Slope Effect on The Vertical Accuracy of Spatial Information Using Multi Rotor UAV

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Abstract. Unmanned aerial vehicle (UAV) recently has been proved to be used for slope mapping studies. Slope map can be created by gathering spatial information including elevations and surface features of the surrounding terrain. Spatial information on a slope is important to enhance the efficiency of slope modeling. Thus, the spatial information must be very accurate and reliable. This study aims to determine the effect of a slope on the vertical accuracy of spatial information acquired by using multi-rotor UAV. The objectives are to investigate the effect of slope elevation and to identify the effect of slope steepness on the vertical accuracy of spatial information acquired using multi-rotor UAV. Terrain Model (DTM), Contour Map, Triangular Irregular Network (TIN), and Slope Map is produced for analysis purpose. It was found that the vertical accuracy of spatial information increase when the elevation of slope and steepness of slope decrease. In conclusion, slope elevation and slope steepness do have an influence on the vertical accuracy of spatial information captured by UAV.

1. Introduction
UAV has been proven that it can be used for slope mapping studies especially for acquiring slope data [5]. Slope map can be created by gathering spatial information including elevations and surface features of the surrounding terrain. Spatial information on a slope is important to enhance the efficiency of slope modeling [6]. Cordova et al. [2] stated that the accuracy of the elevation model must be analyzed to quantify the uncertainty generated by UAV technology. There are many factors that can contribute to the uncertainties generated by UAV technology. Tahar et al. [5] have analyzed the effect of different altitudes of multi-rotor UAV to the accuracy of the Digital Surface Model (DSM) produced.

In other studies, the author assesses the possibilities of using UAV technology to documents the hiking trails in the slope area [3]. The study by Tahar et al. [5] suggested that higher flying altitudes of UAV give more accurate results for slope area. However, he did not describe which part of the area of the slope that contributes to the error. According to Ćwiąkala et al. [3] concluded that UAV based approach is not suitable for recording in a steep slope area where the error in the DTM that has been produced shows an increase in error for the steep area.

Therefore, this study focused on evaluating the effect of slope elevation and slope steepness on the accuracy of spatial information collected by using UAV technology. The slope in the study area is...
classified into different classes depending on their elevation and steepness. The error for elevation is then calculated and analyzed to study the effect of slope elevation and steepness on the spatial information. Other contributions include producing DTM, slope map, contour map, and Triangular Irregular Network (TIN) of the Academic Height in UiTM Perlis Branch from the aerial images captured by multi-rotor UAV.

2. Study Area
The study area for this research is at Academic Height in UiTM Perlis Branch, 02600 Arau, Perlis. The study area covered a total area of 25.6 hectares with a population of 7825 people. This study area is chosen because of the topography are slightly steep and has a various elevation value which is suitable to be used for an elevation assessment. It also provides a safe environment to study. Figure 1 below shows the location of the study area.

![Figure 1. Study Area](image)

3. Methodology
The methodology of this study consists of four phases as shown in Figure 2. The first phase focused on the preparation of equipment and planning for the data collection phase. In this phase, the study area, selection of GNSS and UAV equipment, and method to collect the data are identified and listed out. The second phase is known as data acquisition. This phase is the process of collecting the data that is needed in this research. The data that is required includes the aerial images of Academic Height using multi-rotor UAV and GNSS observation. These data then undergo data processing to produce the DTM, slope map, contour map, and TIN map. Next, the attribute of the data is extracted based on the aim and objectives of the study. The analysis is a closure to the study where all result is explained into details for the readers understanding throughout the process.
3.1. Preparation
A preparation phase for this study includes the selection of study area, selection of equipment, and flight planning. DJI Phantom 4 Pro is used because it is suitable for mapping. It also a complete all-in-one UAV system that provides the aircraft and camera in one package. Phantom 4 Pro can resist wind speed up to 10m/s. The hover accuracy range between 0.5m for vertical and 1.5m for horizontal with GPS Positioning. For the camera, it uses 1-inch complementary metal-oxide-semiconductor sensors with 20 megapixels effective pixels. Thus, it has a great battery life and can capture a high-quality image. Figure 3 below shows the DJI Phantom 4 Pro that is used for UAV data collection in this study.
Next, Topcon GR-5 is used to produce ground control points (GCP) for the correction of image orientation that acquired from the photogrammetry survey and for the verification point (VP) for the sake of comparing spatial information collected by UAV technology with the GNSS reference points for slope mapping. Positioning information acquired from the GNSS survey is considered the best since it is commonly used to create a datum to start a survey. Topcon GR-5 has a rugged design and is guaranteed to resist 2m pole drop to concrete. It also has a dual hot-swappable battery which means it can be operated for a long time. Figure 4 shows the Topcon GR-5 that is used to collect GNSS data for this study.

The flight planning was done using Drone Deploy freeware. The flight speed of 8-meter per second is chosen for this study because the UAV cannot be too fast to preserve the quality of each image, but it also cannot be too slow because the battery life of the UAV is limited. The flight height for the UAV is set to be 100m in altitude. The software estimates the resolutions of images taken to be 3cm per pixel. The overlap percentage that was selected for forwarding overlap is 80% and side overlap is 75%.

3.2. Data Acquisition

In this stage, it involves the establishment of GCP, establishment of VP, and flight mission. The establishment of GCP and VP was done using GNSS observation. The method of GNSS observation that was used is Real-Time Kinetic Network (RTK-Net) which provide good accuracy for slope mapping purpose. GCP is used to correct the image orientation for the photogrammetric process. According to Oniga et al. [4] stated a density of one GCP is needed for every 200m square area to obtain a high-quality final product. However, for economic and time limitations, a total of 10 GCP are established around the study area which already gives enough references for photogrammetric processing. Verification points (VP) are established for this study as a real benchmark for quality checking purposes. VP is used to differentiate the accuracy of the topographic model produces from the photogrammetric method and conventional total station method. A total number of 27 VP are established around the study area. Figure 5 below shows the distribution of GCP and VP around the study area.

![Figure 5](image1.jpg)  ![Figure 5](image2.jpg)

**Figure 5.** Distribution of GCP (a) and the verification points (b)
3.3. Data Processing

The data processing involved in this phase is photogrammetric processing and the export of GNSS Raw Data. For the photogrammetric processing, it was done using the Agisoft Metashape Software. The processing that was conducted involved aligning photos, building dense point cloud, building mesh, building model texture, building DEM, setting of the coordinate system, placement of markers for the GCP, classification, and finally building DTM. Figure 6 below shows the product of photogrammetric processing using Agisoft Metashape software that is DTM.

![Digital Terrain Model](image)

**Figure 6. Digital Terrain Model**

GNSS raw data were exported to the Topcon Tools software. Every 10 points of GCP and 27 points of VP are exported to get the positional information of each point. The observation is then proved to be in good position through differentiation with established CRM that is also observed through this method. Table 1 below shows the observed coordinates for 10 GCP through RTK-Net GNSS method with WGS84 datum.

| GCP | Latitude       | Longitude      | Elevation |
|-----|---------------|----------------|-----------|
| 1   | 6.446002964   | 100.276108100  | 21.060    |
| 2   | 6.446633479   | 100.276366300  | 27.272    |
| 3   | 6.446735026   | 100.277020500  | 31.608    |
| 4   | 6.44670416    | 100.277662800  | 25.389    |
| 5   | 6.44693324    | 100.277768700  | 34.790    |
| 6   | 6.447548671   | 100.276965700  | 35.893    |
| 7   | 6.447252586   | 100.275666300  | 21.765    |
| 8   | 6.448014588   | 100.276230600  | 38.080    |
| 9   | 6.448629872   | 100.275296500  | 20.310    |
| 10  | 6.448634929   | 100.276838400  | 36.876    |

**Table 1. Coordinate of GCP using GNSS Method in WGS84**
3.4. Data Analysis
The analysis is to study the effect of slope elevation and slope angle on the vertical accuracy of spatial information collected by using UAV technology will be done using ArcGIS Software where the characteristic of the slope in the study area will be generated from the DTM data such as the slope contour, slope map, and the Triangular Irregular Network (TIN) of the slope. The location of each VP are then further classified into different classes based on their steepness and elevations. The error within each class for vertical are then calculated using RMSE and then compares to each other to see the effect of slope on the vertical accuracy of spatial information collected by using UAV technology. RMSE calculation is defined by using the mean error equation and standard deviation. The RMSE error can be calculated using the following formula.

\[ RMSE_x = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_{i(map)} - x_{i(surveyed)})^2} \]

where \( x_{i(map)} \) is the coordinate in the specified direction of the \( i^{th} \) verification point in the data set, \( x_{i(surveyed)} \) is the coordinate in the specified direction of the \( i^{th} \) verification point in the independent source of higher accuracy, \( n \) is the number of verification points tested, and \( i \) is an integer ranging from 1 to \( n \). RMSE identification must follow the National Standard for Spatial Data Accuracy (NSSDA) documented equations for computations at a 95% confidence interval [1]. These statistics assume that errors approximate a normal error distribution and that the mean error is small relative to the target accuracy. RMSE for vertical value can be used to classify the quality of digital elevation data.

4. Result and Analysis
This part discussed the result for the first objective that is the effect of slope elevation on the vertical accuracy of spatial information collected by using UAV technology and then follows with the result for the second objective that is the effect of slope steepness on the accuracy of spatial information collected by using UAV technology.

4.1. Data of Slope Elevation
In Figure 7(a) below shows the Contour Map of the study area that has been produced from the DTM based on the Spatial Information collected by using photogrammetry method. The contour interval of the map produced is 1 meter. From the contour map, the TIN Map in Figure 7(b) has been produced. The TIN has been divided into five different classes with a 5m elevation interval from 15m to 40m. The location of the VP has been inserted into the map to know the position of each point located in which classes. From the map, it is shown that 3 points are in 15m-20m elevation, 7 points in the 20m-25m elevation, 7 points in the 25m-30m elevation, 7 points in the 30m-35m elevation and 3 points in the 35m-40m elevation classes.
From the TIN map that has been produced, the VP is different based on their elevation classes which are 15m-20m, 20m-25m, 25m-30m, 30m-35m, 35m-40m. The RMSEz are calculated for each class in order to analyze the effect of different slope elevation on the vertical accuracy of DTM produced. The results of RMSEz for each class are shown in Table 2 below. To understand the pattern of error, the line chart in Figure 8 has been made. From Table 2 and Figure 8, it shows that the 35m-40m elevation class shows the largest error which is 0.135m. While the 25m-30m class has the least error, which is 0.060m. The error pattern that is shown in Figure 8 is slightly unclear where the error increase between 15m-20m class and 20m-25m class then it had a major dropdown in error for 25m-30m class. The error then increases smoothly from the 25m-30m class to the 35m-40m class.

The high elevation error for class 15m-20m may be caused by the placement of VP1 at the edge of a sum where it caused a 14.1cm error in elevation. The high elevation error for 20m-25m class on the other hand is caused by the existence of point V23 which has an error of 31.7cm which is believed to be caused by the position of the VP at a high steepness area. This assumption is proven in the results for objective 2. If VP1 and VP23 are removed from this analysis, the graph will show a smooth increase in error when the elevation increases.

### Table 2. RMSEz for VP Based on Different Elevation Classes

| Slope Elevation (m) | RMSEz |
|---------------------|-------|
| 15-20               | 0.082 |
| 20-25               | 0.123 |
4.2. Effect of Slope Steepness

Figure 9 shows the Slope Map that has been generated from the DTM that has been created through photogrammetric processing. The map classifies the study area based on the slope steepness. The slope steepness has been classified into five different classes. The location of the VP has been inserted into the map to know the position of each point belongs in which classes. From the attributes, it was identified that 10 VP was in <5° class, 9 VP was in 5°-10° class, 4 VP in the 10°-15° class, 1 VP in the 15°-20° class, and 3 VP in the <20° class.
From the Slope Map that has been produced, the VP are differentiate based on their steepness classes that are <5°, 5°-10°, 10°-15°, 15°-20°, and >20°. The RMSEz are calculated for each class to analyze the effect of different slope steepness on the vertical accuracy of spatial information collected using UAV technology. The results from the calculations of RMSEz for each class are shown in Table 3 below. For further analyze process on the pattern of error, the line chart in Figure 10 has been made. From Table 3 and Figure 10, the results show that the highest error for vertical is at the steepness of >20° and the least error is at 10°-15° slope steepness. The error pattern is not smooth where it suddenly drops at 10°-15° classes. From further analysis of the results, it shows that VP that causing the increase in error for class <5° and 5°-10° are V19, V20 and V21 which are placed in the high elevation area. If those three points are removed from this analysis, the graph will show a smooth increase in error when the slope steepness increases.

**Table 3. RMSEz for VP Based on Different Elevation Classes**

| Slope Angle | RMSEz |
|-------------|-------|
| <5°         | 0.072 |
| 5°-10°      | 0.068 |
| 10°-15°     | 0.057 |
| 15°-20°     | 0.101 |
| >20°        | 0.225 |

**Figure 10. Line Chart of RMSEz for Different Slope Steepness Classes**

### 5. Conclusion

In conclusion, both objectives of this study are successfully achieved in this study. All the results obtained are answering the objectives of the study. From the result and analysis, although there is some error in the data that triggered by the effect of slope steepness on the accuracy of spatial information, it was proven that elevation of a slope affects the accuracy of spatial information acquired by using a multi-rotor UAV. This is because when the VP that has the error from slope steepness is removed, the high elevation area of the slope is shown to have more error than the low elevation area.

The second objective, it was proven that steepness of a slope affects the accuracy of spatial information acquired by using a multi-rotor UAV. This is because when the VP that have the error from high slope elevation are removed, the steeper area of the slope is shown to have more error than the leaner area.
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