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Study on the use of unmanned aerial vehicles in open mine sites: A case study of Ordu Province Mine Site

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Abstract

Today, UAVs, which help to produce data with remote sensing and photogrammetry techniques, were used for military purposes at first. Unmanned aerial vehicles (UAV), which is a new sensor platform with the developing technology, has found many uses due to its fast, precise and repetitive measurement capabilities. In open mining areas, which is one of these areas, the topographic measurement problem emerges as a problem that needs to be overcome. The fact that the mine fields cover large areas, the measurements take a long time and are costly have made the use of UAVs a necessity. Aerial monitoring of open mining sites, together with the use of UAVs, is used in planning and calculations as an aid in areas such as mine production planning, blasting yield fields, determination of equipment locations, ore production and land application, volumetric calculations, monitoring of slope sensitivities and changes, security. It enables some data to be obtained quickly, reliably and cost-effectively. In this study, the structure of UAVs, the advantages of their use in open mining areas, their areas of use and their benefits for studies are explained.

1. Introduction

The ever-advancing and boundless technology has allowed man-made aircraft and related industries to change rapidly. The aviation adventure, which started with the dream of seeing the world from a bird's eye view and continued for the purpose of passenger and goods transportation, gained a different meaning with the First World War. Because in this great war, airplanes entered military service for the first time and served for offensive, defensive and reconnaissance purposes throughout the war [1].

For the first time in history, an unmanned vehicle was used in a military incident recorded as the first unmanned aerial attack. This happened in 1849, when the Austrians sent unmanned balloons filled with explosives to Venice, Italy. For the first time, the development and production of airplanes for the purpose of flying remotely, that is, unmanned, coincides with the First World War. Unmanned Aerial Vehicles, briefly UAVs, which are defined as flying vehicles that do not contain humans and can be controlled from the ground thanks to a communication system, have been actively used especially after the Second World War [2].

Drones, which are frequently used for civilian purposes other than military purposes, and especially used by today's younger generation born in the 2000s, are preferred because they outperform humans in many areas. Civil aviation unmanned aerial vehicles provide great benefits in fields such as journalism, show business, marketing, agriculture, cargo, health, emergency aid, communication, cartography and fire response.

Developing technology and demands have accelerated the development of UAVs and many studies have been carried out to achieve different missions and purposes, especially in recent years. These aircraft, which were discovered to be used for military purposes rather than civil aviation, serve the defense industry due to the numerous advantages they provide today. In the field of military aviation, Unmanned Aerial Vehicles are used as target designation and bait, in reconnaissance and surveillance conflicts and in high-risk missions [3].

UAVs provide great advantages over normal aircraft due to their 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 of UAVs are that their danger detection abilities are not as strong as a human, they can pose a danger in case of loss of ground control connection, and manned aircraft are vulnerable to air attacks. However, these disadvantages are tried to be minimized with research and development activities in data transfer and artificial intelligence technologies. On the other hand, further increasing flight times will allow these vehicles to be used widely in the near future [7].

Today, Turkey 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 provide effective and efficient use in the detections and post-disaster investigations, tourism, architectural areas and 3D city planning, and 3D modeling of structures before the disaster occurs [8].

Compared to images obtained from traditional aerial photogrammetry, high-precision images can be produced at low cost in low-altitude flights with the help of UAVs [9-10]. Unlike the vehicles used in traditional 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, despite the unnecessary data volume and high cost in small-scale conventional aerial photogrammetry applications, a great deal of savings can be achieved by using UAVs. Studies carried out with the help of UAVs approach the sensitivity of terrestrial photogrammetry and find application opportunities in many different areas due to the fact that the data processing process can be completed in a short time [11]. Twenty years ago, robotic total station was used frequently [12]. However, in recent years, UAV technology has been widely used by many disciplines for different purposes (map production, volume calculations, 3D model making, documentation of cultural heritage and hobby purposes, etc.).

Uysal et al. [13] aimed to produce the Digital Terrain Model (DTM) of the Şahitler Kayası Mound 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, 5 of which are homogeneous, and obtained the coordinates of the GCPs in the ITRF96 datum with the Stonex S9 GNSS (Global Navigation Satellite Systems - Global Positioning Satellite Systems) device using the RTK method. Images were taken with the Canon EOS digital camera on the UAV from an average height of 60 m. As a result of their studies, they evaluated the accuracy of DTM with 30 control points and determined a vertical accuracy of 6.62 cm. They stated that the combination of UAVs and photogrammetric techniques will provide significant contributions to the studies to be carried out 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, due to their low cost and high performance. Although UAVs have short wingspan (fixed or rotating wings) and a light structure, they have a sensitive structure during flight [14-15].

Şenol and Kaya [16] stated that field work of the model should be done to create a 3D model. In order to reveal the 3D model of a structure, they included UAV data collection in their data collection method. In particular, they wanted to minimize the field studies by using the data collection method with the UAV, and for this purpose, they were able to collect data without the need for fieldwork. They also reported that models can be created from images of UAV, terrestrial and rough areas with various software. Measurements made with classical terrestrial methods are difficult, expensive, take a lot of time compared to the photogrammetric method and are not possible due to the nature of some lands. It has become a necessity to prefer various alternative methods in mountainous, rocky and rough terrains where people have difficulty in transportation. With classical measurement methods, it may not be possible to approach dangerous places such as swamps, stream beds and sometimes the edge of a cliff. With UAVs, it is now possible to easily access areas that people cannot reach and have difficulty in taking images. With the overlay images to be taken from the land, the terrain structure can be modeled in 3D and coordinates [17].

Expanding the use of UAVs in mapping rough areas will provide many advantages. Especially in very hilly areas, mapping processes should be done in a short time, and mapping work should be done in stock movements and incubation calculations in the field. Conducting this study with terrestrial methods may create risks in terms of occupational safety, increase costs and cause loss of time. In addition, it provides significant advantages in terms of cost, time and personnel in the production of periodic orthophoto maps using UAVs. In addition, periodic maps of the entire field can be produced with the UAV instead of mapping only within the area where the study is carried out or within a certain region. Thus, it will be possible to make optimum planning by ensuring that potential threats can be predicted in the work area and healthy decisions will be made for the future [18].

Today, UAV is frequently used in cultural heritage studies [19-21]. Photogrammetry and UAVs have been used in land cover classification [22], landslide modeling [23-24], rockfall modeling [25], pond area volume [26]. It has been used in many engineering projects such as measuring the location of inaccessible geological features [27], coastline detection [28], volume calculation [29].

2. Material and Method

The framework for acquiring and processing UAV images in open pit mining areas consists of four main parts. These are configuring the ground network and flight path design, obtaining images, mapping photos using GCPs with the help of photogrammetric software, creating DEM & ortho-images and drawing. First, the distribution of the ground control network was measured by the Turkish National Basic GNSS Network-Active (TUSAGA-Active) System. The flight path has been designed considering specific factors for UAV-based photogrammetric and aerial image guidance. During autonomous flight operations, both UAV images and position and guidance system data are obtained. Orthophoto and DEM maps are created in Pix4D software, which is used as photogrammetric software.

The technical specifications of the FC6310R camera system attached to the Phantom 4 Pro RTK UAV used in the study are shown in Table 1.

Table 1. FC6310R Technical Specifications

Property	Orthophoto	Digital Elevation Model
Row and Column	2886 *2886	2886*2886
Band no	3 (RGB)	1
Pixel type	Unsigned integer	Unsigned integer
Radiometric resolution	8 bit	32 bit
Coordinate system	TUREF/TM39	TUREF/TM39
Zone	37	37

The images were obtained on the open mine site in Ünye district of Ordu province (Figure 1). The mine site was excavated during the bed determination studies and as a result of the estimations, its operations were stopped. The biggest support to these studies has been the UAVs, which enable them to have fast measurement and information about the area. The study area is 13 ha, and 5 control points have been marked in addition to 9 ground control points (YKN) points, with reference to [30].

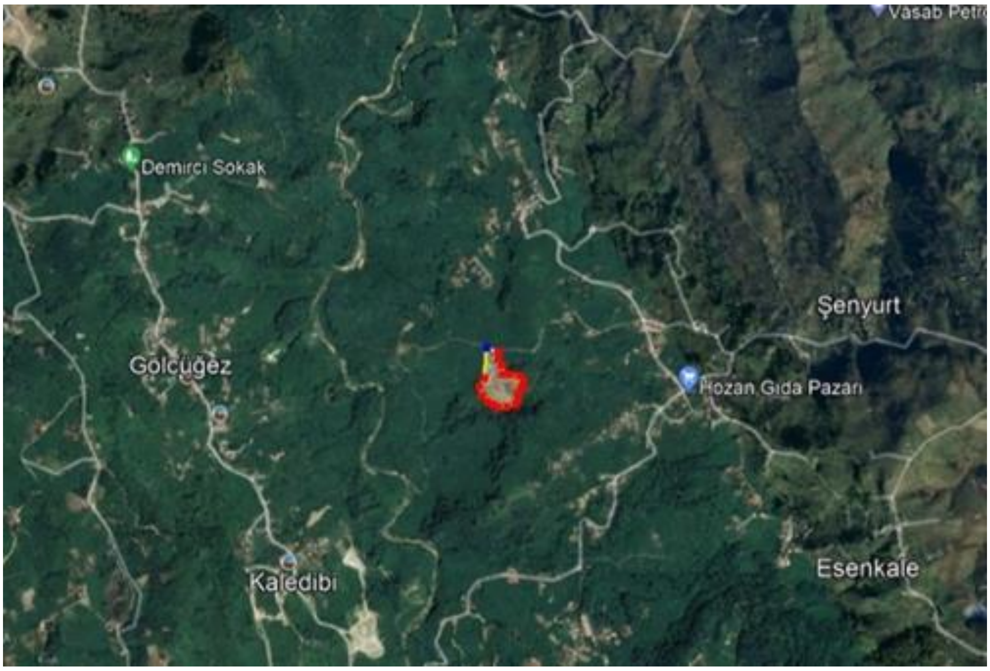

Figure 1. Study area

Coordinates of GCPs and control points (CP), were obtained with the GNSS receiver. GCPs and CPs were added to the Pix4D software according to their types, and the accuracy calculations given in the final report are shown in Table 2.

Table 2. Amount of error for CP

CP Number	X (cm)	Y (cm)	Z (cm)
1	4.1	3.9	3.5
2	3.8	3.1	3.2
3	2.5	2.7	2.4
4	1.9	3.1	5.1
5	3.7	2.2	3.6

Since the mine site is within the densely covered area, a problem occurred in the overlapping of the images outside the site (Figure 2).

Figure 2. Densely covered area

An error occurred in the overlapping of the area marked with red in Figure 2 due to the dense pine cover, and in the second evaluation, the common points were manually marked and the error was eliminated. As a result of the evaluation, dense point cloud and orthophoto image were obtained. Digitization studies were carried out on the point cloud and transferred to the CAD program. As a result, an image of the land was made with the image dressed terrain model (Figure 3).

Figure 3. Pix4d Mesh İmage

The images were obtained on the open mine site in Ünye district of Ordu province (Figure 1). The mine site was excavated during the bed determination studies and as a result of the estimations, its operations were stopped. The biggest support to these studies has been the UAVs, which enable them to have fast measurement and information about the area. The study area is 13 ha, and 5 control points have been marked in addition to 9 ground control points (YKN) points, with reference to [30].

3. Conclusion

In the study, which was prepared with the aim of including unmanned aerial vehicles (UAV) in mining applications and revealing their usage potential, it is aimed to make more accurate and more practical measurements and calculations in shorter times in the mining sector of our country, which is working intensively in open pit mining.

In the study, with the use of unmanned aerial vehicles and appropriate software, the concepts such as volume and mass were studied on-site in areas that are difficult to calculate. It has been proven that studies can be carried out to determine the amount of extraction, which is one of the most important factors in mining operations. Considering the number of errors given in Table 1, it is seen that the UAVs are quite successful. UAV minimizes accidents that may occur during land measurements by highlighting occupational health and safety, especially in mining areas.

136 pictures were taken at the mine site, and 9 GCPs and 5 CPs were marked. While the work in the field took 1 hour and 15 minutes, the processing of the images and the production of the report took 29 minutes. The DSM and orthomosaic images produced are 3.1 cm resolution. By looking at these data, UAVs have proven their usability in open mining operations.

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Author contributions

Alperen Erdogan: Visualization, Writing-Reviewing and Editing, Conceptualization, Methodology, Software. **Mahmut Gorken:** Data curation, Writing-Original draft preparation, Software, Validation. **Adem Kabadayı:** Visualization, Investigation, Software, Validation

Conflicts of interest

The authors declare no conflicts of interest.

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