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Usage of unmanned aerial vehicles in open mine sites

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Abstract

Today, technological developments show themselves in the fields dealing with earth sciences as in every field. Unmanned aerial vehicles (UAV), one of these technological developments, have offered an innovative approach to many sectors. In addition to being used in various fields such as geodesy, disaster management, meteorology, agriculture and security, its use in mining has also become widespread. Topographic surveying problem in open pit mining sites is one of the important challenges to be overcome. Topographic measurements require expensive surveying equipment and professional technical personnel. UAV technology provides cost control to the difficulties encountered in the fields and can easily produce solutions with time saving and measurement accuracy. In recent years, in mining activities in the world; It is used in areas such as production planning, blasting, ore production and stock tracking and volumetric calculations, monitoring of slope sensitivities and changes, calculating the amount of waste, dust emission, security. In this article, the structure of UAVs, their advantages and areas of use in open mining areas, the availability of reasonable results and the benefits that affect the studies are explained by adding case studies in open mining areas.

1. Introduction

Open pit mine sites are often complex terrains and areas with varied geological conditions, limiting accessibility in mining, but sometimes causing inaccessibility in extreme cases, so the use of conventional methods causes difficulties for ground surveys.

The rapid development of unmanned aerial vehicles (UAV) technology, which is one of today's technological developments, has benefited not only the military but also the mining industry as well as in various civilian areas. Mining companies use UAV technologies to monitor and plan mining operations and increase their efficiency, speed and safety. With UAVs, which is a remote sensing technology, comprehensive analyzes can be made by obtaining high resolution data in a short time with less labor.

Recently, a photogrammetry system using UAV has been used for topographic surveys to complement the strengths and weaknesses of ground/air measurement equipment. The UAV photogrammetry system has a relatively large working area compared to existing ground crew equipment and a relatively small measurement error compared to air measurement technologies. Because of these features, the UAV photogrammetry system is considered as a technology that can replace or complement existing measuring equipment (Siebert & Teizer, 2014) and civil construction (Park et al., 2013).

In this study, the usability of UAVs in open pit mines and the advantages of UAV systems are emphasized in line with the studies and analyzes of these studies.

2. Definition, classification and usage areas of unmanned aerial vehicle

There are different definitions of unmanned aerial vehicles in various sources. The common denominator to be derived from these definitions is; UAV is a kind of aircraft that does not have a pilot or passenger, carries only the equipment suitable for its intended use (camera, GNSS, laser scanning device, etc.), can be controlled in the air by a pilot on the ground, or can perform a pre-planned flight plan autonomously. It can be defined as in this context, UAVs basically consist of three components; The

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aircraft itself is the payload on the aircraft and the ground control station.

UAVs, also called drones, are classified as fixed-wing, rotary-wing and Vertical Take of Landing (VTOL) according to their flight capabilities "Fig. 1".

Figure 1. Fixed-wing UAV (a), Rotary-wing UAVs (b), VTOL UAV (c)

Today, UAVs are used in agriculture, meteorology, archaeology, forestry, communications, security, wildlife surveys, habitat studies, landscape planning, environmental surveillance, natural disasters, traffic management, transportation, energy, geology, hydrology, civil engineering, mapping and mining. used in a variety of disciplines, including Some examples of usage area are shown below "Fig. 2".

Figure 2. UAV use in military field (a), UAV use in disaster management (b), UAV use in agricultural applications (c)

2.1. Use of Unmanned Aerial Vehicles in Mine Sites

Mineral resources have an important place in economic development due to their importance in terms of both raw materials and energy (Hu et al., 2014; Xioa et al., 2018a). The demand for mineral resources has increased significantly with the growth of industry and urbanization, and this has led to a greater need for mining. In general, two types of mining are widely used, namely above-ground and underground.

UAVs play an important role in various challenging aspects of the mining industry, inspecting belt conveyors and electrical overhead lines, up-to-date mining databases, blast optimization, mine tailings pond surveillance and tracking of trucks and equipment, geological hazards, pollution monitoring, land reclamation, ecological restoration assessment. is playing. In addition, UAVs provide punctual and regular images to obtain photogrammetric three-dimensional (3D) models of mines in order to monitor the stability of steps and slopes and production amounts.

From UAV photogrammetry, current map production in open mines, determination of production and pickling amount, stock and dump site cubage calculations, land damage assessment, rock detection, geological mapping, excavation planning and installation of hyperspectral cameras, alteration and mineral detection, determination of steep and inaccessible points. used in studies such as mapping.

3. Applications in Open Mine Fields with Unmanned Aerial Vehicles

In open mining areas, sensitive data can be collected in a short time in all kinds of terrain conditions, thanks to UAVs and aerial imaging and measurement systems. Depending on the UAV used, comprehensive and easy-to-analyze quality data can be obtained within a few hours.

With the advancement of drones, the development of high-resolution cameras, and the development of image-based mapping techniques, drone imagery has been a topic of considerable interest among researchers and industries. These images have the potential to provide data with unprecedented spatial and temporal resolution for 3D modelling.

3.1. Use of UAVs in Stock Volume Calculation Studies

Obtaining up-to-date information about an open pit is an understanding of the ever-changing shape of the pit and its embankments, row heights, slopes, etc. It consists of the continuous investigation of elements such as Mining companies tend to monitor their quarries frequently, depending on the material they dig. Monitoring can be done weekly, monthly or quarterly (Mazhdrakov, 2007). No matter how frequent the need to investigate stocks, mining companies should be offered the fastest, most effective and reliable measurement and calculation methods.

Filipova et al., (2016) selected a quarry in Lukovit town of Sofia, the capital of Bulgaria, for the evaluation of volumetric measurements in their study. In this study, it is aimed to test and evaluate the accuracy of UAV data according to GNSS techniques. Two sets of measurements were made. First, stock measurement with GNSS technologies, and secondly, the entire quarry area was mapped by a UAV flight. The selected UAV is eBee SenseFly and the GNSS receiver is Leica viva GS08 Plus. Aerial photographs taken by UAV were processed with PIX4D Mapper software and volumetric calculations were made with this program. AutoCAD Civil 3D was used for volume calculation obtained from GNSS measurements.

With this study, a confirmation of the promising application of UAV in stock volume calculation was sought. Since the data were obtained by two different methods and processed in different ways, two values of the volume of the same stock were created. The volume obtained from the UAV data is 12,749 m^3 and the volume obtained from the GNSS points is 12,606 m^3. As a result, it was revealed that the volume of the UAV was 143.99 m^3 more. In some countries legislation specifies that the volume must be calculated with an accuracy of ±3% of all material. The accuracy achieved is within the 3% legitimate error, which is the main target of the working condition.

Filipova et al., (2016) presented the efficiency and reliability of the data obtained with high resolution by UAV when it comes to volumetric measurements.

3.2. UAV use in production and waste determination studies

Continuous control is required in order to direct production in mines, to produce limited resources efficiently and to maintain economic balances. Because; Continuous monitoring of parameters such as quarry operating efficiency, annual production amount, annual waste amount is required. Inspection of the entire field and amount of waste is both time consuming and very laborious with traditional methods.

Kun & Guler (2019) used a DJI Phantom4 Pro drone in a natural stone open pit mining operation in the district of Korkuteli in Antalya province, and studied the availability of UAVs to determine the production and waste amount in the quarry over a 15-month period. Flights were made in an area of 300,000 m^2. The first data set is the data set obtained with the flight made on April 22, 2017, and the second data set is the data set obtained with the flight on July 01, 2018. During this period, the changes in the natural stone quarry were clearly observed and reflected in the results. The data were processed in the Pix4D Mapper program and the total error of the digital surface model (DEM) optimized with ground control points (GCP) in three axes was found to be less than 5 cm.

Two separate DEMs were created from the two data sets. In the 3D mining software, DEMs were superimposed, cross-sectional images were obtained, and excavation and fill volumes were calculated. At the end of the calculations, the annual excavation amount of the enterprise was determined as 1,20148.37 m3. When the amount offered for sale is subtracted from the annual excavation amount value, the remaining amount constitutes the total amount of waste. According to this; According to the information obtained from the records of the enterprise, as a result of all excavation and on-site dismantling operations, the amount obtained as smooth, dimensional and salable is around 10,500 m3. When this value is compared to the annual excavation amount in the quarry, the yield of the quarry is 8.74%.

Kun & Guler (2019) stated that the datasets obtained by processing the images collected by UAV are processed with photogrammetric software and additionally supported with 3D mining software, operating parameters such as annual excavation and/or production, waste amount, quarry yield of open mining enterprises can be determined quickly and precisely. have reported.

3.3. UAV Use in Topographic Research Studies

Since the unmanned aerial photogrammetry system has a relatively small measurement error compared to the current aerial measurement methods and has a relatively large working area compared to ground survey methods, it is actively used in topographic research applications in open pit mine sites in the country and abroad.

Lee & Choi (2015) conducted a study in an open limestone mine located in Samcheok-si Gangwon-do, Korea to prove that topographic survey can be done with UAV in the mine. 4 YKNs were placed in the study area with the Novatel Smart-V1 GPS device. eBee SenseFly was used as the UAV and Postflight Terra 3D software was used to process the aerial photographs taken. Point cloud data with 3D coordinates was created and finally DEM was produced.

GCPs measured using GPS and the results produced from UAV data were compared and it was seen that the mean square error (RMSE) for 4 GCPs was 15 cm in the X direction, 2 cm in the Y direction, and 14 cm in the Z direction. In other words, it has been analyzed that there is an error of about 15 cm according to the results of the ground survey using high-precision GPS. This result satisfies the maximum vertical error of 30 cm (1:1200, at map scale) and the maximum vertical error of 25 cm (1:1000, at map scale) recommended by ASPRS (1988) for topographic maps. Some studies (Turner et al., 2012; Jung et al., 2009; Uysal et al., 2015) using UAVs show similar error levels. Considering the studies carried out in open pits, it has been concluded that the results of the surveys made with an error level of 15 cm can be sufficiently utilized in the creation of topographic maps.

Lee & Choi (2015) stated that topographic surveys with fixed-wing UAVs are very effective in terms of working time, compared to the one week or longer operating time required for ground survey with light waves, which was done approximately once a year in the research area.

3.4. UAV use in air quality monitoring studies

Both shallow coal seam and large-scale mine blasting produce large amounts of pollutants such as NOX, SOX, COX and heat radiation. Air quality monitoring relies on several stationary samplers to model and verify or predict gas emissions based on indicators such as coal consumption. In recent years, UAVs equipped with gas sensors have been used for remote monitoring and control of pollutants, with good results (Dunnington & Nakagawa 2017; Martin et al., 2015).

In the study by Bui et al., (2019) at the Coc Sau coal mine in Vietnam, various data, primarily images and airborne pollutant concentrations, were collected with the RGB Zenmuse X4S camera mounted on a low-cost rotary-wing DJI Inspire2 UAV, several dust sensors. Field tests were conducted to evaluate the performance of the system. Sensors mounted on the UAV were able to monitor the levels of environmental variables associated with air quality in the pit such as temperature, dust, CO, CO2 and NOX. Taken aerial photographs were processed using Agisoft Photoscan software and 3D topographic maps were modeled. As a result of the evaluation of the accuracy with GCPs, it was seen that the X,Y,Z root mean square error (RMSE) was 6.6 cm, 6.1 cm, 13.8 cm and 16.4 cm, respectively. These values show that it meets the accuracy requirement for mineral exploration tasks.

The distribution of pollutants in a deep pit is dependent on surface wind and air density differences inside and outside the pit. The space inside the pit is divided into 2 sections and named as H1 at -140 m and H2 at 120 m. The UAV systematically passed through these regions. In order to measure the vertical temperature profiles in the pit, it started from the center of the pit floor and flew 250 m above sea level along the vertical line. The collected data was used to create 3D environmental maps. Environment maps in terms of Co, Dust (PM10), NO and temperature were created with ArcGIS software.

According to the field test results in this study, Bui et al., (2019) the availability of low-cost UAV for 3D mapping, demonstrates with relatively high accuracy the air quality monitoring in large and deep coal mines, pollutant control measures can be taken by the system as air pollution profiles can be seen on 3D maps and the main causes of pollution can be easily verified based on 3D maps.

4. Results

The use of UAVs has become widespread in the mining field, as in many other fields, in recent years, as it offers advantages in terms of measurement accuracy, equipment and the variety and quality of data obtained, time saving and cost compared to many measurement methods.

In mining, new measurement technologies, which are practical and cost-effective, have begun to be preferred in order to control, maintain and map the production and the operations performed at this stage. Developing UAV technology has provided solutions to these, not only measuring, but also enabling new areas of use in mining with its aerial imaging system and the variety of equipment that can be used. Sensitive and comprehensive results can be obtained by processing the data taken by the UAV in necessary software suitable for the purpose. The resulting products can be analyzed in many ways in the digital environment. In addition, UAVs can easily make measurements in topography or conditions that are difficult to measure with traditional methods, and can provide precise results in a short time with healthy data, regardless of large or small area according to the UAV capability used

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