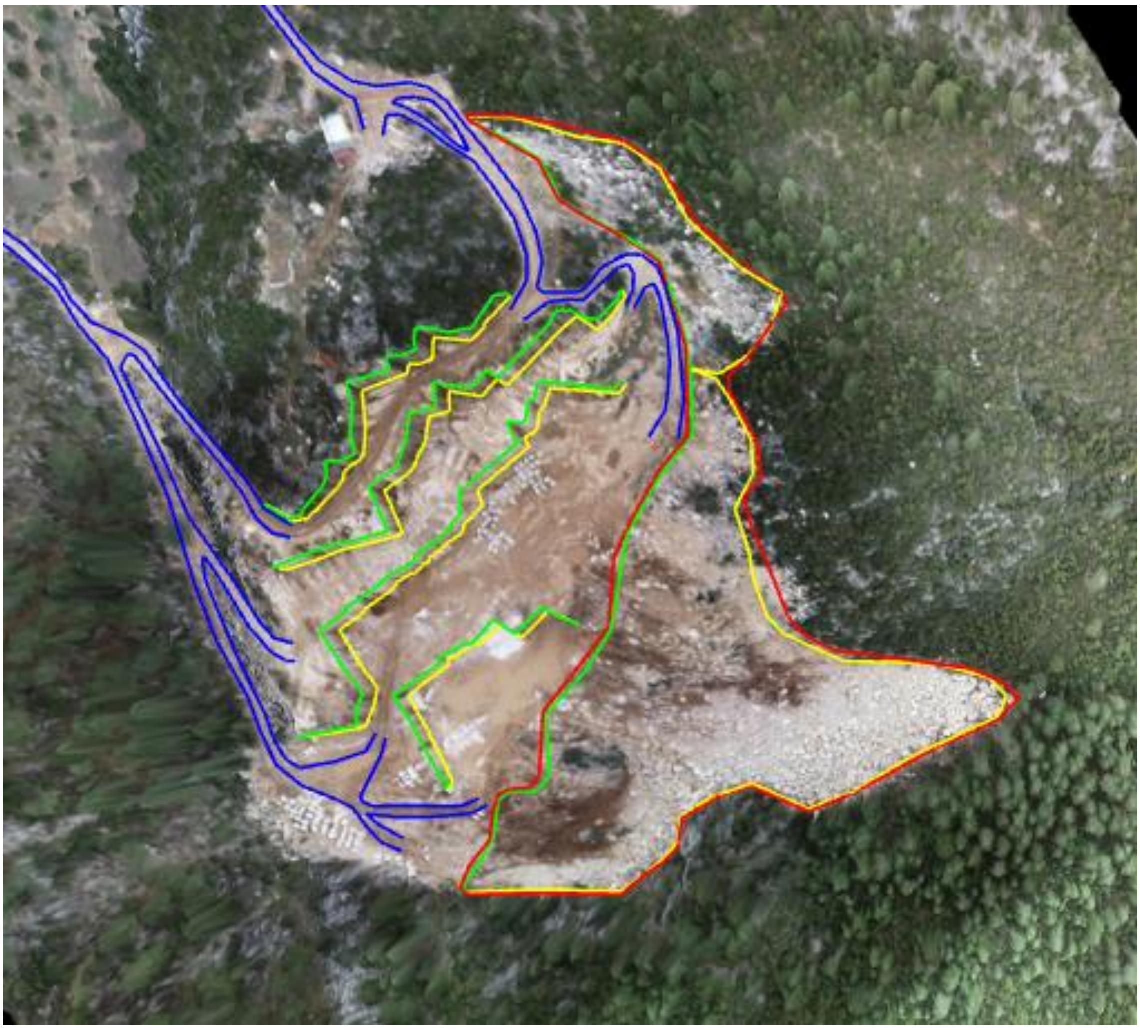


Figure 4. Map data of the land

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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