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MODELLING SLOPE TOPOGRAPHY OF A HILLY TERRAIN USING UNMANNED AERIAL VEHICLE IMAGE TECHNIQUE

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ABSTRACT

Unmanned Aerial Vehicle (UAV) as data acquisition tools are becoming more affordable for many civil engineering applications. However, the accuracy of the output is influenced by many parameters. The main objective of this study was to investigate the effect of flight altitude toward the final output measurement accuracy without using Ground Control Point (GCP). Altitude is a parameter that is very important in flying UAV that must be taken into consideration. Notably, the flight altitude depends on the ground condition, surrounding obstruction, Ground Sample Distance (GSD) and camera monitoring. The UAV should fly in a lower condition when GSD is better. However, this approach rarely can succeed because different site conditions such as flat terrain nor hilly terrain required different flight planning. Therefore, a field experiment will be carried out to investigate the optimum flight altitude to obtain acceptable accuracy of orthomap at hilly type of terrain. This study evaluates both the qualitative of the image and the quantitative aspect of the orthomap. The actual measurement of selected features was made and compared with the on-screen measurement. An orthophoto will be generated by using Pix4Dmapper on a selected slope of the hilly terrain in UPNM Campus. Based on the results, different accuracy obtain on flat surface is 0.14% and slope surface is 2.77%, which needed further study to identify the method to reduce error. It is found that the accuracy without GCP is not having large error of more than 1% for flat area. Due to distortion of image on slope surface, the error is larger and needed GCP calibration. This study shows that UAV is a feasible platform for mapping of small area with acceptable accuracy.

1.0 INTRODUCTION

As to date, the application of UAV as a replacement for satellite and manned aircraft have been showing growing interest. This is mainly due to several critical pull factors such as low cost, fast speed, high manoeuvrability and enhances the safety of UAV system. Data acquisition is the most expensive stage in most civil engineering project and research. UAV promises an acceptable cost for data acquisition with acceptable accuracy. According to Raczynski in [1], the most sophisticated UAV aircraft technology is being driven by land surveyors for various applications. Over the years, drones have become cheaper and handier. New developments in sensors and fly platforms have expanded applications enormously including volume calculations, producing orthophoto maps, generating 3D models, obtaining Geographic Information System (GIS) data, monitoring open-pit mines production, conducting construction checks, general mapping of terrain and more [3-6]. The UAV shortens the length of inquiry from several days to several hours to spend on the field. They also, if used correctly, improve the safety of the person who performs the measurements, as the operator may live in a dangerous zone [7-8]. The low-cost drones are found to produce an accurate product if used appropriately, however, a question remains on how to carry photogrammetric missions to achieve the highest possible accuracy [8-10]. Raczynski mentions the

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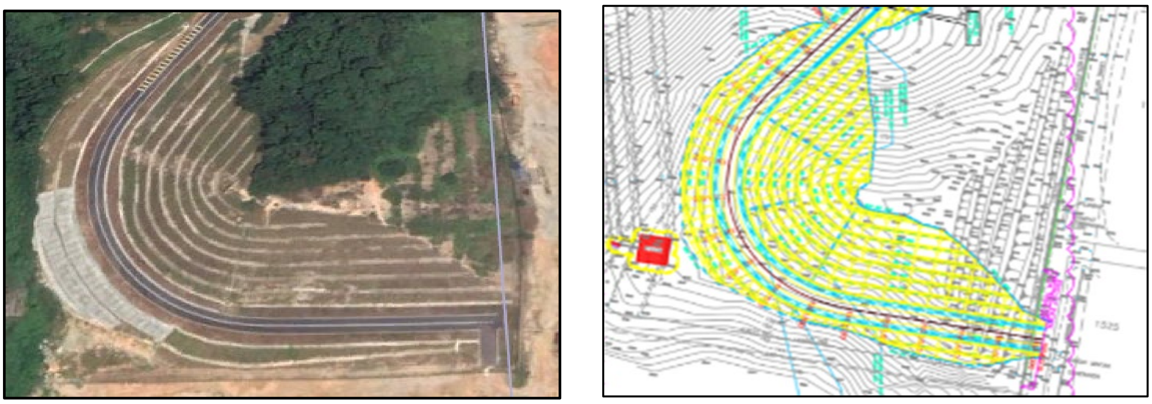
adoption of new innovative technologies, particularly in mapping and surveys, are based on product enhancements offered in terms of accuracy and reliability and the effectiveness of time and money spent on measurement [1].

Many factors must be taken into consideration when capturing data and the most important are flight parameters such as height (altitude) on which UAV is flying, percentage of which adjacent images are overlapping and speed of the aircraft while taking photos, as a sensor used for acquiring images is a rolling shutter camera [11-13]. Moreover, site condition also may influence the data captured. Indirect geo-referencing (geometric correction) plays an important role in bundle block adjustment since the reliability of camera calibration is based on the accuracy of Ground Control Points (GCP). However, no GCP is used in this study and the geo-localization process only depends on the GPS measurements provided by the UAV [14]. Hence, the flight mission parameters such as altitude influencing the accuracy assessment of the final product.

Photogrammetry is the science of making measurements from photographs. From the overlapping images, finding a position of 3D points of a scene is the key problem [15-16]. Thereby, it can be processed later based on collinearity condition. It is a process where a line originates from central projection of a camera and goes through a point in sensor plane (on the image) to the point of the object in the ground coordinate system. The three-dimensional points of a scene location are determined by the intersection of many lines. In order to reconstruct metric model from images, the orientation of image and calibration of camera are essential [17-18]. These two approaches enable it to be achieved which are by classical photogrammetric workflow or computer vision (VC) technique. The model can be resolved when known camera positions and triangulation are placed. This can be countered if the positions of the camera are unknown which is by placing a set of reference markers with 3D coordinates that is known, manually identified in the images and to get the camera positions by using resection [19-20].

2.0 STUDY AREA

Location of the study area is within UPNM campus. An area within a road project will be used as hilly terrain hazardous slope. This site was selected because it has an open area and minimal signal interference hence,
significantly decreases the chances of crashing the UAV. The purpose is to study the accuracy assessment without using GCP.



a) Google earth photo b) Survey data

Figure 1. Study area

3.0 METHODOLOGY

This study was conducted using DJI Phantom 4 drone. The methodology of this study can be divided into five phases. Phase 1 involves the preliminary study. Phase 2 consists of preparation and planning. In phase 3, data was acquired using the UAV and mobile application such as Altizure and DJI GO 4. Phase 4 is data processing stage using Pix4D Mapper and ArcGIS 10.5 software. In Pix4D Mapper, data were processed to generate the output such as Orthophoto and Digital Surface Model (DSM). The contour of the DSM was processed using ArcGIS 10.5. Finally, data analysis is in Phase 5. Figure 2 illustrates the methodology for this study.

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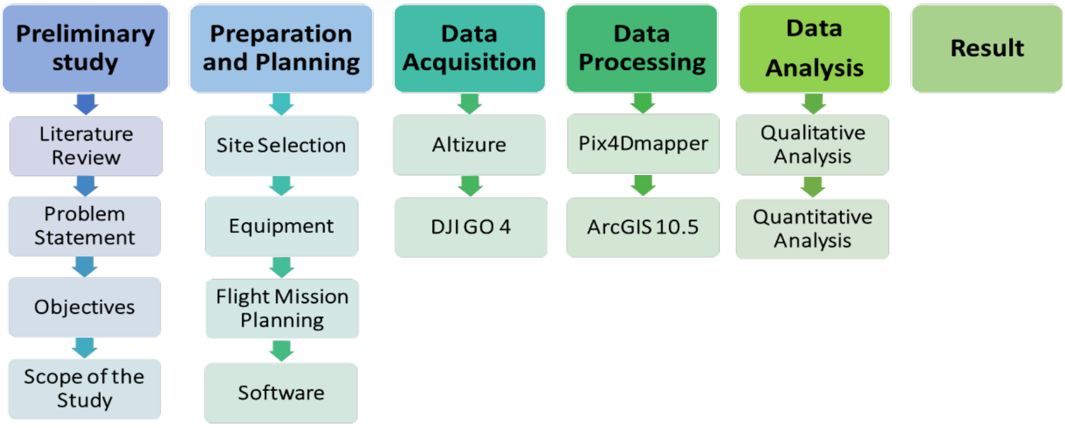


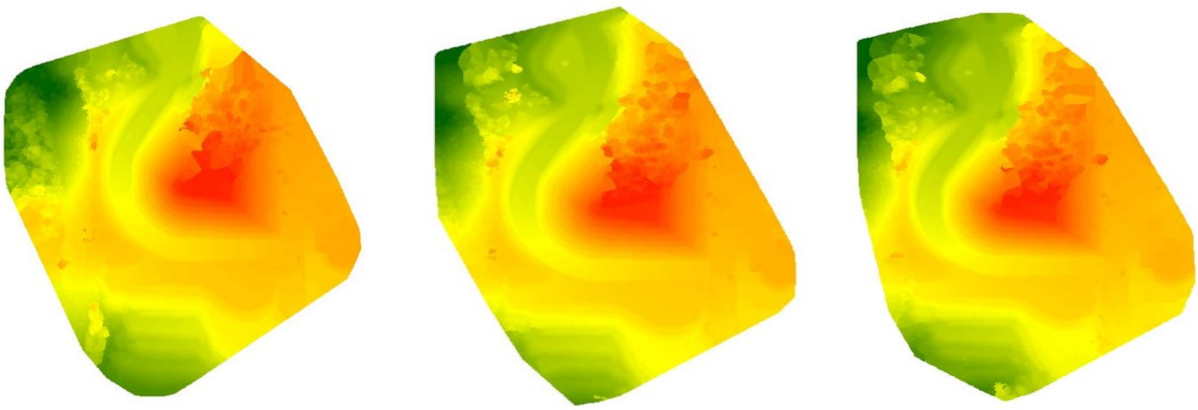
Figure 2. Methodology of the study

Qualitative and quantitative analysis were carried out in this study for accuracy assessment. The qualitative analysis was done by analysing the quality report generated by DSM and generate contour for every altitude. Meanwhile, quantitative analysis was done by analysing the numbers of overlapping images computed and carried out on site measurement. This study was carried out without using GCP in order to investigate the accuracy assessment to be obtained in short of time or during emergency that prohibits the use of GCP. Various studies have proved that accurate data can be obtained when using GCP. Furthermore, the use of GCP is a reliable tool to obtain the accuracy needed. Hence, this study indicated that without the use of GCP, the data obtained are approximately the same as the original data that were conducted using ground survey. This shows that even without GCP the data obtained are still reliable in order to obtain the accuracy assessment with different flight altitude.

4.0 RESULTS AND DISCUSSION

4.1 Qualitative Analysis

Qualitative analysis is carried out on map visualization by digitizing the features in the images. The analysis was done by comparing digital features of ArcGIS 10.5 software and the images taken. A contour of each altitude was generated automatically by using ArcGIS software. One metre interval was used for contour lines. DSM generated by Pix4Dmapper is the main source of contour lines.



a) b) c)
Figure 3: Digital surface model (DSM) of different altitudes; a)60m, b)80m, c)100m

Figure 3 shows that the DSM is approximately the same for 80m and 100m altitude. For 60m altitude, the DSM did not produce good result due to low overlapping of images. Therefore, it was found that 80m and 100m altitude produced a good aerial map.

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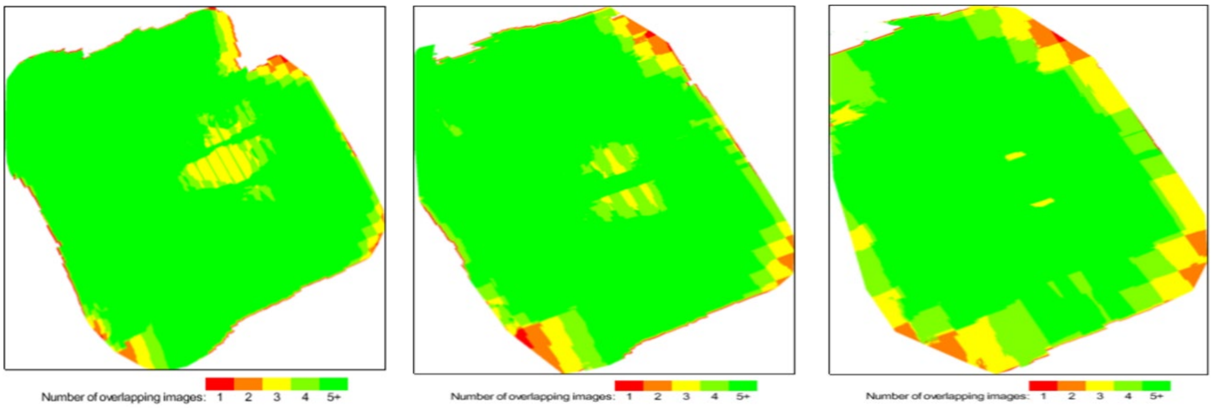
a) b) c)

Figure 4. Contour lines of different altitudes; a)60m, b)80m, c)100m

Figure 4 shows the pattern of contour lines for different altitudes. From the observation, the peak of slope for 80m and 100m altitude was detected. For 60m altitude, the peak of slope was not detected due to low overlapping of images. Therefore, it was found that 80m and 100m altitudes gave better contour lines with one metre interval. The comparison between the contour lines generated by ArcGIS software of the three different altitudes and the survey data is shown in Figure 1 e. From the observation, the peak of the slope of 60m was not detected compared to 80m and 100m. This is because at 60m it did not have enough overlapping of images. Meanwhile, at 80m and 100m it gave better result as per survey data. Based on the comparison of the contour lines with the survey data, it was shown that all of them give the same alignment of road and slope location. But the actual height is not applicable due to not having Ground Control Point (GCP).

4.2 Quantitative Analysis

Quantitative analysis is being done for data calculation and computation in order to obtain numerical quantity.



a) b) c)

Figure 5. Overlapping Images of Different Altitudes; a) 60m, b) 80m, c) 100m

Figure 5 shows the overlapping images of all three altitudes. The observation showed the overlapping images of all of them were varied because the UAV were captured from different flight altitude with the same waypoints. A number of overlapping images was computed for each pixel of the orthophoto. Red and yellow areas indicated low overlap for which poor results may be generated. Green areas indicated an overlap of over 5 images for every pixel. Good quality results can be generated if the number of key point matches is sufficient for these areas. The numbers of overlapping images for altitude 60m were the lowest compared to altitude of 80m and 100m. This shows that 60m altitude generated a poor result in the overlapping images compared to 80m and 100m altitude. This was due to the close distance between the fly altitude and the real height of the site This is because, when calculated that 7 numbers of berm

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with height of 6metre each which is 7 x 6 = 42metre whereas the fly altitude was at 60metre. The actual fly altitude was 60m - 42m = 18metre. So that, the number of overlapping images were at the very lowest at 60 m altitude. Nevertheless, the data generated looks clearer than other altitudes.

On site measurements which was carried out by using the 2D data from ArcGIS software, measurements of some locations were analysed. From the observation and measurement obtained, there were some variances of measurement between on site and 2D data. From the analysis, the measurements have been divided into two types such as on flat terrain and on slope terrain. Regarding to the types, each of the types were separated into two kinds of measurements that were less than 5m and more than 5m. On the flat terrain, data for both less than 5m and more than 5m could be verified. But on slope terrain, only data for more than 5m could be verified.

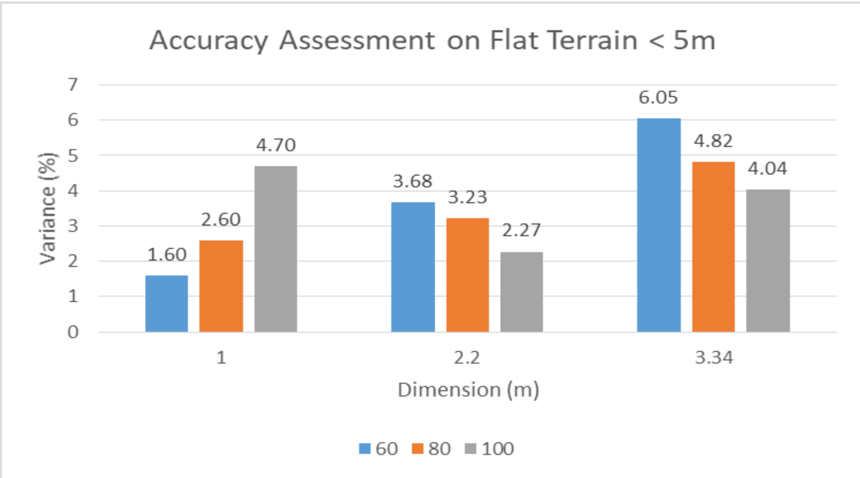

Figure 6. Graph of accuracy assessment on flat terrain not more than 5m

Figure 6 shows the graph for accuracy assessment on flat terrain for features not more than 5m. 1.00m dimension is the measurement of road marking. The colour is white with black background. 2.20m is the measurement of zebra crossing. The colour is between yellow, black and yellow. 3.34m is the measurement of sump of drain. The reverse pattern of graph between dimension 1.00m with 2.20m and 3.34m can be seen. Based on the findings, it is observed that for 60m altitude, the accuracy is lower due to insufficient overlapping of images for high pixel value. For dimension 1.00m, the error increased in small dimension feature because the higher the altitude, the pixel becomes blurrier, and the edge of the feature was undetectable. However, for dimension 2.20m, the error decreased because of the contrast of the colour which is yellow and black that made the edge of feature detectable even though the pixel blurry is 3.34 m dimension which is the same as 2.2m. Therefore, it is suggested that 80m altitude is the optimum flight height to capture the photos because contrast of the colour and the variance are stable.

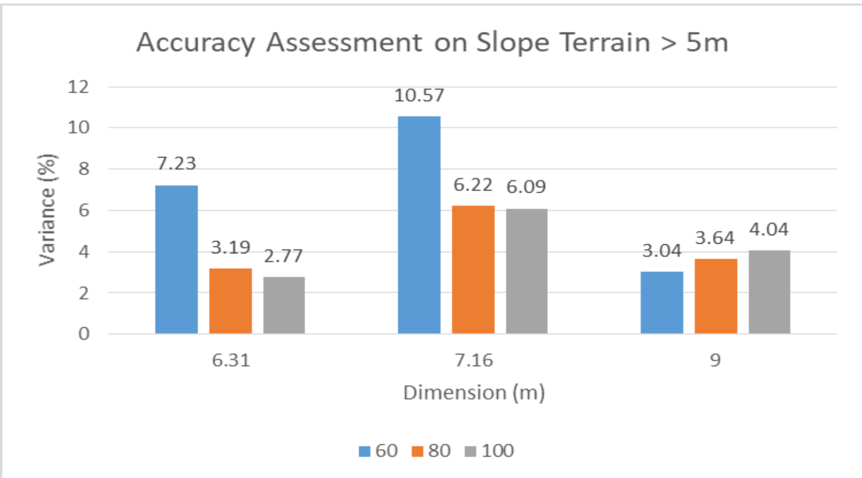

Figure 7. Graph of accuracy assessment on flat surface more than 5m

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Figure 7 shows the graph of accuracy assessment on flat terrain for features more than 5m. 7.07m is the measurement for width of road. 17.5m and 17.8m are the measurement of continuous line. 7.07m has contrast colour of black and green. The findings suggest that it is easier to measure from edge to edge because of the contrast of the colour. However, for dimension 17.5m and 17.8m continuous line, it is hard to identify the length of the feature when measured on screen because of the difficulty in measuring the actual length on site.

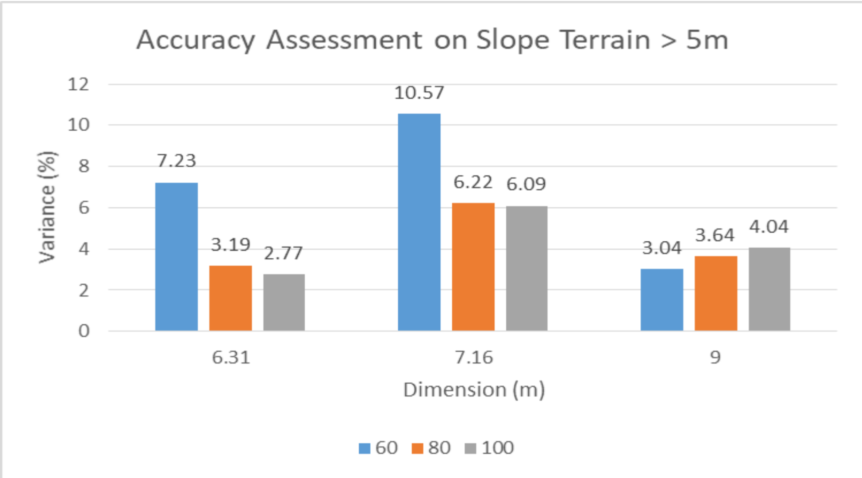

Figure 8. Graph of accuracy assessment on slope surface more than 5m

Figure 8 shows the graph of accuracy assessment on slope terrain for features more than 5m. 6.31m and 9.00m are the measurement of rock at slope. 7.16m is the measurement of berm. The variance of 6.31m and 7.16m is getting smaller once it reaches 80m to 100m by 0.41% and 0.13%. However, for dimension 9m, the variance increased because of the pixel blurry and shadow. The accuracy is stable when it reaches 80m. Therefore, it is suggested that 80m altitude is sufficient to obtain accurate data for hilly site area (slope with 7 berms).

5.0 CONCLUSION

From the study, it can be concluded that the optimum flight height is 80m and above because of the variation of ground height during data acquisition. This is because, 80m is considered as the start of flat and slope terrain at the take-off point. Features with contrast colour give better results at all altitude compared to features with less contrast colour such as black and white. On flat terrain, measuring long line will have a large variation. However, for features of short line with contrast colour give less variation. On slope terrain, lower altitude gives large variation. Therefore, in monitoring slope terrain it is found that the optimum flight altitude is between 80m to 100m. The objective to identify the correlation between flight altitude and accuracy assessment in flat and slope terrain features without Ground Control Point (GCP) have been done flight altitude significantly affects the accuracy. The altitude also affects the pixel of aerial photo which influences the accuracy. The higher the altitude for hilly area, the rate of accuracy is improved while the lower the altitude at hilly area, the accuracy rate becomes lower due to low overlapping of images. The second objective which is to identify the optimum flight altitude of UAV for acceptable accuracy without GCP also been covered. Based on the findings, it is found that 80m is the optimum flight altitude for hilly area that have 7 berms. On top of that, 80m and 100m flight altitude 3D map have high similarity rate when compared to actual survey data.

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