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Identifying the potential use of Unmanned Aerial Vehicle (UAV) technique in mining area for geohazards and safety control

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Abstract. Nowadays, flexible Unmanned Aerial Vehicle (UAV) technology has many benefits especially in geoscience work include; rock types identification, safety developments, data acquisition and land profiling. This study focuses on the potential geohazard threats that may occur in mining areas. Various methods, techniques and approaches in terms of inputs and outputs from previous studies have been analyzed to identify the probabilities of the geohazard problems encountered. It is conducted by performing aerial mapping with flight mode that has been set according to the specifications of the method used, mapping scale and data accuracy. This analysis discusses the effective solutions in identifying the actual accuracy to provide an assessment of the geohazard level at the mining area and then establish safety controls either biological or engineering control. The accuracy of the data and maps are very important to maintain the reliability of the data collected. As a result, the findings from the review can be compared; based on the capability of the UAV methods that have been adopted in producing geohazard output quantity and quality of findings. The output data is then analyzed to give an accurate assessment in determining the level of security to be considered at the mining area. In conclusion, these data can be used as an assessment to determine security control in mining areas based on the shape of the terrain, the capabilities of the UAV techniques used, accessibility, the type of mining applied and others. It is shown that this research can be presented to the authorities in improving the quality of safety in mining centres to ensure the safety of the parties involved.

1. Introduction

Geohazards are events related to geological conditions and processes that offer a potential risk to people, property, and/or the environment. They are very dangerous because it gives the possibility of horrific accidents involving lives and operational losses in large numbers as well as economic catastrophe to a country if not managed properly. Specifically, geohazard in the scope of mining is very dominant to be studied and analyzed; high -risk environments, exposed to toxic coming from explosives, and others. Geohazards in mining are not only harmful to workers and the surrounding conditions alone but involve long -term exposure to other living ecosystems, the food chain, as well as the earth's geology structure [1]. The current trend of the use of Unmanned Aerial Vehicles (UAVs) is very widespread in all areas that require image monitoring from aerial points. Multipurpose output of result is very useful especially related to imaging of ground floor of earth surface. Besides, its ability to make monitoring on a scale by meeting the required requirements on a spot makes the UAV increasingly useful and consistent [2]. In addition, UAV is an ideal platform to generate a geological map that show the features and types of rocks that are on the earth's surface to be analyzed or as secondary data. The use of UAVs in this field has many benefits for locating rocks of the earth more easily and more widely as well as inaccessible areas [3].

Disasters that occur in a mining area usually revolve around the level and control of security on which has been gazette by the owner. This problem is a turning point into a disaster due to attitude, negligence, level of security and the cost is too high to apply [4]. So, various safety levers can be used



in mining to modify exposure to the inherent risks, reduce the likelihood of them occurring, and contain or mitigate the consequences of accidents if they occur. With regard to the conditions in these industries, decision-makers can adopt a variety of attitudes and choices respect to the conditions in industries.

In Malaysia, there are also disasters in mining, but this case is not as severe as abroad. Accidents occur mostly due to the forgetfulness of untrained workers before doing the actual work. This is because the existing mining centers in Malaysia is in a small scale compared to India and African countries that rely on this industry as the largest source of economic income. They make optimal use of mining workers necessary [5]. The use of efficient machines can reduced the number of workers in the mines. Despite of not faced such issues, Malaysia strictly follow general safety measure construction by Occupation Safety Health (OSH) Malaysia. Therefore, this study reveals and analyzing the methods of producing output in mining area. Besides, evaluation on the levels of geohazard is the main objectives of this study.

2. Methodology

Different sensors have been rapidly created in tandem with the evolution of UAV energy technology. Active and passive sensors are the two categories of sensors that can be classified based on their actions. Electromagnetic energy sensors, such as digital cameras or spectral imaging sensors, are passive sensors that can only gather light energy from the sun or from the earth's objects while active the active sensor, such as LiDAR or SAR, sends out electromagnetic waves to ground targets and subsequently collects the information reflected back [6]. This section describes these two sensors along with their ability to produce output results in identifying geohazards in mines include ability spatial and spectrum image.

2.1. Digital Camera (Point Cloud Processing)

True red images can be captured by digital cameras, and the green and blue bands of visible light (400-760 nm) indicate its spectrum and spatial abilities in interpreting the color of an RGB image, resulting in a lower cost and a higher number of pixels (spatial resolution) [6]. This is why the image taken can be processed using appropriate software such as Agisoft Photoscan, Pix4d and others. Its ability is in producing images in Digital Surface Model (DSM), Orthophoto, Digital Terrain Model (DTM) and 3D modeling (point cloud) by using a large number of images for pre-processing so that the combination of features in each image can be combined before produce its output [7]. In the scope of identifying mine geohazards, the image outputs are mainly 3D modeling and orthophoto because these two images can provide the mine area clearly in terms of features in the object, area and x, y, z views of the mine area (Figure 1). The results are very suitable in identifying fractures based on 3D modeling models due to the high accuracy of spatial resolution of image processing. It can analyze the diameter, height, and depth. Therefore, identified fractures can calculate the probability of rockfall by performing analysis with the help of third party software. Usually, the accuracy assessment to produce 3D modeling and Orthpoto maps uses the Root Mean Square (RMSE) method with coordinates from the land survey as a benchmark. Therefore, it is necessary to use geomatics control by establishing Ground Control Point (GCP) and Verify Point (VP) taken in the mine field in order to map high accuracy orientation image .This accuracy assessment is very important to identify the real position fracture identified based on the coordinates that have been established and the value of the height (reduce level) of the Mean Sea Level (MSL) used for the purpose of geohazard rockfall or rockmass. This accuracy assessment is also widely used in various fields such as mapping the purpose of agriculture, urbanization, town planning, heritage area certificate and others [3].

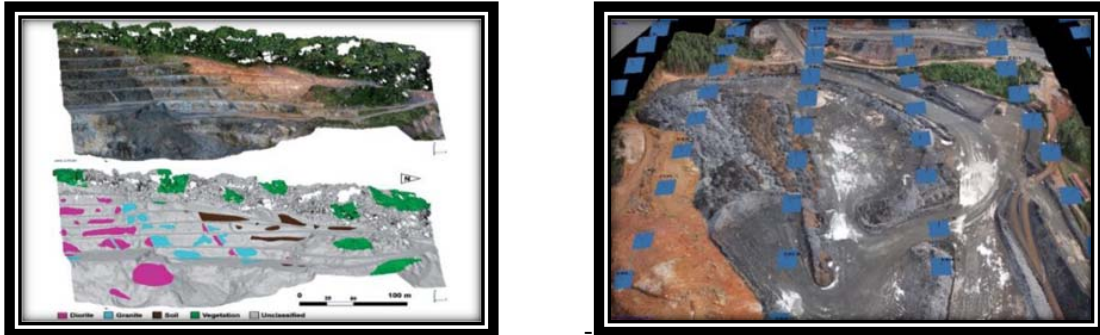


Figure 1. 3D modelling image and Orthophoto at mining area (Source:[12])

2.2. LiDAR

Light Detection and Ranging (LiDAR) is divided into two types: LiDAR (ALS) and LiDAR field (TLS). An active ground observation system is airborne LiDAR. The laser is directed at the ground or object's surface, where it is reflected and relayed to the sensor [6]. LiDAR is extremely precise, and it can generate high-density 3D point data in real time. It also has distinct advantages over standard soil measurement and photogrammetry in remote mountainous places where land control sites are scarce (GCP). In general, TLS by LiDAR is always dependent on GNSS receivers, while photogrammetric methods typically use GCP (Ground Control Point) to geographical reference (georeferenced). Figure 2 shows an example of LiDAR image at mining area in DTM format. In other words, LiDAR cannot 'standalone' requires the help of establish GCP to produce high accuracy output when compared to digital image methods (Ortho and 3D image modeling). Thus, LiDAR's ability is to provide DTM and DSM data in high resolution and accuracy [3]. This is evidenced by LiDAR with TLS type will be laser penetration directly to the earth's surface without being hindered by features that attach to it such as trees, vegetation, buildings and so on; called 'bare surface' because it facilitates the process of data acquisition. The accuracy assessment method used in this LiDAR image is by Ground Sample Distance (GSD); works with on the ground, many pixel centers were measured in a row. Difference flight mode UAV's sensor method between Digital Image (capture) and LiDAR image (penetration laser) is shown in Figure 3.

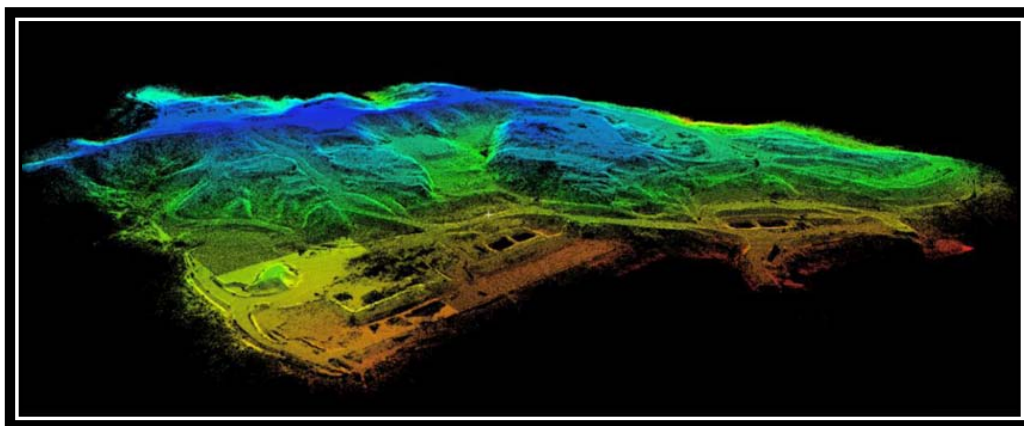


Figure 2. LiDAR (TLS) image at mining area in DTM format (Source:[11])

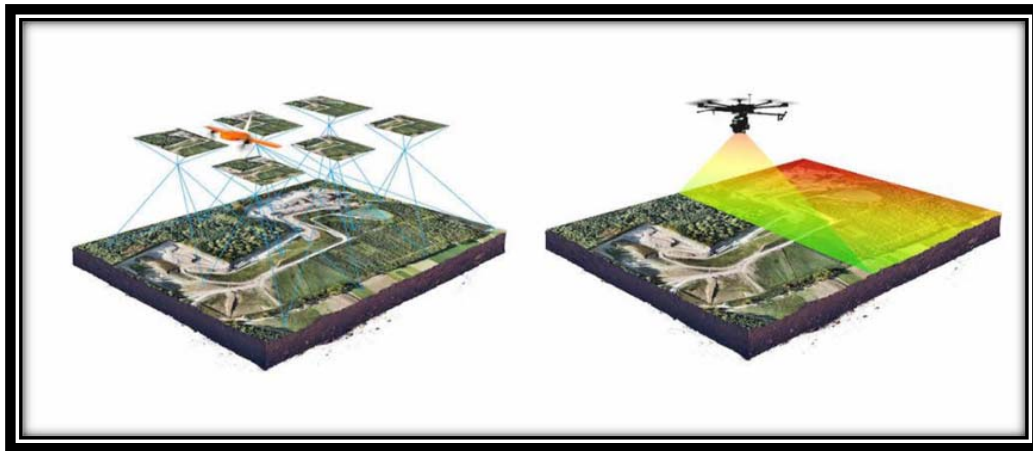


Figure 3. Difference flight mode UAV's sensor method between Digital. (Source:[10])

2.3. Thermal Infrared camera

Thermal imaging cameras must become smaller and lighter as UAVs become more common. Agriculture monitoring, geological surveys, and other fields have all employed UAVs outfitted with powerful infrared sensors. It may also be used to obtain temperature satisfactory findings in temperature, field measurements monitoring, and modelling of self-igniting coal gangue underground coal fires in geological surveys; in 3D modelling and DSM [6]. In addition, these sensors are widely used to know the status of the area after the explosion in the mine especially on the coal mine, air quality; identify hazardous gases (CO_2) in the ambient air medium. In fact, before this, infrared thermal camera technology came from the field of remote sensing. It is the result of a hybrid of these two fields between UAV's and remote sensing. However, the infrared thermal technology available on remote sensing is not the same as UAV's because the scope and imitation in data acquisition are different from each other and also none benchmark to detect the level of accuracy. For example, Figure 4 indicates that the size sensor Temperature and Emissivity Separation (TES) algorithm on UAV's is much smaller than on remote sensing technology because it is at a satellite attitude that is very high than the mean sea level (MSL) [8]. Table 1 summarize the differences of UAV platform sensors in terms of their input, output, detectable type of geohazard, accuracy assessment, advantages and disadvantages

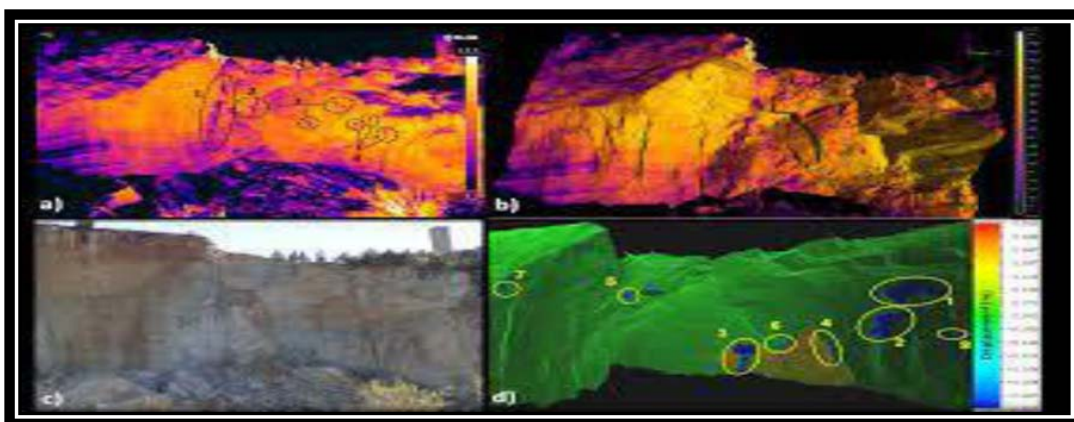


Figure 4. Thermal Infrared Image at mining with analysis by sensor Temperature and Emissivity Separation (TES) algorithm. (Source:[8])

Table 1. Summary of three difference UAV's platform sensors.

UAV's Platform Sensors	Input	Output	Type of Geohazard Detection Capability	Advantages	Disadvantages	Accuracy Assessment
Digital Camera	RGB color image, spatial and spectrum resolution image.	Orhophoto, 3D modelling, Digital Surface Model (DSM)	Fracture, rock fall and rock mass.	Easily analyze the size, height, coordinates and width of a fracture, rock mass or rock fall.	Need to pre - processing the image taken (take a long time).	Root mean square (RMSE), K-neighbors, and other
LiDAR	ALS and TLS active sensors	Digital Terrain Model (DTM) and Digital Surface Model (DSM)	Landslide, stability land or rock, probability rock fall.	High accuracy, more details data output, easy to analyze (automatically).	High cost and very expensive image data.	Ground Sampling Distance (GSD)
Thermal Infrared Camera	Temperature and Emissivity Separation (TES) algorithm, adaptive gradient-based thresholding (SAGBT) algorithm and others (depends on required study)	3D modelling + Digital Surface Model (DSM)	Identify hotspot fire area (ambient temperature, effects of explosion (dust, toxic gases in the air,), and gas leaks.	The only sensor medium can detect temperature and density and flexible.	Low data reliability, and not suitable for small areas	None

3. Results and Discussion

A critical assessment was made in order to determine the discrepancies and gaps between different techniques in identifying geohazard. The capability of the sensor type used for output interpolation before a risk assessment was identified. It is important to know that the most dominant UAV sensors can be maximized for use in the field of geoscience, especially in identifying geohazards.

Mostly works by [1, 6, 9, 10] have focused on the ability of UAV sensors to provide maximum output but in the scope of geohazard studies it is very difficult to identify as it requires scaled monitoring to obtain high data accuracy. They used different algorithms on existing software because most of them focus on the accuracy of coordinate values (x, y, z); not concentrated on the perimeter of the ground surface area absolutely. As a comparison, works by [8] have shown that LiDAR sensors is very wide; covers aspects of algorithms, parameters, and high resolution. This makes it a lot of output can be produced and makes LiDAR very famous for use in high performance industries. This proves that the use of LiDAR UAV sensors is very dominant in this study when compared to the others.

4. Analysis

Additional geological dangers and pollution issues have occasionally arisen during the mining operation, posing a threat to the mine's progress. It is important to identify geohazard as well as analyzing the level of risk of accidents so that progress in terms of production and efficient work culture in the mines can be maintained [1]. Types of geohazard data which are taken randomly from previous research based on the sensors capabilities provided in the above section was then analyzed according to the level of danger provided by Occupational Safety and Health in Mining: Anthology on the situation in 16 mining countries as a benchmark [5]. This research describes the risk rate according to the accident cases that occurred in the 16 countries and also how to overcome it. Figure 5 represents hazard scale probability accident at mining.

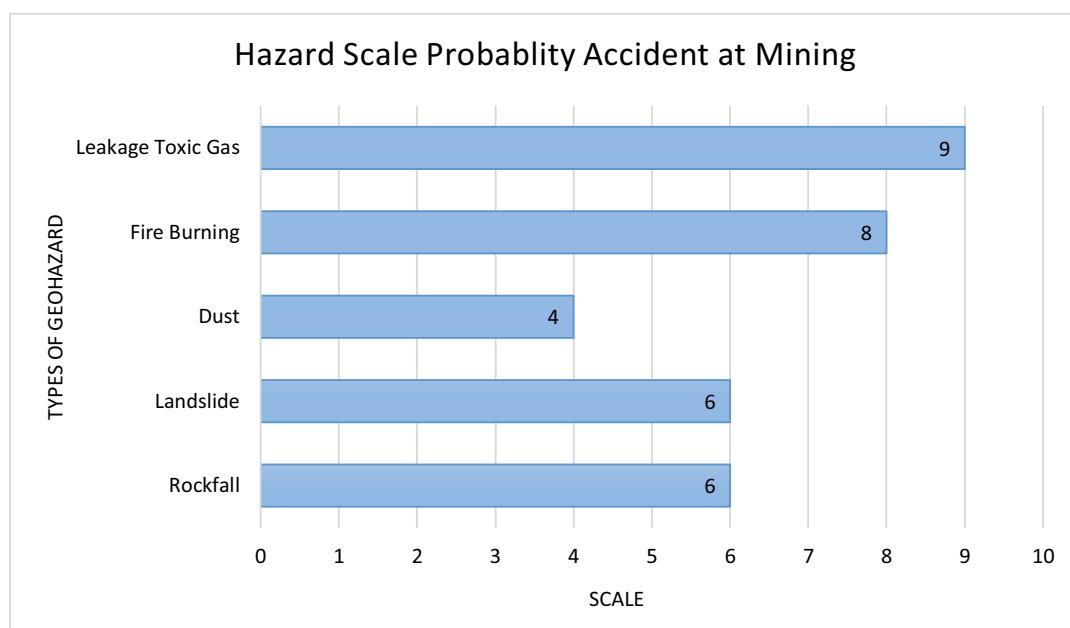


Figure 5. Hazard scale probability accident at mining.

Based on Figure 5, the accident probability geohazard scale is rated starting from 1-10, of which 1-4 is normal, 5-7 is moderate and 8-10 is high. Toxic gas leaks show the highest scale and very risky. It can cause other accidents such as explosions and air pollution. Statistics have proven accidents that claim lives and destroy property in mines due to which data are taken from 1901 to 2010 (OSH) while the lowest data is dust. It does always happen due to tapping, hillside explosions in mines. However, it should not be taken lightly as this dust can cause fatigue, shortness of breath, heart failure because too many small particles get into it through respiration [5]. Landslide and rockfall risk assessment scales are moderate as both are under the control of mine labor workers. The possibility is usually due to the negligence of the workers or the original structure of the soil or rock in the original mine area is weak. Finally, fire burning has a high risk assessment behind toxic gas leakage because it causes a lot of permanent disability and trauma to workers, especially in coal mines, although statistics show a small amount of loss of life due to fire burning. It also gave huge losses to the owners as many assets in the mine were destroyed [5].

5. Recommendation

Analysis on taking security control at the mine based on the capabilities of UAV's does not include geohazard accidents detected using other platforms [1,2,6, 7, 8,9,10]. This aims to see the level of reliability of UAV's data to be used in analyzing geohazard data and continuously with security controls with accuracy assessment as a reference. Benchmarks for safety control measures are referenced from Occupational Safety and Health in Mining: Anthology on the situation in 16 mining countries [5] where each safety control measure is taken in accordance with the problem of accident probability risk that occurs (Figure 5).

5.1. Safety Controls of Dust

It is suggested to introduce new methods for minimizing coal dust's exclusivity such as biology controls with water important medium to overcome it with spray thoroughly and scale on eight mines. Besides, better design and monitoring procedures for safer ground control systems could be implemented especially in deep mines and provide new technology to supply breathable air to miners. In a post-accident environment, new technology should be introduced to supply breathing air to miners.

5.2. Safety Controls of Rockfall and Landslide

Built concrete control, at high cutting (exceeding 4 meters in height) whether stone cement and other after construction should be emphasized. Other than that, risk assessment on areas with cutting and soil structure can be performed using mathematical equations or analysis using the software involved.

5.3. Safety Control of Fire Burning

Schedule periods and times to make explosions effectively; avoid explosions when workers are busy, heavy machinery coming in and out and criteria for action. It is better methods for minimizing explosiveness; record and analyze the capability of an explosion so that there are no negative effects afterwards. Otherwise, adequate training is provided to bombers on a scale for prevent unforeseen cases from occurring.

5.4. Leakage Toxic Gas

Appoint a dedicated security officer to monitor it; expert in chemistry and experienced for reduce the use of machinery or explosives with high levels relate of carbon dioxide (CO₂) in mines; the use of environmentally friendly machinery as an alternative. Besides, prepare complete tools and equipment to workers as a safety measure in the event of a leak such as mask N95 and above, chemical protection suit and others.

6. Conclusion

This UAV technology has a bright future prospect due to the flexibility of the technology available to it. Not only that, its 'hybrid' nature makes all fields able to benefit from it regardless of agriculture, construction, ecology, mathematics and so on. The above facts have proven to be the latest driving platform to the success of the industrial revolution (IR4.0). The selection of sensors is crucial in order to output data; identifying geohazards in mines can be fully utilities when LiDAR sensors used. This output data in quantitative form could contribute in the context of safety and health in the mine; not bound only in the scope of the field of geoscience alone. The made safety controls referenced from Occupation Safety and Health (OSH) assure that the arguments presented are reliable and can be applied with maximum effectiveness. The researcher hopes that the mining area has an accurate survey in terms of security so that the exploitation of wealth can be interpreted with justice either to humans or the environment.

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