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ACCURACY ASSESSMENT OF 3D PHOTOGRAMMETRIC MODEL FROM UNMANNED AERIAL VEHICLE SYSTEM

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Abstract:

Unmanned aerial vehicle (UAV) or well known as a drone is a common technique that has been used in the geospatial field for various applications as well as in three-dimensional modelling application. The UAV is an aerial vehicle that does not carry a human pilot, fly remotely or autonomous and able to carry a sensor to collect data. Nowadays, UAV has been widely used in three-dimensional modelling application around the world. It can model an accurate object in a three-dimensional view; besides that, it also can offer a cheaper solution than other techniques or systems. Therefore, the objectives of this research are to evaluate the accuracy assessment of the 3D building model that is generated from a non-metric camera integrated with a multi-rotor UAV system and also to investigate the effect of camera angle toward the quality of the 3D building model. Block T06 of the Faculty of Built Environment and Surveying was selected as a study area in this study. This building is under the management of Universiti Teknologi Malaysia, located in the district of Skudai, Johor. The quadcopter UAV system has been used to capture the high resolution of the building's aerial image from two different perspectives: nadir and oblique. Each set of aerial images were processed using photogrammetric software for producing a three-dimensional model of Blok T06. Two types of 3D building model have produced in this study which are 3D model-based nadir and oblique aerial photo and 3D model based on nadir aerial photo. Ground control point (GCP) and check point (CPs were established in the study area using the GPS rapid-static technique. Later, the processing of aerial triangulation and accuracy assessment were implementing using these points. A statistical equation was used for evaluating the quality of the three-dimensional model was generated in this research. 3D building model based on nadir and oblique aerial photo is more accurate with RMSE ±1.008m compared 3D building model-based nadir aerial photo with RMSE ±1.145m. In conclusion, the 3D building model of block T06 was successfully produced from UAV data based on UAV photogrammetry and the angle of camera also contributes towards the quality of 3D model in aerial photogrammetry.

Keywords:

3D modelling, Unmanned Aerial Vehicle, Photogrammetry, Accuracy

Introduction

Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena (Wolf and Dewitt, 2000; McGlone, 2004). While, photogrammetry comprises techniques concerned with making measurements of real-world objects and terrain features from images. Applications include the measuring of coordinates, quantification of distances, heights, areas, and volumes, 3D topographic mapping, the extraction of 3D point clouds for surface reconstructions, and the generation of digital elevation models and orthophotographs. The most recent development of point-cloud generation techniques with Structure from Motion–Multi-View Stereo (SfM-MVS) has led to significant advances in 3D geodata acquisition from small format aerial photograph (SFAP) and UAV imagery. The Word of UAV photogrammetry was appearing because of the capability of UAV system integrated with photogrammetry concept and principle to make UAV system useful used in mapping and three-dimensional model application. According to (Eisenbeiss, 2009), UAV Photogrammetry can be described as a new photogrammetric measurement platform, which is able to operate as either remote controlled, semi-autonomous, full-autonomous or combination of these modes without a pilot present inside the platform and use the photogrammetric concept for perform image processing. UAV system have advantages compared with other geospatial technologies. Among of these advantages, UAV able to capture many aerial images in short time. In additional, the aerial images taken are high-resolution image and clear where these criteria are among of the important factors that will helps on production an accurate photogrammetric result. Besides that, it is also having advantages from perspective of cost because the operation cost normally is in reasonable range compared with others system. This is because UAV system is not very complicated and easy to handle without required a professional and skilful pilot. Today, many researchers have been conducted out using UAV technology in many fields including 3D modelling. UAV can be used to produce the high-resolution topographic map, accurate elevation model, contour line and 3D model. Nowadays, 3D modelling has become very important in mapping application because the 3D model can be used for extraction of real information in 3D view. 3D model is very important because it can give the information on the ground in a real situation where the 2D map unable to do so. 3D model is a current demand in many countries around the world including Malaysia. There are many techniques that can be used for the generation of the 3D model such as TLS and Lidar. However, these techniques are very expensive. Therefore, the UAV system can be used as an alternative technique. The development of the UAV system has enhanced the ability of photogrammetry. For example, the creation of the 3D model can be done in short time and accurate model. As mentioned before, the UAV system offers many advantages compared to other technique. Among these advantages is the aerial images of the object can be completed within a short period for the small area and large area. Additionally, the 3D model can provide a visualization of the whole object.

3D modelling techniques can be used in Smart City, cadastral, hydrographic, strata, mapping and others (Darwin et al., 2014). Therefore, one of the research objectives is to investigate the capability of UAV system in generating three-dimensional model of building in the study area.

There are many factors that influenced the quality and accuracy of 3D model when using the UAV system for acquiring point cloud of the object such as the type of platform, altitude, distribution of control points, type of sensor, density of points clouds, angle of camera for data acquisition and many more. In this study, the main aim is to investigate the effect of camera angle toward the quality of the 3D building model. Basically, the aerial photo of the object commonly taken from nadir perspective or the camera's angle is 180 degrees. Nowadays, UAV manufacturers produce camera that can be adjusted at certain angle and the movement of the UAV can be programmed in various modes such as orbiting the target object. According to (Corey and Su, 2017), it is more appropriate to acquire an oblique aerial image to obtain more detail data and create a more accurate 3D model. An oblique aerial image is capable to capture a vertical element of the object like the wall where the nadir aerial image only capable to capture the top of the building. Therefore, to obtain a complete aerial photo of the building, it is necessary to capture the aerial photo on both perspectives. Thus, this study evaluates the effect of the camera angle toward the quality of the 3D building model.

Methodology

Methodology of this study is divided into three main phases. The first phase comprises of literature review and planning. While, the second phase is about the data collection where two types of data were acquired in this phase which include establishment of ground control points (GCPs), check points (CPs) and aerial images of the building. The last phase is investigating the quality of the 3D building model by using statistical equation. Figure 1 illustrates the flow chart in this study.

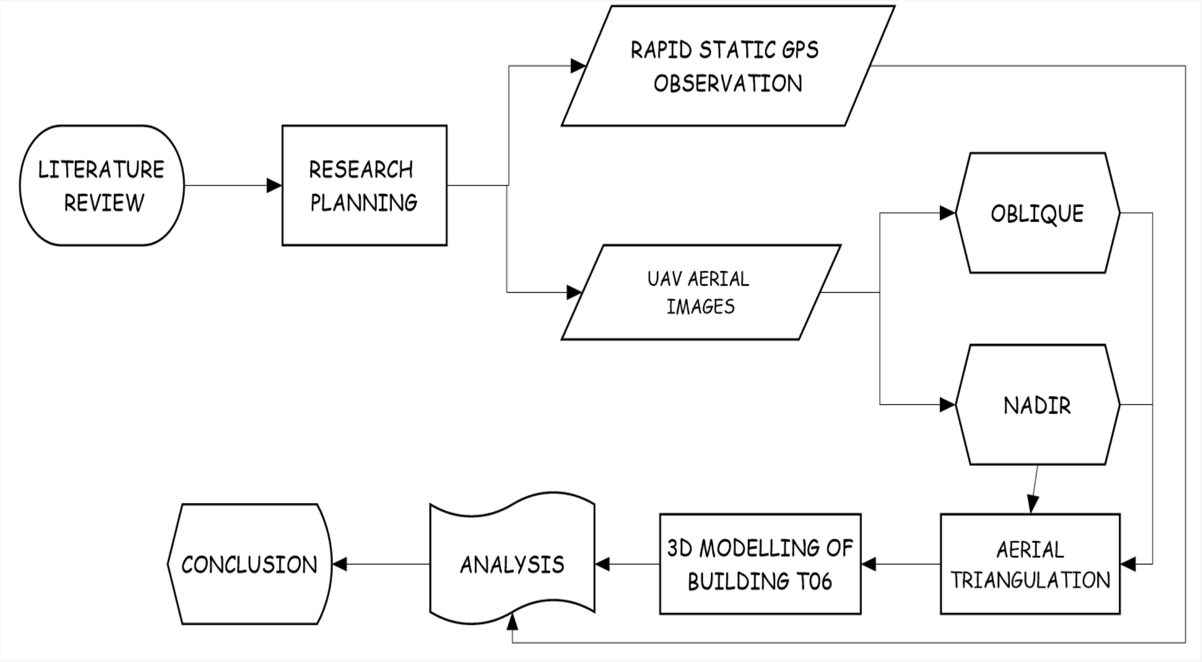

Figure 1: Flow Chart of The Study

Study Area

The Building T06 of Faculty of Built Environment and Surveying, Universiti Teknologi Malaysia (UTM) at Skudai, Johor, Malaysia. The building is located at coordinates 1.561985 Latitude and 103.655561 Longitude. The total area of the building is about 1.40 hectare. The building is located in the various shape of topography where certain place is hilly area and other place is flat area. The location of Building T06 is shown in Figure 2.

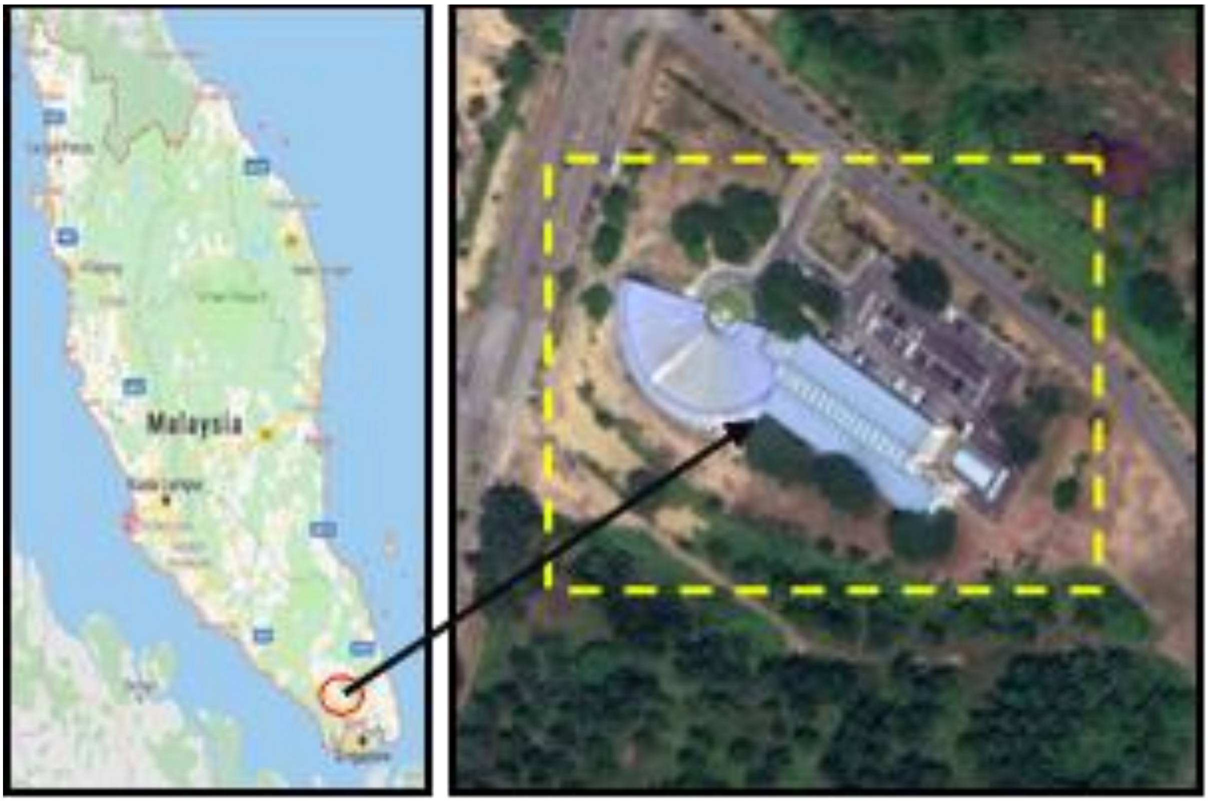

Figure 2: Location of Block T06 in the Google Maps

Data Collection and Data Processing

The camera calibration process must be done before the data acquisition of aerial photos begin. The camera used in this study is non-metric camera where the interior and exterior parameters are unstable and not specialised design for mapping. It is necessary to calibrate the camera to obtain the good quality of the model. Calibration of the camera was done by using the DJI Assistant 2 where this software was developed by DJI company and very suitable used for calibrating the camera attached to the UAV. The quadcopter UAV system was used to capture the aerial photographs of the building from two different perspectives. The aerial photos of the building were acquired from nadir perspective or 180 degrees of the camera's angle. The UAV was flown at 40 meters altitude in autonomous mode using grid flight line. In order to investigate the effect of the camera angle toward the quality of the 3D model. The camera angle was set 45 degree and the UAV was capture the aerial photo by orbiting the building at the same flight altitude. Therefore, there are two sets of aerial photographs were collected in this study. In the flight planning, several parameters are required to set up such as the side overlap and end overlap. In photogrammetry, the minimum overlapping of end lap and side lap are 60 percent and 30 percent respectively. Normally, this concept is usually applied for conventional data acquisition of aerial photogrammetry. However, in close-range photogrammetry especially using UAV system, the percentage of side lap and end lap must be greater which are 80 percent and 60 percent. This is due to the wind resistant where the stability of the UAV system during the data capture is disturb and unstable. It will affect the overlapping of end lap and side lap. GCP and CP were also used for geometric correction of model. Both points were established in the study area using GPS rapid static method. The GPS instrument was used for observing each point for 30 minutes. The height of instrument was measured at each point. Later, the information is used during the data processing of GPS and CP. There are 10 GCPs and 11 CPs were established in the study area. Normally, GCP is used for geometric correction of the model meanwhile CP is used for accuracy assessment of final output. A target with X symbol was place in the study area to represent a GCP and CP on the ground. The location of GCP and CP are shown in Figure 3.

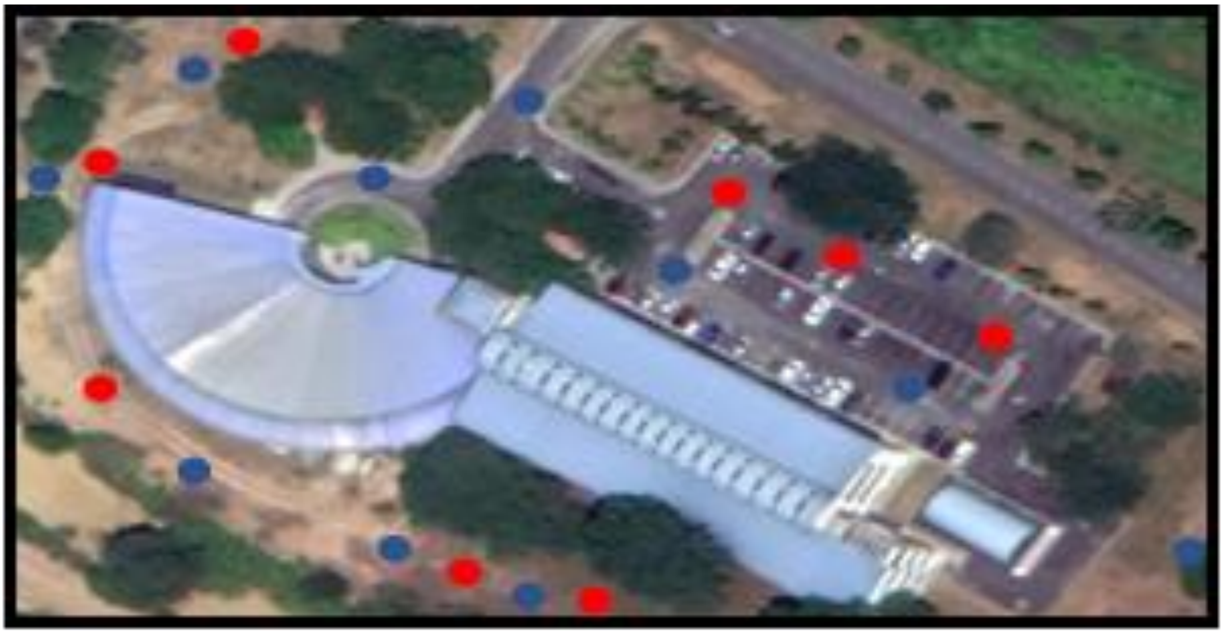

Figure 3: Distribution of GCP (Blue Dot) and CP (Red Dot) in The Study Area

The processing of the aerial photo was divided into two parts. The aerial photographs of building acquired from nadir perspective were processed using photogrammetric software. The second part is the aerial photographs of nadir perspective and oblique perspective was merged to produce a 3D building model. Generally, the step of processing is divided into four main parts. First, the location of aerial photograph was estimated based on the coordinate system extracted from the digital camera. Then, a sparse point cloud is generated. The unwanted point cloud appeared on the model were eliminated. The examples of point cloud that are eliminated include trees, car, gazebo and others. Later, a dense point cloud model of the building is generated, and the projection of the point cloud is corrected using the GCP that were established in the study area. The level of detail 3 or LOD3 is used for generation of the final form of the 3D building model.

Results and Analysis

The main output of this study is 3D building model of Block T06. There are two types of model where the first result is the 3D model produced using aerial the aerial photo taken from the nadir perspective and the second result is the 3D model produce using two sets of data which are the merging of aerial photo taken from nadir and oblique perspectives. Surface from Motion

(SfM) was used for performing aerial triangulation of both models. Pix4D software was used for generation of 3D building model for both cases. The results of 3D building model for both cases are shown in Figure 4 and Figure 5 respectively. While statistical approach which is RMSE equation was used to evaluate the quality of the 3D building. The results of accuracy assessment of both building models are shown in Table1 and Table 2.

Figure 4: The 3D Building Model Based on Nadir Aerial Photo.

Figure 5: The 3D Building Model Based on Nadir and Oblique Aerial Images.

Based on Figure 4 and figure 5, the 3D building model of Block T06 were successful generated using SfM based software which is Pix4D Mapper. Both 3D model building generated in this study were evaluated by using equation 1 and equation 2. RMSE equation can be defined as the standard deviation of the residuals or prediction errors (Chai and Draxler, 2014). Residuals are a measure of how far from the regression line data points. It is a measure of how spread out these residuals. This equation is commonly used for evaluated the quality of photogrammetry product including 3D model (Tahar, 2015; Udin et. al., 2012).

$$\text{RMSE}\ (X, Y) = \pm\sqrt{\sum \frac{(\mathcal{X}-x)^2 + (\mathcal{Y}-y)^2}{\text{N}}} \quad (1)$$

$$\text{RMSE}\ (Z) = \pm\sqrt{\sum \frac{(\mathcal{Z}-z)^2}{\text{N}}} \quad (2)$$

Where,

Z = Height value on the ground
z = Height value on the image.
X, Y = Planimetry coordinate on the ground.
x,y = Planimetry coordinate on the image.
N = Number of check point (CP)

Table 1: RMSE Value of 3D Building Model Nadir Perspective

CP	GPS			Model			Different (m)		
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)	ΔX	ΔY	ΔZ
CP1	628824.118	172753.018	28.366	628825.037	172752.555	27.362	0.919	-0.463	-1.004
CP2	628806.301	172773.945	26.3601	628806.197	172772.29	27.853	-0.104	-1.655	1.493
CP3	628834.026	172735.194	27.8099	628834.65	172735.527	27.300	0.624	0.333	-0.510
CP4	628862.530	172727.409	25.3661	628862.743	172727.337	26.594	0.213	-0.072	1.228
CP5	628870.408	172690.732	26.7263	628869.383	172690.096	26.625	-1.025	-0.636	-0.101
CP6	628810.123	172686.241	28.5514	628808.634	172685.806	27.183	-1.489	-0.435	-1.368
CP9	628747.915	172782.047	25.556	628747.344	172780.259	28.275	-0.571	-1.788	2.719
CP10	628781.667	172795.471	29.5348	628780.026	172794.624	27.688	-1.641	-0.847	-1.847
						RMSE	XY=±1.235		Z=±1.487
						Average	±1.145		

Table 2: The RMSE Value of 3D Building Model from Nadir and Oblique Perspective

CP	GPS			Model			Different (m)		
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)	ΔX	ΔY	ΔZ
CP1	628824.118	172753.018	28.366	628826.233	172753.124	26.860	2.115	0.106	-1.506
CP2	628806.301	172773.945	26.3601	628807.917	172773.761	27.201	1.616	-0.184	0.841
CP3	628834.026	172735.194	27.8099	628835.705	172735.296	27.035	1.679	0.102	-0.775
CP4	628862.530	172727.409	25.3661	628862.992	172726.871	26.200	0.462	-0.538	0.834
CP5	628870.408	172690.732	26.7263	628869.788	172690.934	26.895	-0.62	0.202	0.169
CP6	628810.123	172686.241	28.5514	628808.988	172685.968	28.185	-1.135	-0.273	-0.366
CP9	628747.915	172782.047	25.556	628748.055	172781.903	28.163	0.140	-0.144	2.607
CP10	628781.667	172795.471	29.5348	628781.53	172794.947	26.936	-0.137	-0.524	-2.600
						RMSE	XY=±0.937		Z=±1.099
						Average	±1.008		

Accuracy assessment is carried out by comparing between planimetry coordinate on the ground and planimetry coordinate on the image. Besides that, height of the model was also analysed by comparing the height value on the ground and height value on the image. The RMSE of planimetry and height are calculated using equation 1 and equation 2. Orthophoto and DSM were used to extracts the information of planimetry and height coordinates of the image. Table 2 shows the RMSE of 3D building model based on nadir and oblique aerial photo where the RMSE is ±1.008 meter. This value indicates the 3D building model of Block T06 is more accurate compared to the 3D building model based on nadir aerial photo where the RMSE is ±1.145 meter (Table 1). The different between both RMSE is ± 0.137 meter. In additional, the RMSE of planimetric for 3D building model-based nadir and oblique aerial photo shows ±0.937 meter (Table 2) which is lower than RMSE of planimetric for nadir perspective where the RMSE value is ±1.235 meter (Table 1). For RMSE of height, the 3D building model based on nadir and oblique is lower, the value is ±1.099 meter (Table 2) and the RMSE of height for nadir aerial photo is ±1.487 meter (Table 1). Based on the RMSE value, the 3D building model based on nadir and oblique aerial photo shows the value is lower than the 3D building model based on nadir. This trend indicates that the 3D building model using nadir and oblique aerial photo is more accurate and superior because the lowest value of RMSE shows the prediction error of data is low.

Production of 3D building model using nadir and oblique aerial photograph is capable to produce more accurate and higher quality of the 3D building model rather than only using aerial photograph from one perspective only which is in this study is nadir perspective. Acquisition of aerial photograph from nadir and oblique perspective is able to produce a complete view and higher dense points cloud of the object. In SfM based software, the number of point cloud will affect the quality of the 3D model where more dense point cloud is capable to produce more accurate model. In addition, a very detail of the 3D building model also could be obtained when the number of point cloud increases.

Conclusion

This study has proven that the UAV system and photogrammetric technique is able to produce 3D building model of Block T06 successfully. Aerial photograph of the building can be acquired from two perspectives which are nadir and oblique where the angle of the camera is adjusted to 45 degrees. In this case, the 3D building model based on nadir and oblique aerial photo is more accurate and good quality compared to 3D building model based on nadir aerial photograph. The angle of camera also contributes towards the quality of 3D model in aerial photogrammetry.

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