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Landslide Detection Using Unmanned Aerial Vehicle (UAV)

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Abstract

Natural disaster comes in many forms and landslides are one of the most common disasters in Malaysia. This event itself had caused chaos and ruin thousands of civilians. The effort in preventing this natural disaster has increased through time. As a result, a monitoring system can be useful in reducing the risk of hazard. Unmanned aerial vehicles (UAVs) or drones equipped with cameras were used in this study to acquire clear alerts of a landslide-prone location. It is also to develop a 3D map model in order to combine data and compare the slope condition of the research region. Drones, also known as unmanned aerial vehicles (UAVs), are used in many industries that have embraced UAVs. Model view and data of Bukit Antarabangsa and Jalan Hillview may be obtained using a double-grid mission plan on a UAV utilizing Pix4D Capture which is installed in an iPad mini 4th generation. Pix4D Cloud was used to create 3D Mapping Models, Mozaic Data, and Digital Surface Models (DSM). Slope condition or angle may be assessed using DSM data. The gradient of the same research area was measured at a different time period, the slope measurements of the same research region were compared. To examine the influence of gradient and slope conditions, the data will be compared with a second flight session at the same study area. The slope changes show that different day and time has an influence on slope instability, which can result in landslides.

Keywords: - Unmanned Aerial Vehicle (UAV), Digital Surface Model (DSM), Mozaic data, 3D mapping, slope condition.

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Introduction

This Highlight a section that you want to designate with certain Natural hazards pose a major threat in multiple regions of the world and usually cause crucial economic dislocation, environmental impacts, and fatal injuries. Landslides represent one of the most destructive natural hazards and often cause substantial human and infrastructure losses which form significant obstacles to the sustainable development of a healthy society [1]. Landslides and rockfalls constitute one of the most widespread geo-hazards which take place. Slope-induced landslides are very common in Malaysia especially in an urban area with infrastructures.[2] Some of these landslides have resulted in not only extensive damage to properties but also loss of lives. An investigation has been carried out on one of the major landslides which occurred in Bukit Antarabangsa, Ampang, known to be a landslide-prone area. The method used to overcome such a situation is prevention. A simple UAV device that can detect any upcoming landslide [3].

Remote sensing is the process of detecting and monitoring the physical characteristics of an area by measuring it is reflected and emitted radiation Hence, the main purpose of this project is to generate a 3D model using Pix4D. Next is to extract slope elevation measurement using a 3D model. The final objective is to compare the acquired data with a general formula and manual calculation in order to achieve accurate data.

A future hazardous accident such as the landslide can be detected at an early stage and can be prevented which saves many localities and parties. Furthermore, future studies to further enhance the technology can be done as technologies are getting advanced in the upcoming days [4]. The evaluation and area of slope danger may be mapped throughout the region using today's powerful Geographic Information System (GIS) and remote sensing technologies. A geographic information system (GIS) is a computer-based system for recording, storing, collecting, analyzing, and displaying data.

The computing capability with GIS to be combined and apart from other geographically linked systems, allowing perform modeling operations on spatial data [5]. The principal sources of data in GIS systems are remote sensing and direct import of pictures and classified images, but traditional map construction using photogrammetry is also implemented. Due to this condition which is a set of data with repetitive coverage, and real-time data collecting, remote sensing data is extremely important [6] As a consequence, digital data in the form of satellite imagery allows for exact measurement of various land cover/land use categories and assists in the creation of a data network, which is essential for tracking urban expansion and land-use research [7].

Drone or Unmanned Aerial Vehicle (UAV) technology has advanced to the point that drones may be called the third generation of platforms providing remotely sensed data of the Earth's surface, with tremendous new possibilities in the area of remote sensing [8] As a result, remote sensing is an important part of GIS, and it would be impossible to function without it. Next, development, resulting in increased rock erosion and soil deterioration caused which could lead to a potential landslide [9].

In other way, landslides are caused by urban development in hilly places with potential steep terrain and irregular slope constructions. In Malaysia, landslides are prevalent, especially in steep locations like Ulu Kelang, Selangor. Malaysia's modern urban area undergoing

economic expansion is frequently responsible for landslide damage and deaths. Due to a scarcity of appropriate low-lying locations, people also pushed their commercial operations into the highlands and mountainous regions. The permission was granted. The fast development of mountain areas for high-rise projects raises the danger of landslides [10]. Because landslide is the most common natural disaster across the world, the link between landslides and the gradient of slope hills has been tentatively established over the last few examples by establishing certain condition for a standard measurement of any dangerous situation.

For example, landslides occur when the gradient increases on a hill and has a high rate of increment in a short period of time leading to a potential landslide coming soon [11]. Slope and gradient can be determined using both software and mathematical methods. Landslide early warning systems are constantly becoming popular around the world. Due to their lower economic and environmental costs compared to standard methods, the continuous emergence of local landslide detection technologies, and the increased availability of accurate databases to calibrate warning models [12]. Aside from that, the study is to reduce the risk of loss of life and other negative consequences of landslide events by warning people, families, and organizations impacted by a landslide to plan and react appropriately enough time to lower the potential for harm or loss. As a result, it is critical to establish a normal state for landslide early warning systems that emphasize the involvement of the community and social aspects in general [13].

Finally, the study's goal is to use an unmanned aerial vehicle (UAV) to collect data from the potential landslide area. GIS applications such as Pix4D are then used to examine the data. The analysis procedure is critical for determining the system's evolution from a new perspective [14] The method of obtaining landslide data by deploying a UAV or drone at a height of 100 meters above the landslide-prone area. Imaging data need to be generated from the obtained data which then produces the reflectance map. This method can only be achieved with the aid of a UAV as the imaging data is being collected through pixels in each image. This can be converted into a 3D map model with the quality top view (oblique view). Which then can be regulated [15].

Methodology

Study Area

There are two study areas which both stations are located in Bukit Antarabangsa, Ampang, 68000, Selangor. These areas were chosen as there is plenty of hills and potential landslide area that can be scanned. The framework is made up of both hardware and software components. mosaic data or oblique view photos may be easily gathered and sent to a computer for further analysis using a UAV. These images can be converted using GIS software such as the Pix4D Cloud into sets of data. The research area is both located in Ampang as for its mountainous and hills. With the first station located at Jalan Bukit Antarabangsa Taman Kelab Ukay, 68000 Ampang Jaya, Selangor with a latitude and longitude of 3.186714, 101.771142. The second station for this study area is located at Taman Hill View, 68000, Ampang Jaya, Selangor with a latitude and longitude of 3.175965, 101.761044. Which took place on 23rd November 2021 and 14th December 2021.

Method

The DJI Phantom 4 Pro V2 was utilized to collect data from the subject region in this study. The DJI Phantom 4 Pro V2 is a compact quad-rotor drone that is simple to fly and operate. As a result, the high-quality camera aids in capturing high-quality photographs with a resolution of up to 4K. Furthermore, the DJI Phantom 4 Pro V2 can fly at a height of more than 100 meters, which means it can fly higher than the needed requirement.

In terms of software, Pix4D a GIS software was suggested for this study. The system delivers a seamless working and data collection experience because to its user-friendliness and software compatibility with the DJI brand. Pix4D Capture was utilized on an iPad or tablet to upload the mission plan to the UAV for the flying system. Pix4D Cloud was utilized to process and analyze data collected by the UAV in terms of computer processing software. Even though the camera used is an RGB camera, the programmed outputs 3D model mapping that incorporates DSM data and Imaging data.

Collecting and Processing Data

The study area's UAV flying operation was done lawfully with approval from the appropriate authorities. The block diagram for UAV flight operation for safety and legal reasons, a flying permit is necessary to conduct the flight activity. The local Municipal Council, Jabatan Ukur dan Pemetaan Malaysia (JUPEM), and the Malaysian Civil Aviation Authority were the approved entities (CAAM). The entire process of applying for the permission took a few months. The process of collecting and processing data can be seen in Fig. 1. This process is separated between flight operation for data collection and processing the data using GIS software such as Pix4D. This whole process took place on a different date locating at both study area.

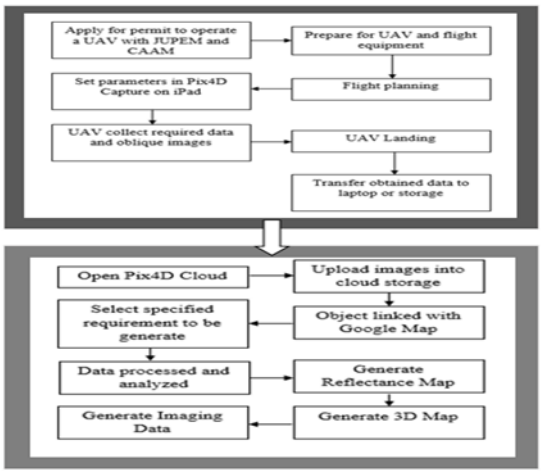

Fig. 1 Flow of Collecting and Processing Data

First and foremost is to have a well-prepared equipment for UAV such as sufficient battery and related connectors. Next, a clear surrounding with no weather restriction or buildings along the flight area is required in order to avoid any noise and restriction due to surrounding. This flight requires a 100m hover above the ground in order to have the best images for this related project. An early preparation using Pix4D Capture can be set before the flight. This helps in getting the specified data to be generate. As for this project, double grid is suggested as it provide more data whereas the drone covers more area compared to a single grid project.

Due to the precision of more capture points and a camera elevation of 70 degree, a double grid mission was chosen to be uploaded into Pix4D Cloud for data processing.

Following data collection, the data was transferred immediately from the UAV's memory card to the laptop. To minimize data corruption during data transfer, the data was also backed up using cloud service which is installed in the tablet (iCloud). Pix4D Cloud is a high-tech software that works with UAVs to convert a huge number of photos into an accurate point cloud, DSMs, and Orthomosaic data. Fig. 1 also shows the Pix4D software's data processing block diagram. The obtained data was uploaded into Pix4D Cloud. The object is then linked with Google Map in order to acquire the 2D and 3D map based on each longitude and latitude. A specific option needs to be selected such as 3D map model and oblique flight for quality purposes. The GCP are being set at default setting. The data is then processed and analyzed taking matter of the slope and elevation difference for each dataset. A reflectance map is required to see the maximum and minimum height of the obtained data. 3D map is then generated which a result in imaging data. Such data requires the aid of thermal and spectral image which can be further study. The whole process of extracting data from each dataset is approximately 45 minutes each. A total of 3 hours to complete both station whereas each station has 2 flight session.

$$E_1 - E_1' = E_2 + E_3$$
$$E_1 - E_1' = Mg \times \Delta H$$
$$E_2 = \sum(\mu_i \times \Delta m_i g \times s_i)$$
$$E_3 = \sum(c_i + \sigma_i tan\varphi_i) \times l_i \times l_{i\sim f}$$
$$Y = KX + b$$
$$E_2 = \sum(\mu_i \times \Delta m_i g \times s_i) = \sum[\mu_i \times \gamma_i \times (Ks_i + b) \times \Delta s_i \times s_i] = \int_0^L [\gamma(s) \times \mu(s) \times (Ks^2 + bs)]\, ds$$
$$Mg \times \Delta H = \int_0^L [\gamma(s) \times \mu(s) \times (Ks^2 + bs)]\, ds + \sum(c_i + \sigma_i tan\varphi_i) \times l_i \times l_{i\sim f}$$

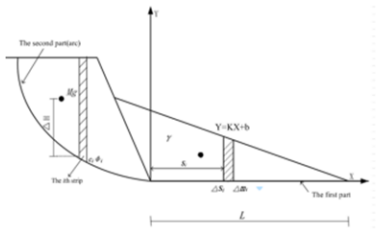

Fig. 2 Formulas for slope detection

Calculation and Formula for Potential Landslide

In every finding or solution must have formula and landslide can be calculated with such formula. Fig. 2 shows the manual calculation and formula on slopes for potential landslide. This process is no longer used as the technologies are getting advanced, such software as Pix4D can directly calculate the slope for each images The calculated formula for slope of hills can be demonstrate in the figure above.

Result and Discussion

Due to both Bukit Antarabangsa and Jalan HillView are mountainous locations with a history of landslides, they were chosen as research sites. With their landscape condition, a 3D map model was built using an image obtained by UAV and uploaded to Pix4D Cloud. On 23 November 2021, Fig. 3 shows a 3D mapping model of the study area in Bukit Antarabangsa.

By charting a plot from high-level terrain to low-level terrain, a slope elevation profile may be created. Fig. 4 shows slope measurement data, including slope elevation angle while Fig. 5 shows the slope elevation graph for the Bukit Antarabangsa study area on 23 November 2021.

Fig. 3 3D model for Bukit Antarabangsa on 23 November 2021

Fig. 3 shows how a polyline was used to create elevation from two locations. An elevation data was created using this polyline. As in Fig. 3, polyline as a blue line cutting across the steep landscape.

The elevation data was shown in Fig. 4. This can be progress into a slope elevation with the aid of reflectance map that was built-in along with Pix4D Cloud.

Parameters	Value
2D Length	126.623m
3D Length	136.731m
Min. Elevation	129.691m
Max. Elevation	181.286m
Elevation Difference	51.596m
Slope	22.1735°

Fig. 4 Slope measurement data for Bukit Antarabangsa on 23 November 2021

As a graph line that plotted the height against the length. The graph can be seen in Fig 5. This method acquires plotting the polyline with a minimum of 10 plot along the elevation. As a result, we are able to create a reflectance map that shows the slope elevation graph of Bukit Antarabangsa study area on 23 November 2021. With a result of 22.1753 °. This data is then being compared with a second flight on an interval date. This process is to reduce noises between each flight and to get the accurate reading of the slope

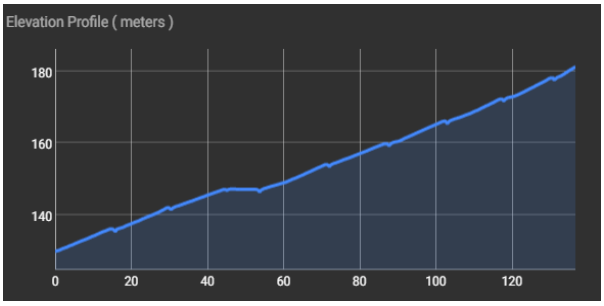

Fig. 5 Slope elevation of Bukit Antarabangsa study area on 23 November 2021

After the 2nd flight on December 14, 2021, comparisons have been made. To evaluate the data, it was uploaded to Pix4D Cloud. The slope information was collected by charting a plot from high-level terrain to low-level terrains, using a 3D map model. On December 14, 2021, Fig. 6 shows a 3D map model of the research region in Bukit Antarabangsa for second flight. Fig. 7 shows the slope measurement data for Bukit Antarabangsa study areas. Whereas Fig. 8 shows the slope elevation of Bukit Antarabangsa study area on 14 December 2021.

Fig. 6 3D model for Bukit Antarabangsa on 14 December 2021

Parameters	Value
2D Length	126.638m
3D Length	135.14m
Min. Elevation	104.964m
Max. Elevation	152.142m
Elevation Difference	47.177m
Slope	20.4546°

Fig.7 Slope measurement data for Bukit Antarabangsa on 14 December 2021

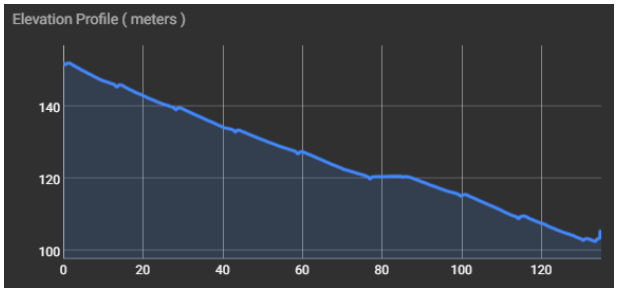

Fig. 8 Slope elevation of Bukit Antarabangsa study area on 14 December 2021

Plotting the polyline as in Fig. 10 shows a further measurement data in Fig. 11. The slope angle was the most essential measurement. On 14 December 2021, the slope angle in Bukit Antarabangsa research area was 20.4546°, as shown in Fig. 11. At Bukit Antarabangsa study area, the elevation difference and slope angle were different on both flight dates. The differences on both angles were tabulated in Table 1

Fig. 9 3D model for Jalan HillView on 23 November 2021

As from previous statement, Jalan HillView are a mountainous location with a history of landslides, they were chosen as research sites. With their landscape condition, a 3D map model was built using an image obtained by UAV and uploaded to Pix4D Cloud. On 14 December 2021, Fig. 9 shows a 3D mapping model of the research region in Bukit Antarabangsa. By charting a plot from high-level terrain to low-level terrain, a slope elevation profile may be created. Fig. 10 shows slope measurement data, including slope elevation angle while Fig. 11 defined the slope elevation graph for Jalan HillView research study area on 23 November 2021

Parameters	Value
2D Length	129.327m
3D Length	132.349m
Min. Elevation	60.023m
Max. Elevation	88.146m
Elevation Difference	28.123m
Slope	12.2613°

Fig. 10 Slope measurement data for Jalan HillView on 23 November 2021

Fig. 9 shows how a polyline was used to create elevation from two locations. An elevation data was created using this polyline. As in Fig. 9, polyline as a yellow line cutting across the steep landscape. The elevation data was shown in Fig. 10. This can be progress into a slope elevation with the usage of reflectance map that was built-in along with Pix4D Cloud. As a graph line that plotted the height against the length. The graph can be seen in Fig. 11. This method acquires plotting the polyline with a minimum of 10 plot along the elevation. As a result, we are able to create a reflectance map that shows the slope elevation graph of Jalan

HillView study area on 23 November 2021. With a result of 12.2613 °. This data is then being compared with a second flight on an interval date. This process is to reduce noises between each flight and to get the accurate reading of the slope

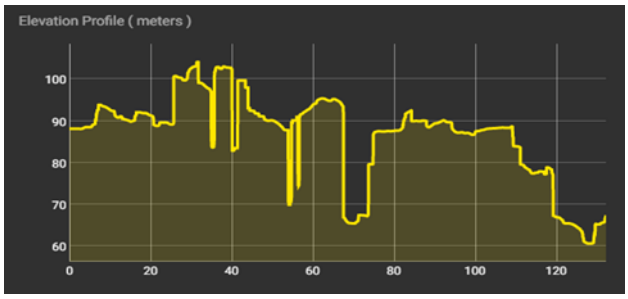

Fig. 11 Slope elevation of Jalan HillView study area on 23 November 2021

This station also required a 2nd flight which was done on December 14, 2021. Due to this, comparisons have been made. To evaluate the data, it was uploaded to Pix4D Cloud. The slope information was collected by charting a plot from high-level terrain to low-level terrains, using a 3D map model. On December 14, 2021, Fig. 12 shows a 3D map model of the research region in Jalan HillView for second flight. Fig. 13 shows the slope measurement data for Jalan HillView study area. Whereas Fig. 14 shows the slope elevation of Jalan HillView study area on 14 December 2021.

Fig. 12 3D model for Jalan HillView on 14 December 2021

Plotting the polyline as in Fig. 11 shows a further measurement data in Fig. 12. The slope angle was the most essential measurement. On 14 December 2021, the slope angle in Jalan HillView research area was 11.23°, as shown in Fig. 12. At Jalan HillView study area, the elevation difference and slope angle were different on both flight dates. The differences on both angles were tabulated in Table 1

Parameters	Value
2D Length	129.916m
3D Length	132.455m
Min. Elevation	67.436m
Max. Elevation	93.246m
Elevation Difference	25.81m
Slope	11.23°

Fig. 13 Slope measurement data for Jalan Hillview on 14 December 2021

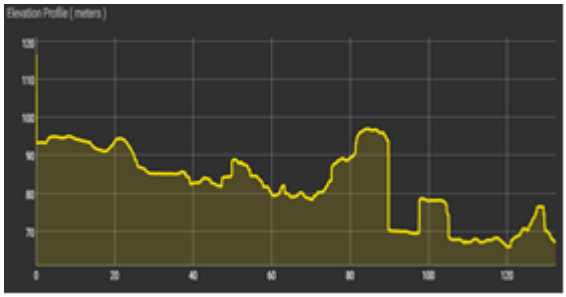

Fig. 14: Slope elevation of Jalan HillView study area on 14 December 2021

Both study area shows different slope angle readings on both flight occasion. These parameters can be shown in a tabulated data. Table 1 and 2 shows the slope angle and elevation difference for both on both 23 November and 14 December.

Table 1: Slope angles comparison of two separate flight durations in two different research areas

Research Area	Slope Angles (°) / Gradient	
	23/11/21	14/12/21
Bukit Antarabangsa	22.1735	20.4546
Jalan Hillview	12.2613	11.23

Table 2: Elevation difference comparison of two separate flight duration in two different research areas

Research Area	Elevation Difference (m)	
	23/11/21	14/12/21
Bukit Antarabangsa	51.596	47.177
Jalan Hillview	28.123	25.81

Based on the reading of Table 1, the research area of Jalan HillView has the least difference reading for both flights. From a reading of 12.2613° to 11.23°, with a decrement of 1.0313° in slope angle. Whereas the study area for Bukit Antarabangsa has a bigger decrement which is from 22.1735° to 20.4546°, such as the decrement of 1.7189° in slope angle. This indicates that the slope angle in Jalan HillView has lowered 5.3% from the original slope angle, while the slope angle in the Bukit Antarabangsa study area has fallen 7.7% from the starting slope angle.

According to Table 2, the highest height variation is between 51.596m on November 23, 2021, and 47.177m on December 14, 2021, for Bukit Antarabangsa. The rate of change was 4.419m between two flight period which is 22 days. These factors may be affected as the presence of large terrain such as trees and hills. The elevation difference between Jalan HillView on 23 November 2021 with 28.123m on 14 December 2021 was 25.81m. The rate of change was 2.313m. Once again this is due to the noise of large terrain such as trees and forest

Referring to factor selection, the factor selected in determining a potential landslide is by calculating the gradient of the hills and study area. The gradient is selected as one of the factors as by measuring the gradient, the potential of hazardous and geographic causes can also be measured. Based on recent study, researchers believe that landslides occur between

30° and 40°, while most studies confirmed that it would occur above 25° Due to the limitation of devices, an aerial device (UAV) is only able to capture images of potential landslide site which then can be converted into a result of data that provide the slope angle and elevation difference. Which then can be interpreted with the aid of imaging data with spectral images and thermal images as for result, landslide will possibly occur at a major difference of slope angles and elevation difference. This data can be collected through the same process of this Technical Paper. This can be concluded that any types of hills or mountains are safe to the community as long as the slope and elevation difference are in a good state. A continuation on checking the slope and gradient difference for this type of area should be done regularly by enforcers.

Conclusion

In conclusion, landslides can be prevented with an early access to data upon related to the potential landslide. Unmanned aerial vehicle (UAV) such as drone helps in this founding of data. With the implementation of professional software such as PIX4D where it can create a 3D model based on the received data. By this, any location or in force can alert with the current method. This process should be further studied in order to achieve the best landslide prevention and alert.

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