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Accuracy Assessment of Height Coordinate Using Unmanned Aerial Vehicle Images Based On Leveling Height

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Abstract

Most of the Unmanned Aerial Vehicle (UAV) images studies are focusing on the horizontal plane with minimal covered on its height values. This thesis will study about the accuracy assessment in height coordinates using UAV images processing based on orthometric height observation data. In this study, Agisoft PhotoScan v0.9.0 and Global Mapper v15.2.3 are the software used for the processing and analysis. Ground control points and check points were established using leveling method. There are two photogrammetric products produced in this study such as orthophoto and digital elevation model (DEM). The analyses of the photogrammetric products were performed based on different ground control point of orthometric height levelling data. The results of this study showed that the height accuracy of photogrammetric products using UAV images processing based on 10 GCPs produced better accuracy than 5 GCPs. RMSE values of check point height coordinates based on data from leveling method are ± 0.161 meter for 5 GCPs and ± 0.116 meter for 10 GCPs. As conclusion, UAV images can be used to generate DEM that give height coordinate values with sub-meter accuracy.

Key-word: - Unmanned Aerial Vehicle (UAV), orthometric height, leveling method

1. Introduction

Photogrammetric technique becomes faster, simpler and lower cost due to rapid development of technologies in mapping. The development in digital technologies has increased the reliability in data captured. Although the Unmanned Aerial Vehicle (UAV) was found that capable in producing digital orthophoto and digital map, but most of the studies are focusing on the horizontal plane with minimal covered on its height values. There are many factors that can affect the height coordinates such as camera lens (Tahar, 2013), flying height (Tahar, 2013), image resolution (Zarco-Tejadaa et al., 2014), digital camera format (Ahmad, 2011) and many more.

This thesis will study about the accuracy assessment in height measurement by using digital elevation model (DEM) generated from processed UAV images comparing with known height values of ground control points (GCP). The data of ground control points will establish using the leveling method. The study is expected to provide contribution for an easy and fast way in getting height points value other than using conventional method such as leveling. In this study, UAV is used as a platform to capture digital image using high resolution digital camera. The study area is surrounding the Universiti Teknologi Malaysia (UTM).

From the previous research, there are many factors that influence the height coordinate. Tahar et al. (2012), in his study using UAV on production of slope map, he found that each coordinates of easting; northing and height recorded the RMSE value of +1.342, +1.660 and +4.666 meters. The result shows a big error on height value.

He deduces that a big error on height value might be caused by the auto tie points that were not well established, which were being effected due to the image resolution, color balancing and image quality itself such as blurring effects. Ahmad (2011), in his research using low altitude UAV for digital mapping, the differences in height coordinates between ground height from GPS and ground height from Erdas Imagine software product reached 1.595 meters. In his research, he used a small format digital camera and high accuracy could be achieved by the large format metric camera.

2. Methodology

Generally, there are four (4) phases or stages involved in this study. Each phase of the study describes as the procedure to achieve the objective of the study. Phase 1 is the preparation stage. This stage involved the preparation to the instruments or equipment's used, the software used, the study area, the camera used and the design of the flight planning. Phase 2 is data acquisition. The main data need to be collected at the study area are UAV images and GCPs. In phase 3, there are several software will be used to do the data processing. Agisoft PhotoScan version 0.9.0 and Global Mapper version 15.2.3 are used to process UAV images. Topcon Tools version 8.2.3 is used to convert GPS ellipsoidal height to GPS orthometric height. The last phase is data analysis. In this stage, qualitative and quantitative assessment will be evaluated.

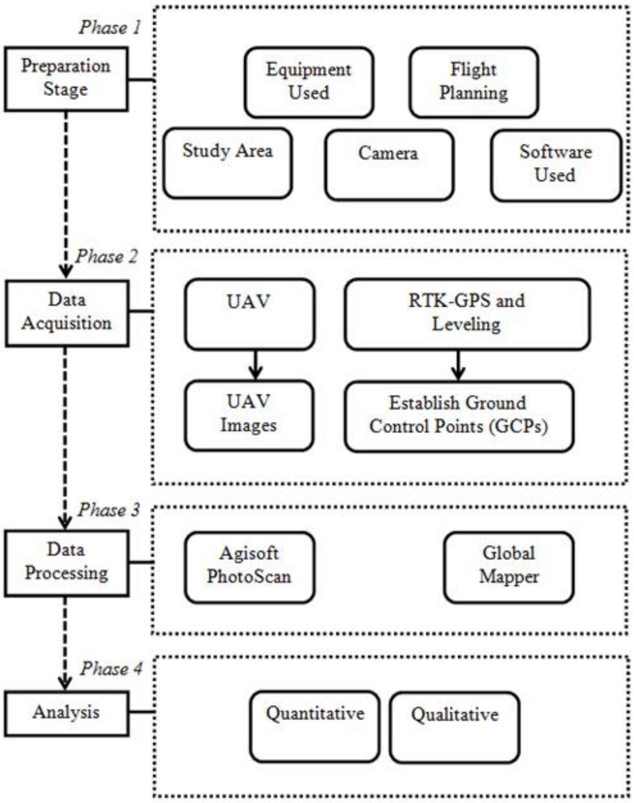

Figure 1: Flowchart of research methodology

High resolution digital camera was used to capture the images. The camera was attached at the UAV. Canon PowerShot SX230 HS digital camera has been used in acquiring model images. The Canon PowerShot digital camera has been attached at the bottom of UAV to capture aerial images during flight operation.

Camera calibration process gives several parameters of the camera. The parameter provided is beneficial in flight planning and photogrammetric processing. In this study, a printed calibration grid with A1 size paper was used to calibrate the digital camera. The calibration grid paper was used as camera calibration platform. Eight images of calibration grid paper were captured from four different positions. Each position has two images that were taken in portrait view and landscape view. The distance and angle between camera and calibration grid paper should be about the same during the capturing process. The images then were processed by using PhotoModeler software to produce calibration parameter of digital camera.

Table 1: The result of camera calibration

Camera Parameter: Canon PowerShot SX230 HS digital camera			
Focal Length	4.647674 mm	K1 – radial distortion 1	0.0009059
Xp – principal point x	3.155800 mm	K2 – radial distortion 2	-0.0000173
Yp – principal point y	2.395994 mm	K3 – radial distortion 3	0.0000000
Fw – format width	6.196596 mm	P1 – decentering distortion 1	-0.0009214
Fh – format height	4.648200 mm	P2 – decentering distortion 2	0.0011280

Basically, the minimum two persons are needed to do the autonomous UAV. One person will act as operator that will control UAV during launching and landing while the other person will monitor the UAV behavior and also to make sure UAV at the right flight line during flying mission. The UAV images will be captured by using digital camera that attached below the UAV. Ground control point (GCP) normally established after the aerial photography has been done. Several GCPs were selected refer to UAV images which enclosed the overlapped area.

In this study, height coordinates at UAV images and in field refers to mean sea level (MSL) or orthomertic height. For the data acquisition, GPS Real Time Kinematic technique was used for the determination of ground control points and check points at the study area. Leveling observation is carried out to establish vertical control point. In this study, the leveling observation is carried out from the point with known height value to the GCPs and CPs at the study area. There are 28 photos or UAV images were used for orthophoto and DEM generation using Agisoft PhotoScan software. Ground control point's data obtained from leveling method is used along the processes in order to generate photogrammetric products.

3. Data Processing

The processing of UAV data can be separated into two (2) stages. The first stage of processing is to create digital orthophoto and DEM by using Agisoft PhotoScan. Global Mapper software is applied for analysis in the second stage. The steps or the procedures involved in the processing using Agisoft PhotoScan software are setting the parameter, add photo, align photo, remove spark, build geometry, build texture, export orthophoto, export DEM and add GCP. More ground control point makes the result better. The final goal of images processing with Agisoft PhotoScan is to construct a textured 3D model (Agisoft, 2013).

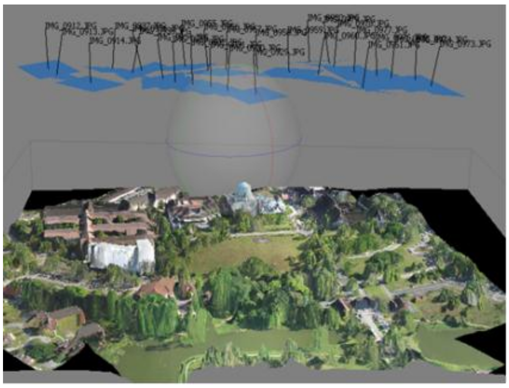

Figure 2: The 3D image after building texture processed

There are two types of analysis can be occupied that are quantitative and qualitative assessments. In this study, quantitative assessments involved the calculation to the coordinate's height. The qualitative assessment is more to analyze the quality of orthophoto and DEM generation. The quantitative assessment is performing by using Root Mean Square Error (RMSE) formula to calculate the accuracy of DEM. It is because DEM represents a topographical surface such as slope, aspect and spot height. The height coordinates on the ground were compared with height coordinates values estimates established by photogrammetric products. The formula or equation to calculate RMSE for height is shown in Equation (1) (Tahar et al., 2011). This study will focus on height coordinates RMSE for the accuracy assessment.

$$\text{RMSEz} = \pm\sqrt{\frac{\sum_{i=1}^{i=n}(Z_i - Z_o)^2}{n}} \qquad \text{……………………………………..(1)}$$

Where:

Zi	=	Observed heights from field survey
Zo	=	Observed heights from Agisoft Photoscan
n	=	Total number of points observation

Quantitative analysis can be done by calculating the data to get their RMSE value. Quantitative analyses in this study generally are carried out by comparison height coordinates of points using leveling method and height coordinates of photogrammetric products (UAV images processing based on leveling method) from Agisoft PhotoScan. Apart from that, the accuracy of photogrammetric products using UAV images processing based on 10 GCPs and 5 GCPs towards RMSE value is also studied.

4. Result and Analysis

Point analysis is carried out using Global Mapper software by overlay the orthophoto and DEM generated by Agisoft PhotoScan. By combining orthophoto and DEM, the East, North and height coordinates of interest point can be determined. Comparisons are made by comparing the control point's coordinates digital photogrammetric products with the coordinates gained from field survey.

There are seventeen (17) points have surveyed to use as ground control points and check points in this study. The points were surveyed using RTK-GPS for positioning and leveling method for heights. The comparisons are made by comparing the photogrammetric products using UAV images processing based on 10 GCPs and 5 GCPs. There are seven check points are used to perform the comparison.

There are several types of accuracy which can be used as a reference for orthophoto and digital elevation model (DEM) production assessment. In this study, the analysis is focused on the vertical accuracy assessment of DEM. For vertical accuracy of the derived DEM, American Society for Photogrammetry and Remote Sensing (ASPRS) has divided the vertical map accuracy standard into three classes. Table 1.2 shows the vertical map accuracy standard by ASPRS 1990 based on Class 1, Class 2 and Class 3 maps in feet unit.

Table 2: The vertical map accuracy standard by ASPRS 1990

Contour Interval (Feet)	ASPRS 1990 Class 1 Limiting RMSEz (Feet)	ASPRS 1990 Class 2 Limiting RMSEz (Feet)	ASPRS 1990 Class 3 Limiting RMSEz (Feet)
1	0.333	0.667	1.0
2	0.667	1.333	2.0
4	1.333	2.667	4.0
5	1.667	3.333	5.0
1 Feet = 0.304 meter			

The height coordinates obtained leveling method is compared with the coordinates from Agisoft PhotoScan product for point analysis. The point analysis is carried out by calculate their RMSE values. Table 1.3 shows the comparison between the check point coordinates (leveling method) and the coordinates obtained from Agisoft PhotoScan using UAV images processing based 10 GCPs. Table 1.4 shows the comparison between the check point coordinates (leveling method) and the coordinates obtained from Agisoft PhotoScan using UAV images processing based on 5 GCPs.

Table 3: The comparison between the check point coordinates (leveling method) and the coordinates obtained from Agisoft PhotoScan using UAV images processing based on 10 GCPs

No	Point	CP from leveling method Height (m)	CP from Agisoft PhotoScan (leveling method and 10 GCPs) Height (m)	Difference ∆H (m)
1	P2	33.819	33.943	-0.124
2	P4	33.926	33.867	0.059
3	P6	34.167	33.949	0.218
4	P8	34.272	34.129	0.143
5	P11	21.654	21.603	0.051
6	P15	18.779	18.72	0.059
7	P17	19.977	19.937	0.040
			RMSE	**± 0.116**

Table 4: The comparison between the check point coordinates (leveling method) and the coordinates obtained from Agisoft PhotoScan using UAV images processing based on 5 GCPs

No	Point	CP from leveling method Height (m)	CP from Agisoft PhotoScan (leveling method and 5 GCPs) Height (m)	Difference ∆H (m)
1	P2	33.819	34.086	-0.267
2	P4	33.926	33.962	-0.036
3	P6	34.167	33.893	0.274
4	P8	34.272	34.145	0.127
5	P11	21.654	21.630	0.024
6	P15	18.779	18.652	0.127
7	P17	19.977	20.013	-0.036
			RMSE	**± 0.161**

Besides that, the path profile of the study area is also generated using Global Mapper software v15.2.3. The path profile is created to view the surface condition based on the line features for visual analysis. The same path between photogrammetric products is created to get a vertical profile and to look for the different. Figure 1.3 shows the line feature to create path profile at the study area.

Figure 3: The line feature (yellow line) to create path profile at the study area

The path profile in this study shows the ground surface for lowland area and highland area. From the visualization to the path profile, there are slightly not many differences between the path profiles. Figure 1.4 shows the path profile of photogrammetric product (DEM) using UAV images processing based on 10 GCPs. Figure 1.5 shows the path profile of photogrammetric product (DEM) using UAV images processing based on 5 GCPs.

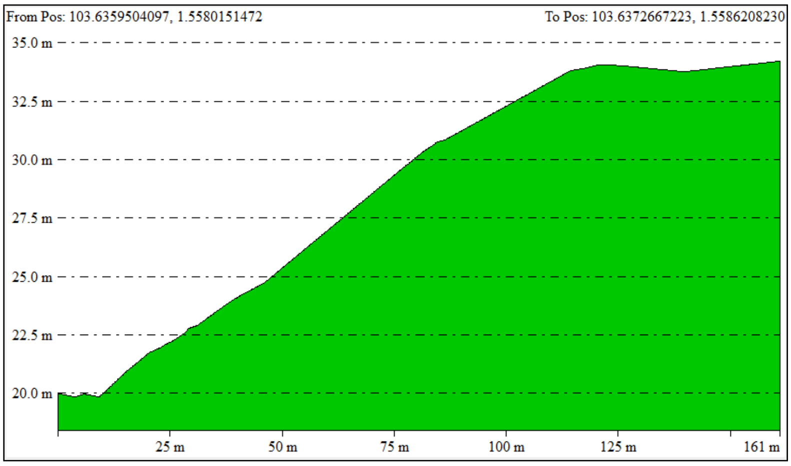

Figure 4: The path profile of photogrammetric product (DEM) using UAV images processing based on 10 GCPs

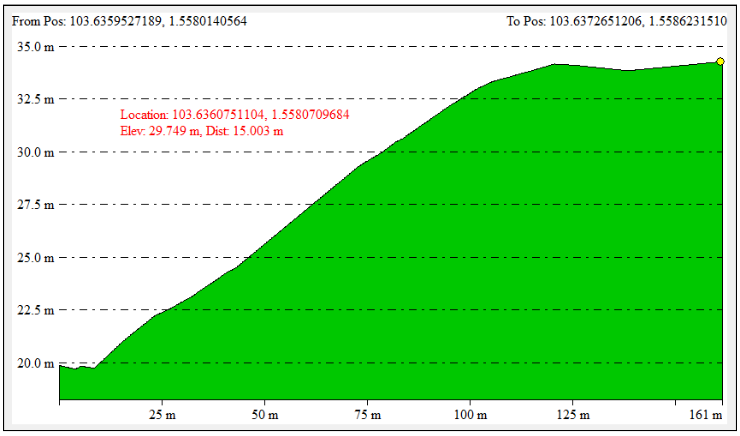

Figure 5: The path profile of photogrammetric product (DEM) using UAV images processing based on 5 GCPs

5. Conclusion

The analysis shows that the different number of GCP in photogrammetric processing give different accuracy in photogrammetric results and automatically achieve the objective. In this study, 10 GCPs used in processing give better result than 5 GCPs. However, it shows that the different in RMSE value is small. For small area, it has proved that 5 GCPs is enough to give accurate height value for an area covering 0.10 km². Finally, it can be concluded that UAV images can be used for obtain height coordinate and give good results.

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