Visual Slope Inspection using Unmanned Aerial Vehicle (UAV)

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Abstract. Nowadays the natural slope cuts for the purpose of the construction of public transport is ubiquitous in Malaysia. These cuts cause the changes of the natural slope structure thus make the slope structure become unstable and causes to rubble. In order to avoid the slope’s failure, the monitoring work on slope should be carried out by the responsible party to ensure that the slopes are in good condition and the advance warning can be issued before the occurrence of the rubble. Conventional method of slope monitoring is extremely high risk. Usually, maintenance personnel will climb up to the top of the slope to take pictures for the purpose of monitoring reports [1]. Slope monitoring activities are also limited as climbing steep slope structures require a lot of energy and takes quite a while. Therefore, this research aims to explore the ability of the micro UAV aircraft usage in order to monitor the slope condition. The aim of study is to monitor the high risk slope using UAV. To achieve the aim, the following objectives are formulated by produce orthomosaic image, Digital Terrain Model (DTM) and Digital Surface Model (DSM) using pix4d mapper software, analysis the image of drainage system taken by UAV and developed contour of the slopes and analyse watershed of the slope using global mapper software. In this paper, the drainage on the slope becomes the focus since its plays an important role as it reduces the existence of groundwater and to transport the rainwater pours on slope surface. The study was conducted at two places where first at Kuala Pilah Federal Route 361 and second at Jalan Bangi Selangor State Route B17. The processes involved were planning and preparation before flight, data retrieval using UAV aircraft, image processing using Pix4dmapper software and assessment of the slope using Global Mapper software. Subsequently, the slope condition can be determine based on the monitoring of the slope drainage. Through this study, the condition of slope surface can be seen by images taken from UAV such as cracking on slope structure and excessive vegetation growth in slope drainage. Besides that, the slope inclination, height and water flows on surface can be known. Therefore, the usage of UAV aircraft for slope monitoring and inspection was successfully and the aims of this paper was achieved since the device shows a very good tendency and the ability to monitor the slope condition.

1. Introduction

In Malaysia, there are many man-made slopes where the slope is cut for the construction of infrastructure and the construction of man-made slopes if not carefully monitored will result in landslide occurred. Slope failure typically exists when there is heavy rain where it will decrease soil shear strength as well as increase the stress in the ground as the result of its water conditions in the soil...
This issue can have a great impact on the surrounding such as safety of life and property and public morals issues. In this study, the slope drainage will be focus. Slope drainage is important in maintaining slope stability. The present of groundwater in slopes is never good as it destabilizes the slope by adding weight, destroying cohesion between grains, and reducing friction. When water takes the place of air between the grains of soil, it will most likely increase the probability of downslope mass movement and lead to slope failures as the earth in slopes become a lot heavier [3].

In conventional monitoring method, a professional surveyors is require to conduct the survey in the study area and it is not practical for large areas because it would involve a lot of labor, a huge cost and time to complete the investigation work [4]. This study will carried out to facilitate the work of examination slope surface structure by using a micro UAV technology. This method is an alternative for acquiring the image and video quality for the inspection and monitoring of the slope. It also can reduce the risk of slope safety inspectors to conduct inspections in addition to saving energy and working time.

2. Literature review
Unmanned Aerial Vehicle (UAV) is a small, unmanned aircraft programmed for more dynamic flights. In Malaysia, the use of the UAV over the last two decades is aimed at national defence, mapping, monitoring coastal areas and air traffic and remote sensing [5]. The UAV also comes with a camera that offers the possibility to map areas faster and more flexibility than classic aerial photos [6]. Now the use of UAV has been further developed in the field of civil engineering. The UAV became popular for large scale use in low budget mapping [7]. In conclusion, this UAV is a small plane with high resolution cameras combined with a very light platform as one of the data acquisition systems to capture digital images from the air [8].

In this study, the UAV micro aircraft used is DJI Phantom 3 Advance. The UAV is used to retrieve information and slope data visually. The UAV is powered by Sony's 1 / 2.3-inch camera sensor, with a 12-megapixel image resolution allowing for clearer shooting. The aircraft is taken with a failsafe system where the aircraft will return to its original position by itself and immediately land before it runs out of power. It is controlled by a remote-connected remote controller on the plane using Wi-Fi connected to the smartphone that has been installed DJI Phantom 3 Advance software.

In obtaining the data, Pix4Dcapture is an application that turns consumer drone into a professional drone mapping tool. A free companion to Pix4D photogrammetry software, Pix4Dcapture is the perfect tool to automatically capture image data for optimal 3D models and maps. After that, all the data will be processed by using Pix4Dmapper and Global Mapper. Pix4Dmapper is the software that naturally forms the pictures that were taken from the air using Unmanned Aerial Vehicle (UAV) micro aircraft or by using digital camera from the ground. It utilizes technology that takes a shot at the guideline of perceiving the picture content (pixels) so as to make a total 3D model of the subject [9]

Global Mapper is a viewer capable of displaying the Geographic Information System (GIS) raster, elevation, and vector datasets, allowing users to easily view, edit and export their data in multiple formats. The all-in-one GIS application that friendly use. This remarkable software combines a powerful array of spatial data processing tools with an unmatched list of compatible file formats resulting in a program that no GIS professional or map [10].

3. Methodology
The methodology study explains how objective is achieved and the scope of the study that has been described based on the methods used throughout the study. Methodology also helps research find out more clearly what is needed and what needs to be done in order to make sure that a survey is
conducted through the selection of a particular method. The methodology includes four fundamental stages including flight arranging, UAV preparation, and data collection.

3.1 Flight planning
In the planning stage of the flight, the planning must be done first before aviation activities take place. This is to facilitate data retrieval work and to ensure that research works well as well as obtaining accurate information. Some parameters need to be explained during the flight planning stage.

The flight planning be done by determine the pattern of the fly. In this study, grid mission is used as a pattern to capture the image for both slopes. The mission is run by using Pix4Dcapture that have to be install in smartphone. This application will help the flights are run smoothly. The figure 1 show the same pattern of flight which is grid for both slopes at different places. The height of flight need to be set before start the flight mission. The UAV flown from height of 60 metre for slope at Jalan Kuala Pilah and 50 metre for slope at Jalan Bangi. The height is different because of the height of slopes are different.

The grid size is set for slope at Jalan Kuala Pilah is 4000cmx3000cm and 5472cmx3648cm for slope at Jalan Bangi. By using this application, the UAV will flies with consistent speed that is 4m/s for both mission. As a whole, the UAV controlled automatically by Pix4dcapture application. The most important during flight mission is ensure that the Global Positioning System (GPS) of UAV are connected with the smartphone through Pix4dcapture application.

![Figure 1. Images of slope with grid mission flight using Pix4Dcapture at location (a) Jalan Kuala Pilah and (b) Jalan Bangi](image)

3.2 UAV Preparation
A few things should be checked before flight mission, for example, usefulness of self-sufficient chipset, radio modem, camera mount to hold computerized camera, intensity of battery, electronic speed controller and global situating system. At that point, the operator needs to check the movement sensor of the UAV, for example, lift, rudder and throttle before propelling it. The equipment used is a set of DJI Phantom 3 Advance model aircraft equipped with a smartphone with a built-in application of this special UAV aircraft.

3.3 Data Collection
To obtain the data, only one person can operate the remote control UAVs. The UAV will be flown around the slopes to be used as a study site. When UAV flights are carried out, the altitude of the UAV distance from the slope surface and its speed should be maintained so that the picture can be taken clearly and have greater quality. The image will automatically take by using Pix4dcapture application that installed in smartphone. The height of drone flight will be set in this application. Figure 2 show
the image of slope via UAV at slope in Jalan Kuala Pilah at height 60 metre where in Jalan Bangi, UAV flies with height 50 metre.

![Image](image_url)

**Figure 2.** The slope at (a) Jalan Kuala Pilah at a height of 60 metre and (b) is slope at Jalan Bangi at a height of 50 metre

### 3.4 Image Processing by Pix4Dmapper

Visual analysis of slopes is done with processing of image by using Pix4Dmapper. Pix4Dmapper will produce orthomosaic photo, Digital Terrain model and Digital Surface model. All these are used to generate contour and watershed analysis. This software is based on automatically finding thousands of common points between images. Each characteristic point found in an image is called a key point. When 2 key points on 2 different images are found to be the same, they are matched key points. Each group of correctly matched key points will generate one 3D point.

### 4.0 Result and Discussions

The Image of both slope processed using the Pix4Dmapper software to produce Orthomosaic Photo, Digital Terrain Model (DTM) and Digital Surface Model (DSM). Once image processing is completed, files will be exported to Global Mapper Software for analysis. By using this software, it allows the user to perform a watershed analysis on loaded terrain data to find stream paths as well as delineate the watershed areas that drain into a given stream section. Additionally, the contour can also be identified through this software.

#### 4.1 Image Processing using Pix4Dmapper

Image of both slopes taken via UAV by using the Pix4Dcapture application installed in the smartphone will be processed using the Pix4Dmapper software to produce Orthomosaic Photo, Digital Terrain Model (DTM) and Digital Surface Model (DSM). Pix4Dmapper will combine all the photo taken by UAV for both slopes. There are 40 images of slope at Jalan Kuala Pilah and 73 images of slope at Jalan Bangi. This can be seen in figure 3.

An orthomosaic photo is an aerial photograph geometrically where the scale is uniform and the photo has the same lack of distortion as a map. Unlike an uncorrected aerial photograph, an orthomosaic phoyo can be used to measure true distances, because it is an accurate representation of the Earth’s surface, having been adjusted for topographic relief, lens distortion, and camera tilt [11].

Prior to generating the orthomosaic Pix4D generates a 3D point cloud. The point cloud generated by the 40 images for slope at Jalan Kuala Pilah and 73 images for slope at Jalan Bangi. The point cloud can be edited to remove any spurious points. The point cloud looks quite pixelated, so there is an option in Pix4D to view a 3D mesh instead. The 3D mesh is a 3D model where all the dots of the point cloud are connected in order to create a surface.

A digital terrain model (DTM) can be described as a three – dimensional representation of a terrain surface consisting of X, Y, Z coordinates stored in digital form. It includes not only heights and
elevations but other geographical elements and natural features such as rivers, ridge lines, etc. [12]. This process is done by using Pix4Dmapper as shown in figure 4.

![Orthomosaic of slope at Jalan Kuala Pilah](image1)
![Orthomosaic of slope at Jalan Bangi](image2)

![3D mesh view of slope at Jalan Kuala Pilah](image3)
![3D mesh view of slope at Jalan Bangi](image4)

**Figure 3.** The orthomosaic and point cloud with 3D mesh view photo processed by Pix4Dmapper for both slope

![DTM of Slope at Jalan Kuala Pilah](image5)
![DTM of Slope at Jalan Bangi](image6)

**Figure 4.** The digital terrain model for both slope generated using Pix4Dmapper

The final process in Pix4Dmapper is digital surface model (DSM). DSM generated using the 40 overlapping overhead images for slope at Jalan Kuala Pilah and 73 overlapping overhead images for slope at Jalan Bangi. The colours represent the different heights. The slope and the flat surface of the ground can be easily identified. Different from DTM, DSM show all the vegetation, road and other surface. Figure 5 shows that the blue colour represents the lowest height and almost red-orange colour represent the highest height.
4.2 Slope Analysis Using Global Mapper Software

In this study, perform a watershed analysis on loaded terrain data to find stream paths as well as delineate the watershed areas that drain into a given stream section and to check the conditions of the drainage system of the slopes whether the drainage can drain the water into the mainstream. Figure 6 shows the result of watershed analysis for both slopes. It can clearly see the stream network as well as the drainage areas for each stream segment.

The most common method of representing the topography of a particular area is to use contour lines. A contour is an imaginary line that connects points of equal elevation. Global Mapper can easily
obtain geographic information from different sources, in a simple way. To create contour lines anywhere in the world, it must first review the metadata. In this study, data DTM generated from Pix4Dmapper is used. Contour interval is the vertical distance between contour lines. In this study, both slope is generated contour with interval of 2 metre. The contour generated by Global Mapper software can determine the height of the monitored slope. Additionally, contraceptives can determine the highest area in the area studied. Based on the resulting contours, the height of the slope at Jalan Kuala Pilah is 16 metre and Jalan Bangi is 17 metre. Table 1 shows the contour line and cross section that generated from Global Mapper Software whereby the calculation as shown in figure 7.

Table 1. The contour and the cross section for both slope

| Line | Slope | Height | Slope Distance |
|------|-------|--------|----------------|
| 1 | Jalan Kuala Pilah | 15m | 21.2m |
| 2 | Jalan Kuala Pilah | 16.25m | 23.4m |
| 3 | Jalan Kuala Pilah | 14.5m | 19.5m |
| 1 | Jalan Bangi | 16m | 28.8m |
| 2 | Jalan Bangi | 18m | 31.1m |
| 3 | Jalan Bangi | 14m | 29.5m |
Calculation of Determine Percentage Different height between Contour Map and Cross Section

i. Slope at Jalan Kuala Pilah
   - Height of slope from contour = 16 metre
   - Highest height of slope from cross section = 16.25 metre
   - Different height (%) = \( \frac{(16.25-16)}{(16.25+16)/2} \times 100 = 0.39\% \)

ii. Slope at Jalan Bangi
   - Height of slope from contour = 17 metre
   - Highest height of slope from cross section = 18 metre
   - Different height (%) = \( \frac{(18-17)}{(18+17)/2} \times 100 = 1.43\% \)

Calculation of Determine Slope Gradient

i. Slope Gradient at Jalan Kuala Pilah
   - Average height from cross section = 15+16.25+14.5 = 15.25 metre
   - Average distance from cross section = 21.2+23.4+19.5 = 21.37 metre
   - Slope Gradient, \( \theta = \tan^{-1}(15.25/21.27) = 35.64^\circ \)

ii. Slope Gradient at Jalan Bangi
   - Average height from cross section = 16+18+16 =16 metre
   - Average distance from cross section = 28.8+31.1+29.5 = 29.8 metre
   - Slope Gradient, \( \theta = \tan^{-1}(16/29.8) = 28.23^\circ \)

Figure 7. The simple calculation in obtain percentage different height and slope gradient

The three cross sections produced from 3 different places. Line 1, 2 and 3 indicate where the cross section is done. From the height obtained from cross section, the top height of slope at Jalan Kuala Pilah is 16.25 metre. Therefore, the altitude difference of the slope produced through the contouring and cross section of the slope at Jalan Kuala Pilah is 0.39%. The gradient is also obtained by the presence of this cross section. The gradient of the slope in Jalan Kuala Pilah was 35.57 degree. For the slope at Jalan Bangi, the top height of slope is 18 metre. Thus, the difference height difference of the slope produced through the contouring and cross section of the slope is 1.43%. Just as the slope in Jalan Kuala Pilah, Jalan Bangi slope gradient can also be obtained. The slope gradient at Jalan Bangi is 28.23 degree.

4.3 Figuring the Damage of Slope Drainage Structure
The monitoring and evaluation of the slope drainage conditions is made through the images taken from the UAV. This monitoring is aimed at achieving the objectives of the study. Surface drains will be seen if there is any blockage occurs from excessive vegetation growing in drainage channels. The slope at Jalan Kuala Pilah is a slope constructed from concrete. This means that this slope has the
highest potential of cracking than the slope of Jalan Bangi where the slope of Jalan Bangi is composed of soil. However, this study only monitors the drainage system of slopes.

The growth of vegetation on the slope drainage structure is one of the problems with the slope drainage structure. Vegetation that grow in the slope of the slope can cause waterways to be stuck and may also result in overflowing of water. It can be identified through the taking of UAVs on both slopes that are monitored. Figure 8 shows the vegetation found in the monitored slope.

![Figure 8. The excessive growth of vegetation in slope drainage at Jalan Kuala Pilah](image)

Slope drainage at Jalan Bangi also found plant growth on the surface of the drain. This can be seen on images taken from UAV. The slope at Jalan Bangi is a soil slope, therefore the drain is filled with silt and fine particle from soil. This is because sand and fine particles are carried by rainwater. Water is a fluid that flows and is capable of bringing this fine particle into the drain. This can cause clogged drainage and the surface of the drainage will be covered. When the drainage surface is filled with sand, it will block the flow of water in the drain and cause water to flow out of the drain as depicted in figure 8 and 9.

![Figure 9. The vegetation growth on slope and the silt in drainage at Jalan Bangi](image)

Based on the captured picture, almost the entire both surface slope drainage is filled with plants. This can be stated that these slopes are not maintained or monitored by the responsible party. Figure 10
show that almost the surface of slope drainage at Jalan Kuala Pilah and Jalan Bangi were covered by vegetation. By using Global Mapper software, the length of highlighted slope drainage can be determining. By using the length of the drain, it can facilitate the maintenance work of the slope drainage.

Figure 10. The overall view of slope drainage covered by vegetation, sand and silt at (a) Jalan Kuala Pilah and (b) Jalan Bangi

The cracking on the drainage structure is also one of the common problems in the slope structure. In this study, cracks will be check on slope surface and drainage. Cracks that work on the surface of slope or drainage can cause the failure of the slope to occur where the water enters the crack cavity will then become a pressure within the slope structure. Cracking on drainage surface are not found because the drainage surface is covered by vegetation. Figure 11 show the crack happened on slope surface.

Figure 11. The crack occur and exact spot of cracking occur at slope Jalan Bangi.

5. Conclusions
As a conclusion, this study has been conducted as a monitoring method on the surface of the slope using Unmanned Aerial Vehicle (UAV). The use of UAV is aimed at helping maintenance work be carried out easily without having to climb at each level of the slope. The study was conducted at two locations, the slope in Jalan Kuala Pilah Federal Route number 361 and the slope in Jalan Bangi Selangor State Road number B17. For the elevation of the flight, the slope image at Jalan Kuala Pilah was taken at 60 meters high while the slope of Jalan Bangi was at 50 meters high. The height difference is due to different height slope altitude. This study introduces the use of UAVs could be used as an alternative in acquiring information and identify the damage occurring on the surface of the slope. In addition, the combined information obtained from UAV with software such as Pix4Dmapper and Global Mapper can help to analyse the slope in obtaining contours and the flow of water that occurs on the slope. Therefore, this method can facilitate monitoring work and some analysis of the slopes while saving time and energy. Conventional methods such as climbing slope slopes are still in use where this method can invite various hazard risks such as dropping falls or getting poisonous from
animal attacks. Consequently, the use of UAV micro aircraft in slope monitoring work should be used as a major alternative especially on high and steep slopes. In addition, the frequency of slope monitoring should also be done so that the slope structure condition is always safe. This can prevent the collapse of the slope occurs and the safety of road users are not endangered.

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