DIGITAL SLOPE MAPPING USING UNMANNED AERIAL VEHICLE (UAV)

M.F. Ishak, M.F. Zolkepli, N. Muhammad

Abstract

This paper discusses the applications of unmanned aerial vehicle (UAV) for slope mapping and its important parameters including perimeter, area and volume of four selected areas of slope A, slope B, slope C and slope D. Modern UAV is able to capture high quality images and convert them into a natural mapping output extracted from the commercial software such as Digital Surface Model (DSM) and Digital Orthophoto. Two locations in Kuantan Pahang were selected at Sungai Lembing and Politeknik Sultan Ahmad Shah 'POLISAS' for slope mapping analysis. The main interest of this study is to measure the perimeter, area and volume of selected study areas using a commercial software. In addition, this modern method of mapping was proven to be more effective than the traditional method in terms of less cost, can generate huge data entry in a brief time, low man power and no potential risk of hazardous effect to man. In conclusion, modern technology of UAV is an efficient way of mapping for geotechnical engineering. Slope mapping help researchers and engineers to obtain slope measurement within a short period of time compared to previous traditional method.

Keywords Unmanned Aerial Vehicle (UAV), Slope Mapping, Digital Surface Model (DSM), Digital Orthophoto

Introduction

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Faculty of Civil Engineering Technology, UMP Research Series: Construction Engineering and Management, Vol. 1, [insert doi here later]

Nowadays, the instruments used for data acquisition in geological topography have been rapidly improved. With the development of modern technology, the equipment used to gather all information related to earth surfaces becomes cheaper, smaller and accurate, and expedites time of large number of data collection (Kumar et al., 2018). Unmanned aerial vehicles ('UAVs') is also known by many other names, such as unmanned aircraft system ('UAS'), remotely piloted aircraft ('RPA') and micro air vehicle ('MAV') (Beretta et al., 2018).

These devices are light, mobile, easy to manoeuvre, fully automated and provide access to most remote areas. Advances in UAV technology have enabled the acquisition of high-resolution and real-time aerial images for photogrammetry (Turner et al., 2016; Park et al., 2019). An unmanned aerial vehicle (UAV) is a normal aircraft that launches and flies without a human on board (Eid et al., 2013).

Recently, the use of UAV in research study and commercial term are widely practised by researchers (Kumar et al., 2018). According to Ismail et al. (2018), geophysical surveys in mountains and natural terrains were challenging due to the site conditions. This affected the quality of data acquisition. Unmanned aerial vehicle (UAV) or known as drone, effectively monitored a large area of land and infrastructures within a very short time interval compared to conventional techniques (Tziavou et al., 2018).

The UAV was operated remotely in the form of small platform, attached completely with camera and available as small or micro aircrafts (Tziavou et al., 2018; Zolkepli et al., 2021). The UAV photogrammetry provides an information used for image stitching. Autopilot system is able to lock the planned flight path, and the pictures triggered from auto-control camera can be captured at every waypoint (Kumar et al., 2018). A high amount of information was contained in the video signal (Kumar *et al.*, 2018).

The effectiveness of land monitoring together with existing infrastructures can be conducted within a short period of time using the UAV compared to conventional techniques, especially for urgent cases like natural disasters (Greenwood et al., 2016; Tannant et al., 2017). Together with the UAV and advance data processing technologies, this technique leads to extensive use in various fields (Scholtz et al., 2012; Colomina and Molina, 2014; Chen et al., 2016; Torok et al., 2020). Table 1 shows the disadvantages of using traditional method of mapping based on previous studies.

Table 1: Disadvantages of mapping using traditional method (Ibrahim, 2020)

Authors	Types and Disadvantages	
Fitzpatrick (2016)	Manned Aircraft (this method of mapping and volume consumes a lot of time, costly and less accurate)	
Beretta *et al*. (2018)	Laser Scanning Survey (Expensive, low quality mapping and time consuming)	

Authors	Types and Disadvantages	
Sebbane (2018)	GPS Point Survey (Inaccurate and not very dense in information)	
Siebert and Teizer (2014)	Tachymetry (Theodolite) Surveying (Time consuming, needs a lot of workers and inaccurate in results)	
Tahar *et al*. (2011); Malehmir *et al*. (2017)	Rotary Wing UAV (High cost and time consuming. Noise level is high and needs extreme magnetic field)	

The aim of this paper is to generate the slope maps from two locations within the area of Kuantan, Pahang, which are Sungai Lembing and POLISAS, using unmanned aerial vehicle (UAV) or commercially known as a drone. Further analyses of this map including measurement of each slopes, which are perimeter, area and volume, were considered another interest of this study. In addition, the advantages of slope mapping using the UAV method are compared with the traditional method to prove which method is reliable.

Research Methodology

Two locations within the area of Kuantan, Pahang (Sungai Lembing and POLISAS) were selected for this study. Both sites have different terrain profiles. The sites are completely free from any distraction and obstacle on the air for the UAV to freely move around. Figure 1 and Figure 2 show the maps of Sungai Lembing and POLISAS, respectively.

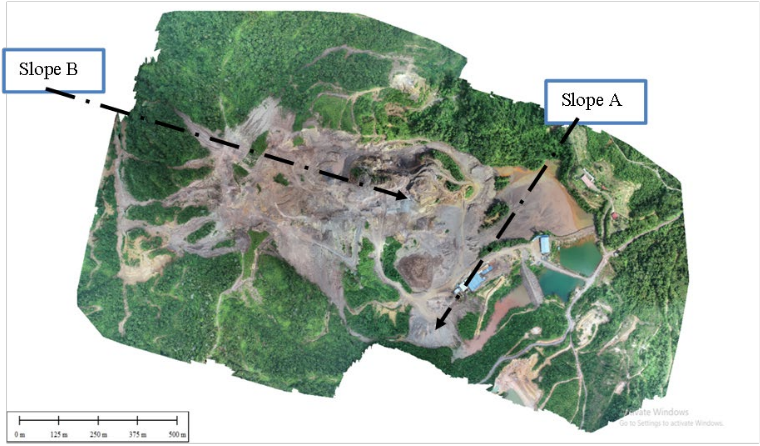


Figure 1: Sungai Lembing

Figure 1 covers a total of 1,755,000 m^2 with a total perimeter of 5,195 m. The site was located at a mine area in Sungai Lembing, Pahang. The analysis of this map involved two slopes, which were slope A and slope B. The details of both slope A and slope B will be discussed further in results and discussion sections. A total of 30 minutes is needed to map this area.

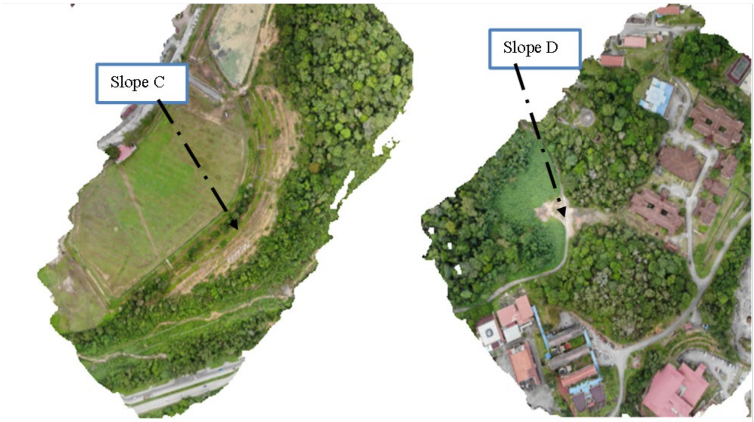


Figure 2: POLISAS, Kuantan

Figure 2 covers a total of 766,000 m^2 with a total perimeter of 3,377 m. The site was located at POLISAS, Pahang. The analysis of this map involved two slopes, which were slope C and slope D. Further details of both slope C and slope D will be discussed further in results and discussion sections. A total 20 minutes is needed to map this area.

DJI Inspire 2

The DJI Inspire 2, weighted around 3.44 kg, is a powerful and a high technology type of drone. This UAV has a speed of 94 km/h, which makes it very impressive. The maximum ascent speed was 6 m/s in sport mode and the maximum descent speed was 4 m/s. The length of this UAV was 42.7 cm, with a height of 31.7 cm and width of 42.5 cm. DJI Inspire 2 has a maximum transmission distance of 7 km and capable to deliver both 1080p and 720p videos. Figure 3 shows the image of DJI Inspire 2. Table 2 shows the specification and features of DJI Inspire 2.

Figure 3: DJI Inspire 2

UAV model DJI Inspire 2 was used in this study because this model is powerful enough to do mapping for a large area, like the one in this study. This UAV with the addition of gimbal was able to record a maximum of 4k resolution video and produced a high quality image that later can be transferred into a map.

Table 2: Specification of DJI Inspire 2

Parameters	Details
Flight time	25-27 minutes
Speed	94 km/h
Sensory range	30 m
Battery	98 Wh dual battery
Raw video recoding	Yes
Ports	USB and HDMI
Obstacle avoidance system	Yes
Control range	7 km
Video resolution	5.2K and 4K
Live View	1080P
Remote controller frequency	2.4 GHz and 5.8 GHz
Design material	Magnesium aluminium composite shell with carbon fibre arm

Image acquisition

Many researchers and practitioners used this normalised workflow for image acquisition (Zolkepli et al., 2021). Figure 4 shows the steps for image acquisition. The results obtained from the UAV monitoring were transferred into global mapper version 18.1 for further analysis.

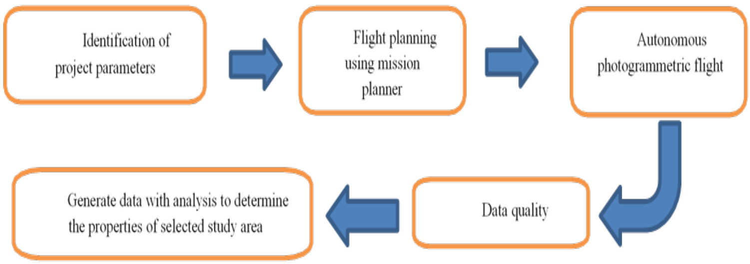
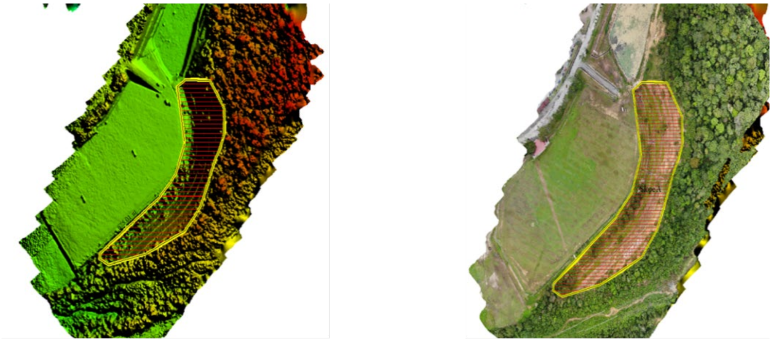


Figure 4: Workflow for data acquisition

Results and Discussion

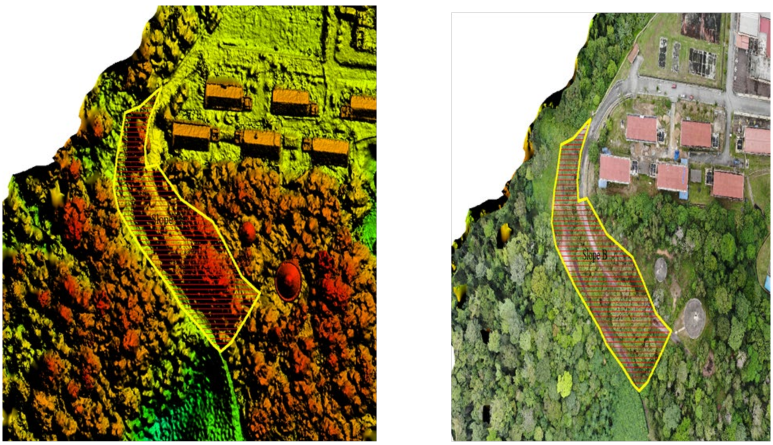
The result of this study was presented in two types of images, which were digital orthophoto and digital surface model (DSM). According to Zolkepli *et al.* (2021), both maps were important for further analyses since digital orthophoto presents the exact image of slope at study area, while DSM presents the path profiles of all slopes. Both maps are needed to analyse the elevation of marked area.

The ground control points (GCP) was absent in this study as it did not gave much errors from the results obtained. The independent orthoimages were used to generate a digital orthophoto in photogrammetric process. Figure 5, Figure 6, Figure 7 and Figure 8 show the images of slope A, B, C and D, respectively.



(a) (b)

Figure 7: (a) Digital surface model (DSM) of slope C, (b) Digital orthophoto of slope C



(a) (b)

Figure 8: (a) Digital surface model (DSM) of slope D, (b) Digital orthophoto of slope D

The application of unmanned aerial vehicle (UAV) is not only limited for area mapping, but it can also help to determine the measurement of those slope areas, such as perimeter, area and volume. The use of global mapper software version 18.1 can meet the requirement needed in order to obtain the measurement of selected study areas. The marked area for all slopes A, B, C and D are shown in Figure 9, Figure 10, Figure 11 and Figure 12, respectively. Table 3 presents the measurement of slope A, B, C and D.

Figure 9: Slope A

Figure 10: Slope B

Figure 11: Slope C

Figure 12: Slope D

Table 3: Measurement of slope A, B, C and D

Measurement	Slope A	Slope B	Slope C	Slope D
Cut Volume	14128.357 m^3	464630.89 m^3	1683.08 m^3	3443.51 m^3
Cut Area	7890 m^2	41290 m^2	1301.00 m^2	982.00 m^2
Perimeter	777.75 m	1018 m	675.44 m	366.64 m

Table 3 presents the measurement of slope A, slope B, slope C and slope D. From Table 3, slope B can be considered the largest slope compared to slope A, slope C and slope D. The cut volume of slope B was 464630.89 m^3, while the smallest was slope C with cut volume of 1683.08 m^3. The second largest slope was slope A with total cut volume of 14128.357 m^3, followed by slope C with cut volume of 1683.08 m^3. The cut area of slope B was also the largest with a total of 41290 m^2, while the smallest was slope D with cut area of 982.00 m^2. The total perimeter of slope B was 1018 m, while the smallest perimeter was slope D with 366.64 m.

Table 4 shows the comparison of slope mapping between Unmanned Aerial Vehicle (UAV) and traditional method. First comparison was in terms of area scale, where the unmanned aerial vehicle (UAV) acts as an aerial photogrammetric technique that effectively generates a medium to extra-large scale mapping. The traditional method is effectively applied for small area that has limited budget and time.

The UAV method allows surveyors to map in a short period of time and requires minimum labour, which proven to be better method of mapping compared to those methods suggested by Fitzpatrick (2016), which was using manned aircraft; Siebert and Teizer (2014), which was using tachymetry (theodolite) surveying techniques and Tahar et al. (2018); Malehmir et al. (2017), which was using a rotary wing UAVs survey. They stated that this traditional method was time consuming and required more labours.

This UAV technique is one of the alternatives for a faster, easy and safe way in data acquisition. According to Beretta et al. (2018), Sebbane (2018) and Siebert and Teizer (2014) that were using laser scanning; GPS point survey; tachymetry (theodolite) surveying techniques that have described that those methods were consuming lot of times and much more complicated for data acquisition and processing, was also unsafe for workers due to the challenging site topography.

UAV-acquired datasets have better resolutions in both temporal and spatial aspects with high quality, cheaper and impressive level of details in the outputs, while the method that uses a laser scanning survey was expensive, generates low-quality products and unimpressive level of details in the outputs (Beretta et al., 2018).

Table 4: Comparison of slope mapping using UAV and traditional method

Comparison	Unmanned Aerial Vehicle (UAV) Method	Traditional Method
Area	Medium to extra large	Small
Time consuming	Short	Long
Usability	Easy	Much Complex
Data quality	High	Low
Cost	Cheap	Expensive
Worker	Minimum (one is more than enough)	Maximum (depend on site)
Potential hazard to man	Safe	Unsafe (especially in high and hilly region)
Data acquisition	Fast	Slow

Conclusion

From this study, the uses of UAV have been proven to effectively reduce the cost, consume less time, easy to operate and can gather large amount of data within a short time interval for slope mapping. This modern technology will help in research and also commercial works, making work easier and faster. In this study, the combination of data from UAV and established software can provide researcher with important parameters and information about topography of study area. Other than that, the measurements of the study area such as its perimeter, area and volume can be obtained precisely. Mapping using UAV proves to provide modern solution when compared with mapping using the traditional method.

The map of Sungai Lembing and POLISAS were generated based on the images captured by the UAV, which fulfilled the first objectives. Both maps were in digital orthophoto, which presented the actual image at study area, and digital surface model (DSM), which presented the path profiles and elevation of study area. These map can be analysed further for obtaining the measurement of all slopes (A, B, C and D) within the study areas, which answered the second objective of this study.

Last objective was to compare between mapping using UAV and traditional method. Overall, mapping using UAV proves to be more effective compared to traditional method of mapping, since the mapping using UAV can cover large area, less time consuming, easy to manoeuvre, produce high quality data using the gimbal that was able to capture a 4k resolution images, less operating cost (enough to be done by single manpower), zero hazard or danger for a person manoeuvring the UAV, and less time for generating data acquisition.

Acknowledgement

The authors fully acknowledged Faculty of Civil Engineering Technology, Universiti Malaysia Pahang for the approved fund

(RDU1903144), which makes this important research viable and effective.

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