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Application of UAV photogrammetry for quarry monitoring

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Abstract: In quarry production, survey work is necessary to monitor the height of stockpile and quarry's walls to obey the rules and regulation stated by authority. Conventional method of surveying is by ground-based surveying on these sites to measure the X, Y and Z data. Nevertheless, these approaches are very time consuming and a dangerous undertaking for the staff. Advancement of remote sensing specifically unmanned aerial vehicle (UAV) have become an alternative for surveying work. The use of drone for survey that is remotely piloted is able to replace the traditional method of surveying in quarries. This paper describes the application of drone mapping for quarry monitoring and management of stockpile and slope assessment. Quadcopter was used to acquire the aerial images for stockpile and both aerial and side images for slope assessment. The captured images were processed using a photogrammetry software, Agisoft Photoscan to produce the final output consisting of orthophoto, digital surface model, 3D dense point cloud and 3D model. Based on the output, volume, height and area of stockpile computational were made in the photogrammetry software. The slope stability assessment computation was made using facet extraction to identify the major discontinuity sets for rock slope stability analysis. UAV photogrammetry grants precise approach to provide fast data recovery and time saving for mapping a large quarry area.

Keywords: UAV, photogrammetry, quarry, rock slope

INTRODUCTION

Mining activity involves excavating the earth surface for exploring the minerals and it is the oldest economic activity after agriculture (Mondal & Chakravarty, 2013). Mining without appropriate planning and lack of modern technologies usage have adverse impact on the atmosphere especially on dust emission (Nartey *et al*., 2012). Consistently changing nature of quarry landscape implies that a regular monitoring of the whole area helps in effective management of such activities for example re-routing roads, position of heavy machinery, location of different type of stockpile and surveying of blast material and stock piles. Successful organization of a quarry needs quick and precise information where the results must conform to a specific legislation. Quarry data collection consists of constant surveying on the changing shape of the quarry and its elements such as berms, bench heights, slopes, and reliable computation of the volume of the extracted mass (Raeva *et al.,* 2016).

The utilization of innovative technology such as UAV will be very important to learn and monitor mining and quarry areas especially in risk assessment and management. The use of UAV will enable mapping of the entire quarry in a fast way to improve the overall project management. Additionally, it will be very beneficial in measuring stockpile volume, height, diameter and density to assist in stock calculation, arrangement of deliveries and to support robbery prevention. Conventional surveying method of using total stations and traditional global positioning system (GPS) are time consuming, requiring many readings on one stockpile for accurate measurement of the stockpile.

Although conventional method has been practiced in characterizing the rock masses in quarry, the use of UAV photogrammetry method is reliable and effective (Salvini *et al*., 2017) (González-Aguilera *et al.*, 2012). Application of UAV photogrammetry in many engineering applications signifies it as a suitable and effective solution considering the accessibility and lower investment cost of using UAV (González-Aguilera *et al*., 2012). Photogrammetric survey is able to produce digital orthophoto, digital surface model (DSM) and 3D dense point cloud with the aid of structure from motion (SfM) software (Esposito *et al*., 2017).

With the development of UAV, geologists are able to document the normally accessible elements of geological outcrops or the dangerous parts of the rock mass. Images

from the digital camera mounted on a UAV is able to capture the geological outcrops, big areas and to attain inaccessible valuable missing data (Blistan *et al*., 2016). This method can be used to overcome the problem of unseen areas and to acquire detailed information on any feature. 3D point clouds obtained from image processing have been used to rebuild the quarry geometry and then discontinuities were then mapped deterministically in detail (Salvini *et al*., 2017).

Analysis of UAV images by SfM approach establishes a reliable and validated tool for surveyors who are concerned with high-resolution reconstruction and monitoring of quarries. Photogrammetry output provide a useful tool for management of the environmental risk of dangerous and inaccessible areas, and they enhance the geotechnical interpretation for engineers to make decision (Rossi *et al*., 2017). This paper presents the method to monitory and manage quarrying work effectively through photogrammetry output with minimal cost.

STUDY AREA

This study was conducted in Kuad Quarry at Kubang Semang, Pulau Pinang which serves as a nonmetallic mineral mining and quarrying site. The site is located at coordinate of 100.47 north and 5.41 south. The bedrock of the study area is acid intrusive which is the igneous rock. Figure 1 below shows the location of study area and its geology.

METHODOLOGY

The main elements in this study is to carry out the UAV flight mission to obtain aerial imageries for quarry monitoring and assessment. Mission planning were done using DJI Ground Station Pro application to input all the acquisition parameter. Mapping area boundary was marked on an interactive map, including flying height of the UAV to capture images, the course angle of pathway and the percentage of front and side photos overlapped. The percentage of overlapping photos is critical in producing an accurate sparse cloud of the study area. Front and side images overlapping ratio is 80% and 70% respectively. Waypoints were generated after all the settings were set, showing the global position, distance covered, flying height above ground, number of images that will be captured, the estimated battery usage and duration of the flying mission.

Agisoft PhotoScan Professional version 1.4.3 was used to process images through photogrammetric

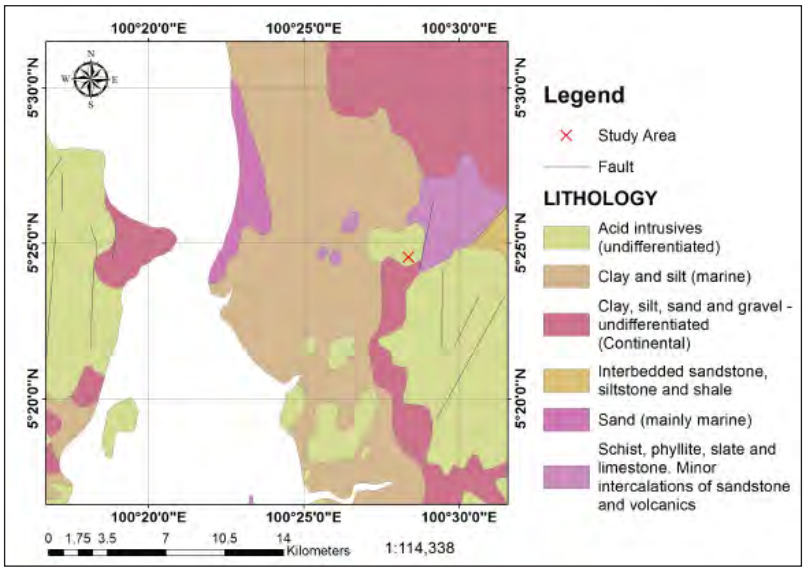

Figure 1: Location and geology map of study area.

Figure 2: Summary of methodology.

technique. All images were aligned together accordingly before generation of dense point loud and model through interpolation and aerial triangulation process. The structure from motion (SfM) algorithms in the software will extract and match the same features appeared in the images automatically known as tie points and followed by bundle block adjustment. Sparse clouds will be produced as an output of the process. Then, dense geometry was ready to be constructed with its accuracy set to high level to obtain a denser point cloud. Construction of 3D textured model, Digital Surface Model (DSM) and orthophoto were then processed from the dense point clouds.

Stockpile assessment was made through Agisoft PhotoScan for calculation of area, volume, and height of stockpile. Output from the photogrammetric process then is exported into CloudCompare a free software to perform facet extraction for rock slope assessment with the value of mean dip/dip direction. After the meshes or facets are extracted, they can be classified by orientation (dip/dip direction) into single planes and plane families. Facets is then filtered based on their orientation to identify the major discontinuity sets. A stereogram can be produced based on the major discontinuity sets which can be useful for rock slope stability analysis. Query can be done on the stereogram with the outcrop portion being selected. This data can be very useful to check the stability of the rock slope without performing the traditional geological mapping work on the discontinuity.

RESULTS AND DISCUSSION

Stock pile mapping

PhotoScan is able to provide high accuracy polygon models and DSM which guarantees accurate area and volume measurements including length, width and height. Figure 4 below shows the photogrammetric output for stockpile data processing which is the orthophoto and DSM.

The 3D model can be utilized to compute the correct volume of stockpile at site, regardless of any kind of shape as shown in Figure 5. Aerial data and successive analysis can be simply shared to the stakeholders, permitting clients to keep track of their contracted stockpiles materials. It allows the mining engineer to keep track of their large trucks, excavators, and other assets, to ensure accountability and cost reduction in machinery. Traditional method of stockpile survey is to walk to each pile to take manual reading which requires workforce and time consuming. With drone survey, stockpile measurement is able to be completed in hours not days.

Rock slope mapping

Rock slope mapping using UAV is also very important to analyze the stability of slope after mining work in a fast manner. Figure 6 below depicted the outcome of rock slope mapping. Based on the 3D dense cloud, automatically extract planar facets using the FACET plugin in CloudCompare software as shown in Figure 7. Best

Figure 3: Flowchart of geological planes extraction in CloudCompare.

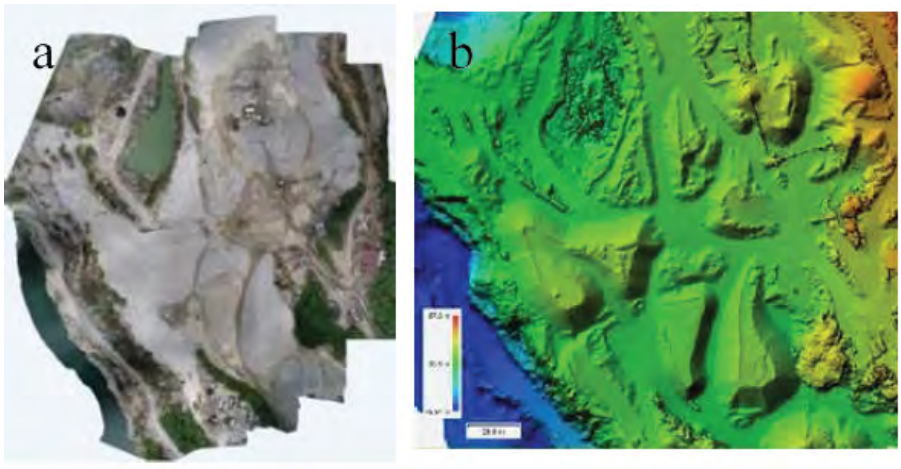

Figure 4: (a) Orthophoto (b) Digital Surface model for stockpile mapping.

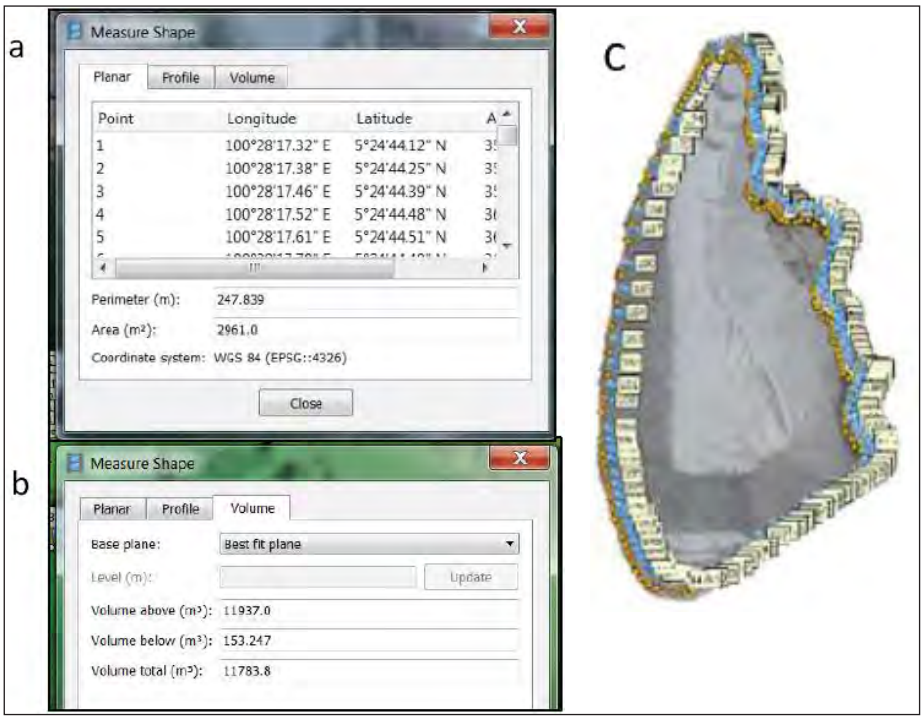

Figure 5: (a) Area and perimeter (b) Volume (c) Stockpile used for the measurement.

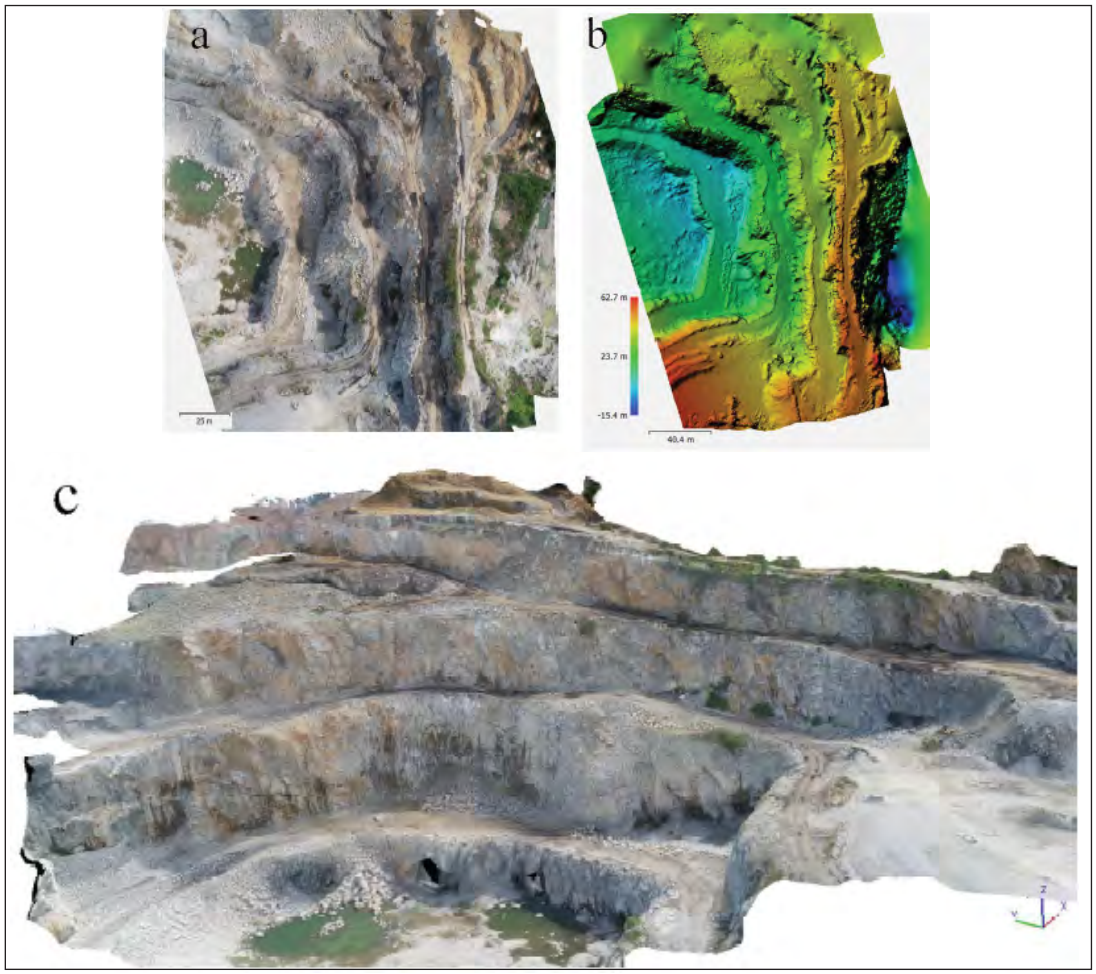

Figure 6:
(a) Orthophoto
(b) DSM
(c) 3D Model of rock slope.

features of FACETS is having the capability to discover planar objects but also 3D points with the stereogram tool.

Stereograms diagram were generated based on the major geological planes which gives out the mean value of dip/dip direction. This value is significant to assess the rock slope in the preliminary stages before using a detailed slope stability software. Further analysis can be made based on the 3D model exported from the photogrammetric process into the slope stability software which represent the real site condition. For the entire rock slope, the mean dip/dip direction is 035°/186°.

Rock quarrying area is usually prone with steep slopes, unstable rock faces and lots of heavy machinery, it can be hazardous space to work. UAV mapping ability to improve worker safety by eliminating the necessity to have men on the site and around the operating space especially near the stockpiles and equipment. Collecting ground control points (GCP) undeniably improve the accuracy of volumetric measurements. GCPs must be placed or marked permanently at the working space for repeated use. However, for this paper integration of GCP in UAV mapping is excluded. The overall accuracy of the UAV mapping without GCP implementation can be categorized as relative accuracy.

CONCLUSION

UAV is becoming very common in industry mainly civil engineering and mining. UAV photogrammetric application can be useful in quarrying work because quarries landscape is changing from time to time. Therefore, quarry site must be scanned frequently and efficiently for planning, management and reporting purposes by the quarry operation team. Output from the photogrammetric process can be used to plan operations such as the reposition the equipment and machinery, stockpile inspection and redirecting the

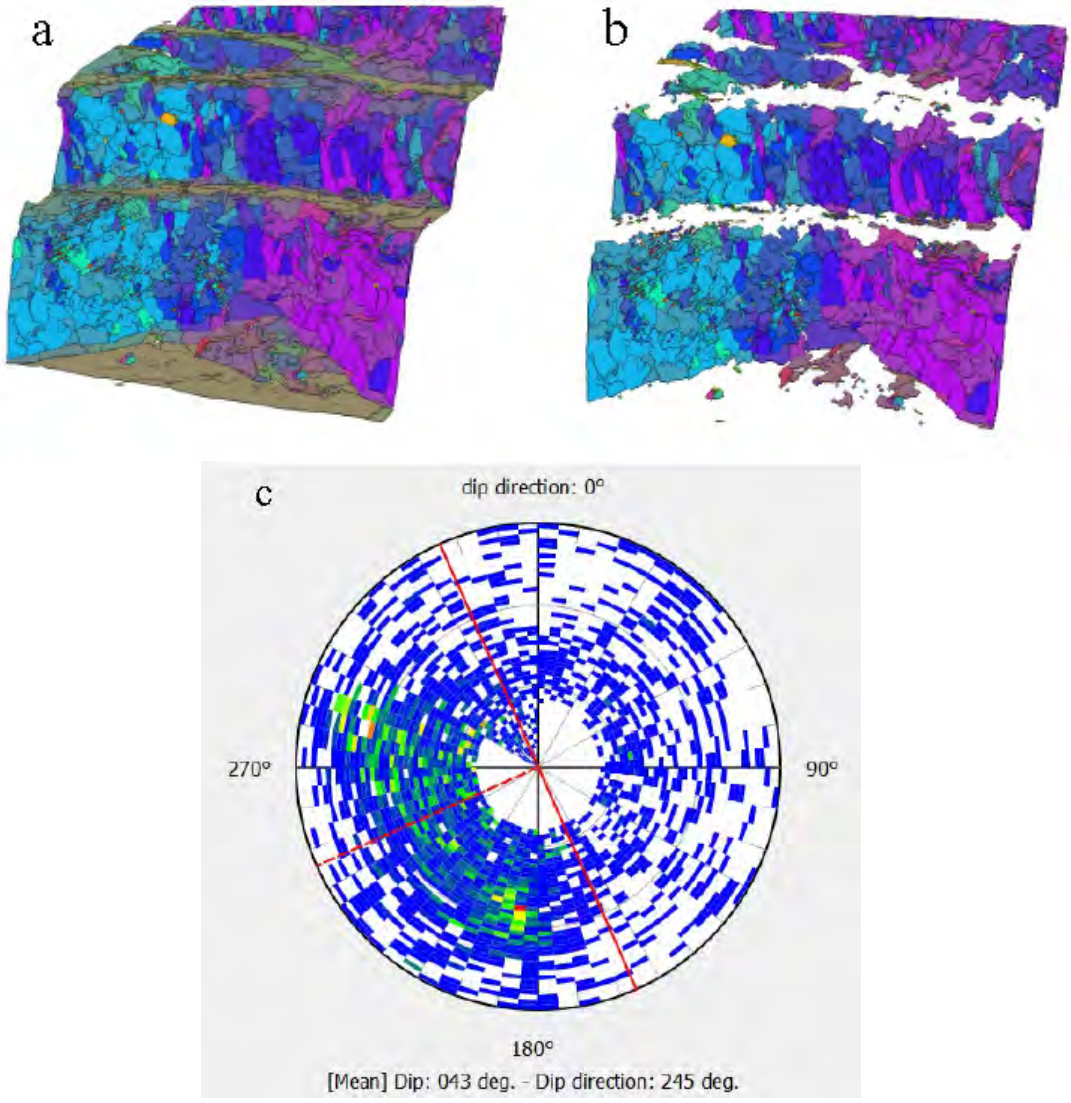

Figure 7: (a) Facets extracted (b) Filtered facet (c) Stereogram.

access roads for transferring the quarry product. The use of photogrammetric output and FACET extraction in stockpile and rock slope assessment is able to provide useful data to make preliminary decision at the working space in short period. Besides, UAV data can be very useful to give an overall view of the quarry site, projection for future changes and to identify anomaly.

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