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ORIGINAL ARTICLE

The Implementation of Unmanned Aerial Vehicle (UAV) for Slope Mapping

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ABSTRACT – This paper discusses the applications of unmanned aerial vehicle (UAV) for slope mapping and its important parameters including perimeter, area and volume of certain selected areas at Perumahan Taman Gambang Damai in Kuantan Pahang. Previous work of slope mapping using traditional survey equipment considered as time consuming and very challenging especially in hilly regions. This study also focused on determining the potential slope hazard based on slope angle. Modern UAV able to take high quality image which essential for the effectiveness and nature of normal mapping output such as Digital Elevation Model (DEM) and Digital Orthophoto. These photos captured by the UAV will later exported to Agisoft to generate full map of study area. With the help of Global Mapper, the measurement such as perimeter, area and volume of selected study areas can be determined easily and considered as the main interest in this study. In addition, another outcome of this study is, this modern method of mapping helps researchers and engineers to study the possibility of slope hazard based on their respective slope angle. In conclusion, modern technology of UAV proves to be very effective for mapping in geotechnical engineering. Slope mapping using multi-rotor UAV help researchers and engineers to obtain slope measurement within short period of time compared to previous traditional method.

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INTRODUCTION

A slope is defined as a surface which one end or side is at higher level than another neither a rising nor falling surface [1]. According to Ishak *et al*. [1], one event took place at Hidayah Madrasah Al-Taqwa orphanage at km 14 Jalan Hulu Langat, Selangor. This tragedy occurred during a long spell of daily torrential rainfall event which suddenly triggered the landslide, wrecked the houses and killing 16 orphans. Further investigation of the surrounding area revealed that cutting down trees at the toe of a slope lead to this disaster [2].

The technologies used to collect data related to terrain profiles have developed rapidly in recent years [3]. Technology used to acquire all information about the earth's surface has gotten more accurate, smaller, and more cost-effective with the advancement of modern technology [4], [5], [6]. Airborne also classified as one of UAV. It works remotely in a small platform that is mounted to the camera and is available as a small or micro aircraft [7]. The advantages of this photography technology over conventional in-person surveys is it reduced time for detailed data collection [8]. A digital orthophoto by UAV is an image obtained by vertical parallel projection of a surface, and has the geometric accuracy of a map and visual characteristics of an image [9]. For geomorphological applications, digital elevation model (DEM) is important as spatial information tools containing the elevation profile of terrain. This is owing to DEM's ability to extract the most prominent features (slope, aspect, profile curvature, and flow direction) [7]. Therefore, UAV helps to speed up and facilitate the work of data collection if compared with the other data collection methods such as traditional in-situ surveying, topography mapping and remote sensing.

As suggested by [10], Zolkepli *et al*. [11], Zolkepli *et al*. [12] and Bar *et al*. [13], by using UAVs, geotechnical engineers and researchers may interact more quickly and safely since they can see the possible failure of the slope, critical slope, and slope hazard. UAV technology has made it possible to acquire high-resolution and real-time aerial photographs for photogrammetry in order to determine the potential slope hazard location [14]. Additionally, human activities such as slope excavation, construction activities, deforestation, or other land use are considered true causes of slope failures or landslides [15].

Therefore, the aim of this paper is to obtain the digital orthophoto and DEM of several selected slope area located at Perumahan Taman Gambang Damai, Kuantan by utilizing UAV or commercially known as drone. This work determining potential slope hazard were based on finding possible dangerous area according to their respective slope angle.

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Traditional Mapping

The advancements in surveying technology have enhanced the methods for obtaining the elevation of the land surface: from ground surveying with theodolites and Total Stations to aerial surveying [16] . Indeed, this procedure is a complex process that requires highly competent and patient surveyors. According to Lehmann *et al*. [17], several researchers have looked into the subject of low-cost surveying works and slope mapping using satellite photos. In contrast to satellite photos which require a set amount of time to gather photographs in the same area, UAVs can roam in the same area for an endless amount of time in a single day [18].

Technology of Unmanned Aerial Vehicle (UAV)

Modern technology has made the earth surface data collection equipment cheaper, smaller, and more accurate. The cost needed to operate a UAV is lower than working man surveyors [17]. This equipment are light, mobile, efficient to use, completely automated, and can access almost inaccessible study areas [19]. According to Giordan *et al*. [20], UAV developments have improved high-resolution real-time aerial photogrammetry. Geophysical surveys in mountains and natural terrains are normally challenging due to the site conditions, which may affect the quality of data acquisition. Using UAVs offers for faster surveillance of large areas of land and infrastructures than conventional methods [21].

RESEARCH METHODOLOGY

Study Area

The study area is at Perumahan Taman Gambang Damai in Kuantan Pahang. This site was located about 11 km from Universiti Malaysia Pahang. The site area has a variety of topographical features. Unobstructed airspace allows the UAV to fly freely around this location. This site was chosen as it was free from predators such as hawks and eagles. Figure 1(a) shows the study area.

Data Acquire & Data Processing

DJI Phantom 4 Pro weighs around 1.38 kg is the most iconic drone design with the Phantom quadcopter line and high technology drone (Peppa *et al*., [25]). This UAV has a 72 km/h speed, making it pretty impressive. The max ascent speed is 6 m/s in sport mode, and the max descent speed is 4 m/s. DJI Phantom 4 Pro camera is equipped with a 1-inch 20-megapixel sensor capable of shooting 4K/60fps video and Burst Mode stills at 14 fps [26]. Figure 1(b) show DJI Phantom 4 Pro that was utilized in this research.

(a)

(b)

Figure 1: (a) Study area (Google Maps), (b) DJI Phantom 4 Pro

UAV data is imported into Agisoft Metashape Pro to generate a digital orthophoto and DEM. Also, Global Mapper version 18.1 was used to determine the perimeter, area, and volume of the selected slopes. Commercial software also aids in obtaining a cross-section of the designated research region to visualize each slope's topographical profile. Also, commercial software can evaluate the potential slope hazard to know which area has a high risk of potential slope failure. The ground control points (GCP) is explicitly insignificant to be used in this study as it does not give much error for the results obtained.

The normal workflow accepted for image acquisition has been used by many researchers and practitioners. Following are the steps for image acquisition as in Figure 3. For these slope mapping, the average altitude used is 300 m from sea level which are set earlier before flight planning. The resolution used for these mapping is 4k (2160p). The datum used in this study is WGS84 (Projection UTM, Zone 48 (102º E – 108º E- Northern Hemisphere).

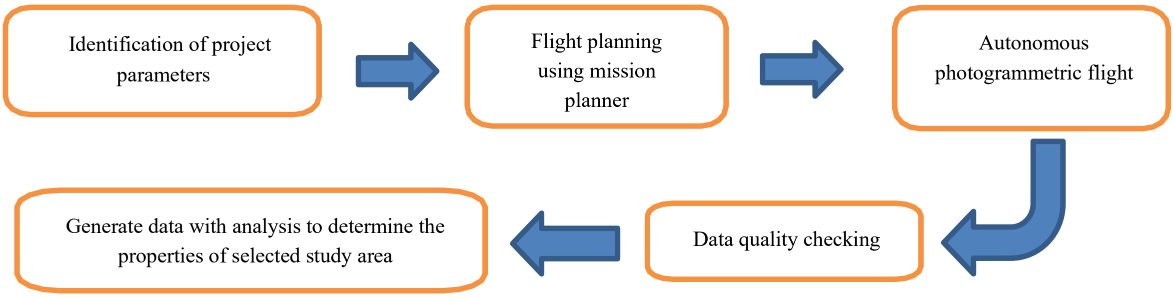


Figure 3: Workflow for data acquisition [12], [13]

Field Work and the Flight Mission

Using UAV to retrieval slopes images is an important step that must be performed. Before aerial pictures can be taken, flight planning must be performed. During flight planning, some factors must be considered, such as flying height, area coverage, focus length, scale, and coordinates. The weather and the time obtained from aerial pictures of the research region, which might alter the brightness of the images, play an essential role in the collection of the real site images. The best period to take aerial pictures of the research region was between 3 to 6 pm to maximize the image quality of pictures taken. With the considerations of all factors, the pictures were captured with very good quality for photogrammetric processing. Figure 4 present the flight path for slope A and slope B.

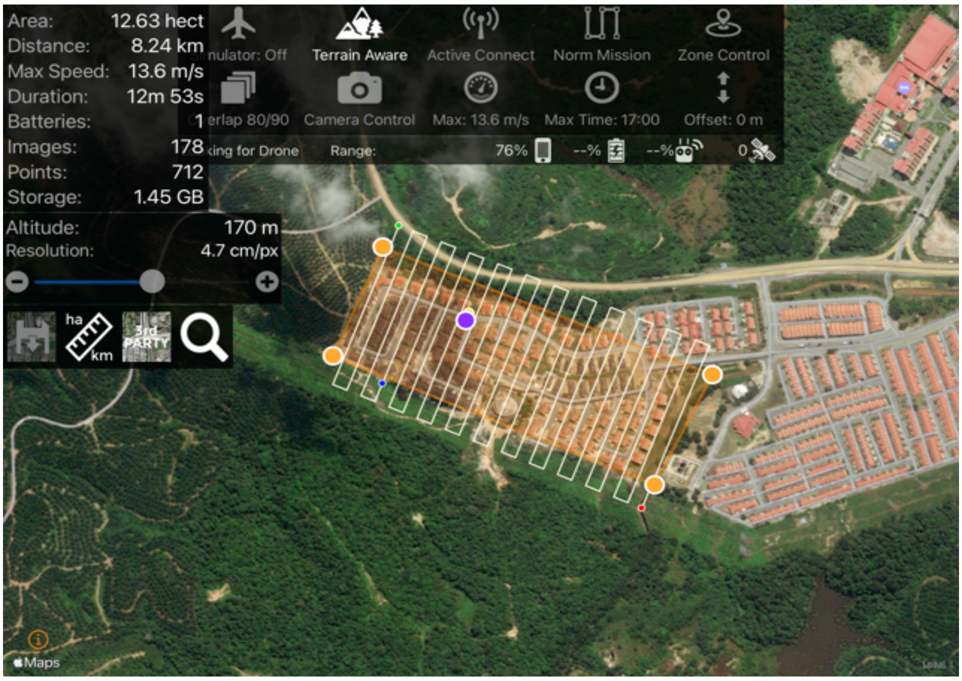


Figure 4: Flight path for slope A and slope B

Agisoft Metashape

Agisoft Metashape is a standalone application that provides photogrammetric processing on digital photos and creates 3D spatial data for usage in GIS applications, heritage and culture documentation, visual effects development, and indirect measurements of objects of various dimensions**.** Agisoft Metashape is a cutting-edge software solution, featuring a core engine that pushes photogrammetry to a greater level. Images from multispectral cameras, including multi-camera systems, can be processed into high-value spatial information in the form of dense point clouds, textured polygonal models, orthomosaics, and DSMs/DEMs. Further post-processing allows you to remove shadows and texture from the models, generate vegetation indices and extract data for farming equipment action maps, and classify dense point clouds automatically.

Global Mapper

The software that was used in the study was Global Mapper version 18.1, which is a multi-dimensional digital elevation model software. This version was used to generate digital slope dimensions for the selected slope areas. Global Mapper 18.1 is a great development effort that features good design and configuration, as well as good layer management. It also has several functional upgrades that are focused on 3D data processing. The 3D display is a dynamically rendered version of all the data loaded in an object. It displays the data in a uniform and detailed manner. The dynamic presentation process allows you to create stunning 3D maps and data sets with minimal effort. It simplifies the work of developers by allowing them to easily generate high-resolution maps and data sets with minimal effort. In 3D Views, the latest display engine has added support for multi-surface viewing. This feature allows planes to be positioned on various surfaces while viewing from a lower perspective.

RESULTS AND DISCUSSIONS

Digital Orthophoto

In this study, slope A and slope B were selected for further analyses since both slopes were already failed due to heavy rainfall. These slopes were presented in both digital orthophoto and DEM. Figure 5 shows the image of the area study presented in digital orthophoto by using UAV.

Figure 5: Digital orthophoto by Unmanned Aerial Vehicle (UAV)

Digital Orthophoto and Digital Elevation Model (DEM)

Slope A and slope B, were presented in both digital orthophoto and DEM that are required for further analyses. Figure 6 present the digital orthophoto and DEM for slope A and slope B.

The application of UAV is not only for mapping, but also measure the volume, area and perimeter of the slopes. The measurement profile of slope A and slope B are summarized in Table 1. From Table 1, the total volume of slope A is 1382.94 m^3 while the total volume for slope B is 1469.17 m^3. Next the cut volume for slope A is 264.99 m^3 and the cut volume for slope B is 669.54 m^3. The cut area of slope A is 385.24 m^2 and the cut area of slope B is 303.28 m^2. The fill volume of slope A is 1117.95 m^3 and for slope B is 799.63 m^3. whereas its fill area for slope A is 1243.60 m^2 and fill area for slope B is 460.99 m^2. Besides, the perimeter of slope A is 162.28 m and for slope B is 159.45 m. In conclusion, slope B was bigger compare to slope A based on the total volume for both slopes.

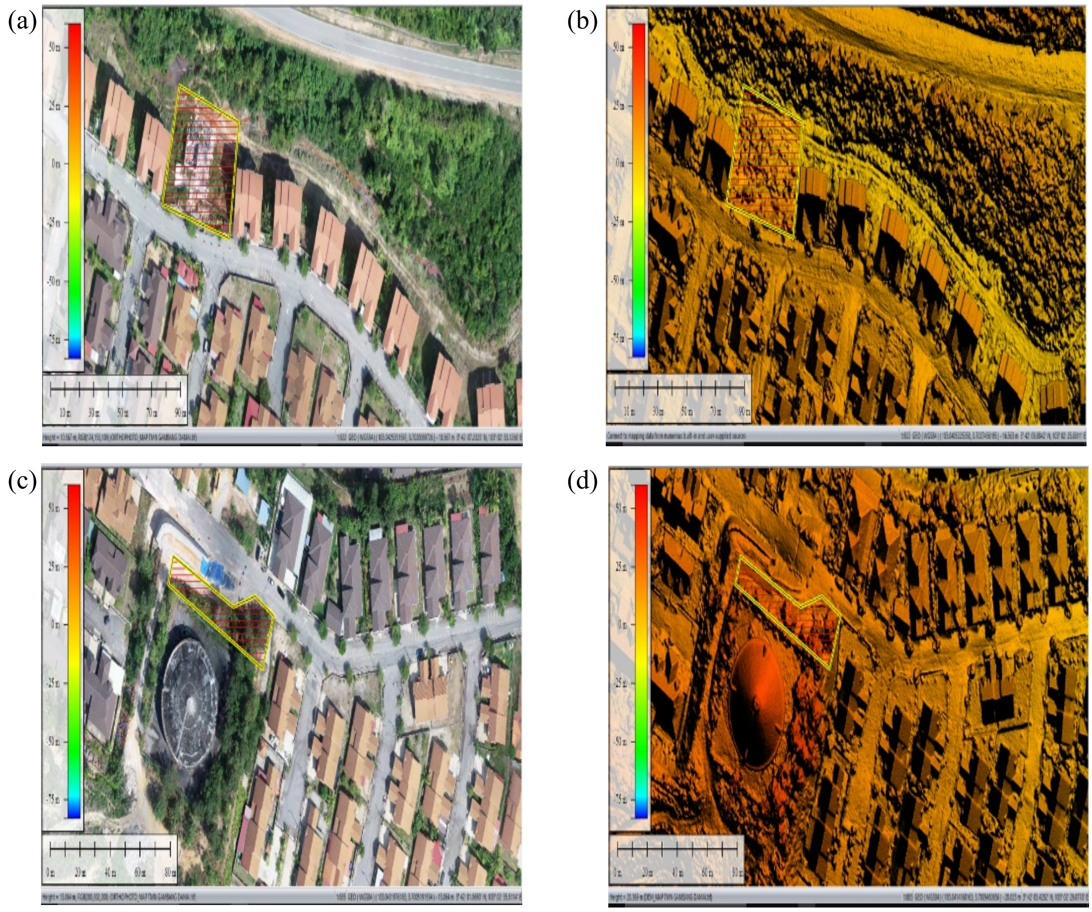


Figure 6: (a) Digital orthophoto, slope A, (b) DEM, slope A, (c) Digital orthophoto, Slope B, (d) DEM, slope B

Table 1: Summary of slope measurement for slope A and slope B

Measurement	Slope A	Slope B
Total Volume	1382.94 m³	1469.17 m³
Cut Volume	264.99 m³	669.54 m³
Cut Area	385.24 m²	303.28 m²
Cut Area 3D	543.41 m²	584.61 m²
Fill Volume	1117.95 m³	799.63 m³
Fill Area	1243.60 m²	460.99 m²
Fill Area 3D	1441.10 m²	714.60 m²
Enclosed Area	1634.30 m²	766.86 m²
Perimeter	162.28 m	159.45 m

Potential Risks of Slope Hazard

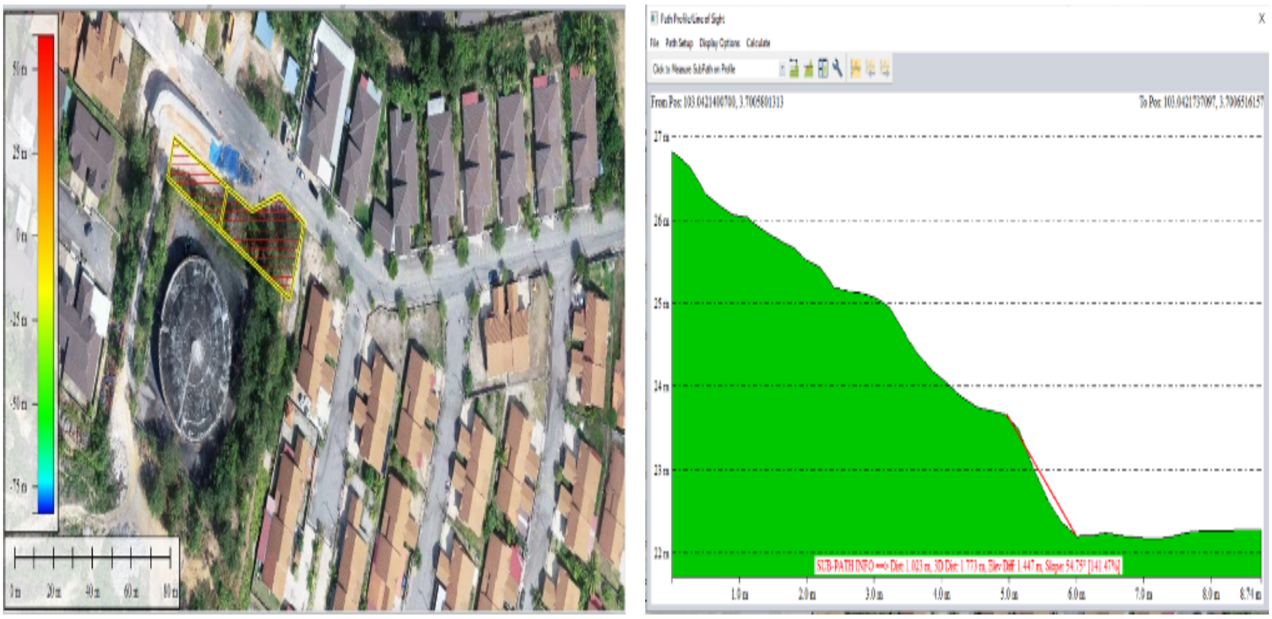
The determination of slope angle was very important before constructing a building. By identifying the hazard of the slope, the slope angle needs to be considered because it may contribute slope hazard to occur. As indicated by [27], the slope classes are shown in the Table 2 respectively. Figure 7 present the potential slope hazard for slope A.

Table 2: Summary tablefor classes of slope

Researcher	Classes of slope	Angle of slope	Condition of slope
Galloway and Zachery (2020)	A	0.2	Nearly level
	B	2-6	Gently sloping
	C	6-12	Moderately sloping
	D	12-18	Strongly sloping
	E	18-25	Moderately steep
	F	25-35	Steep
	G	35-100	Very steep

Figure 7: Potential slope hazard for slope A

The selected vertices were located between the coordinates of (103.0414991709, 3.7020320122) and (103.0415429983, 3.7021317573). The highest point of the selected vertex 2.57 m and the lowest point of the selected vertex is 2.04 m. The horizontal distance between these two vertices is 0.473m. The slope angle between these two vertices is 47.35°. Based on Table 2, the selected slope is in the category of Class G which is very steep. Thus, it can be classified as a potential slope hazard. Figure 8 present the potential slope hazard for slope B.



(a) (b)

Figure 8: Potential slope hazard for slope B

Figure 8(b) shows the path profile of the cross-section of Slope B. The selected vertices were located between the coordinates of (103.0421400700, 3.7005801313) and (103.0421737097, 3.7006516157). The highest point of the selected vertex is 23.655m, and the lowest point of the selected vertex is 22.23m. The horizontal distance between these two vertices is 1.023m. The slope angle between these two vertices is 54.75°. Based on Table 3, the selected slope is in Class G, which is very steep. Thus, it can be classified as a potential slope hazard.

Table 3: Classes of slope

Slope	Horizontal Distance (m)	Slope Angle (⁰)	Category	Classification
A	0.473	47.35	G	Very steep
B	1.023	54.75	G	Very steep

From Table 3, slope angle for Slope A is 47.35° and Slope B is 54.75°. Based on Table 3 classes of slope, since the angle of slope is above 35°, so, the both slopes can be considered as very steep slope (class G, > 35°-100°) and classified as the slope hazard.

CONCLUSION

From this study, the uses of UAV have proven to be very effective such as low costing, low time consuming, easily to operate and can gather huge amount of data within short time interval for slope mapping. This modern technology will help in research and also commercial works which make work easier and faster. In this study, with the combination of data from UAV and also established software provide researchers with important parameters and information about topography of study area. Other than that, the measurements of the study area such as its perimeter, area, volume and more can be obtain precisely. From Table 1, it can be concluded that slope B was larger compare to slope A based on the total volume for both slopes.

Besides, the use of UAV can further extend by determining the potential risks of slope hazard based on slope angle. As suggested by Galloway and Zachery (2020), there are seven (7) classes of slope angle with their respective classes and condition. The angle of slope A was 47.35° while the angle for slope B was 54.75°. Both slope A and slope B can be considered as very steep slope with slope angle between 35° to 100°.

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