

# Assessment of Photogrammetric Mapping Accuracy Based on Variation Flying Altitude Using Unmanned Aerial Vehicle

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**Abstract.** Photogrammetry is the earliest technique used to collect data for topographic mapping. The recent development in aerial photogrammetry is the used of large format digital aerial camera for producing topographic map. The aerial photograph can be in the form of metric or non-metric imagery. The cost of mapping using aerial photogrammetry is very expensive. In certain application, there is a need to map small area with limited budget. Due to the development of technology, small format aerial photogrammetry technology has been introduced and offers many advantages. Currently, digital map can be extracted from digital aerial imagery of small format camera mounted on light weight platform such as unmanned aerial vehicle (UAV). This study utilizes UAV system for large scale stream mapping. The first objective of this study is to investigate the use of light weight rotary-wing UAV for stream mapping based on different flying height. Aerial photograph were acquired at 60% forward lap and 30% sidelap specifications. Ground control points and check points were established using Total Station technique. The digital camera attached to the UAV was calibrated and the recovered camera calibration parameters were then used in the digital images processing. The second objective is to determine the accuracy of the photogrammetric output. In this study, the photogrammetric output such as stereomodel in three dimensional (3D), contour lines, digital elevation model (DEM) and orthophoto were produced from a small stream of 200m long and 10m width. The research output is evaluated for planimetry and vertical accuracy using root mean square error (RMSE). Based on the finding, sub-meter accuracy is achieved and the RMSE value decreases as the flying height increases. The difference is relatively small. Finally, this study shows that UAV is very useful platform for obtaining aerial photograph and subsequently used for photogrammetric mapping and other applications.

## 1. Introduction

Photogrammetry means a three dimensional coordinate measuring technique which utilizes photographs as the fundamental medium for measurement. Photogrammetry can be divided into aerial photogrammetry and terrestrial photogrammetry. The primary use of aerial photogrammetry is mapping. Both planimetric and topographic maps can be prepared at a specified standard of accuracy from aerial photographs. However, aerial photogrammetry is expensive and improper technique especially for large scale mapping [1]. It is expensive and time consuming due to appropriate planning in order to gain efficient information. Aerial photogrammetry involves the acquisition of aerial photograph using metric camera from aircraft, helicopter, hot air balloon, kite or parachute. Besides, it needs photogrammetry expertise to control the camera during flying mode. Apart from large format<sup>1</sup>

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metric camera, small format non-metric camera can also be used for aerial photography, however, it covers only small area.

The demands of aerial photogrammetry have increased especially after the development of design, research and production of unmanned aerial vehicle (UAV) platform [2]. The small format digital camera can be placed in a balloon light aircraft such as gliders, rotary and fixed wing UAV and other platform. This platform offers several flight modes such as manual, semi-automated or fully-automated. [3]. UAV has been applied in many applications such as farming, surveillance, road maintenance, recording and documentation of cultural heritage [4]. In this study, two main hardware are used which include the light weight rotary-wing UAV and high resolution digital camera. Y6 UAV is easy to build and offers a great way into the world of multirotor UAV flying, aerial photography and more and at a very affordable price. The Y frame configuration gives a much better camera view for aerial photography and the 6 motors (two per arm) configuration also offers much greater levels of safety. The Y6 UAV is very stable, which makes it together with its power, a suitable platform for imagery gathering. In this study, Sony Nex-5N digital camera is attached to the Y6 unmanned aerial vehicle as data acquisition system in acquiring the aerial photograph of the study area. Figure 1 shows the Y6 UAV. Figure 2 shows the Sony Alpha NEX-5N digital camera with interactive 16.1 megapixel. The digital camera has tiltable 3.0" touch liquid crystal display (LCD) screen.



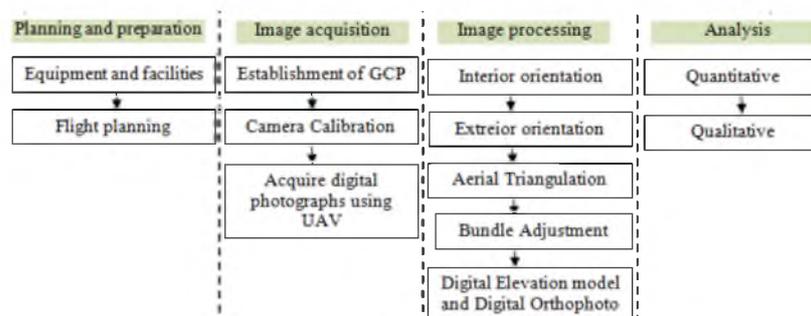
**Figure 1.** Y6 UAV.



**Figure 2.** Alpa NEX-5N digital camera

## 2. Research methodology

The research methodology adopted in this study is shown in Figure 3. Each phase of the study is explained as the procedure of orthophoto production using digital aerial imagery.



**Figure 3.** Flow chart of research methodology.

### 2.1. Planning stage

This phase involved the study area, software and instrument selection such as digital camera and types of UAV platform. The digital aerial imagery is processed using digital photogrammetric software for producing orthophoto of the stream. Total Station is used to establish ground control point (GCP) and check points (CP) for accuracy assessment. The study area is an area in the precinct of Universiti

Teknologi Malaysia (UTM) main campus in Johor Bahru, Malaysia. The study area is a stream of 200m long regulated stretch. Water level and discharge are fairly low and constant in the natural bed of the stream and the shallow waters are usually clear. Stream width varies between 6m to 10m. Figure 4 shows the study area.



**Figure 4.** Study area

### 2.2. Preparation stage

This stage involves flight planning, photographic scale, flying height of UAV, coverage and others are determined before acquisition of digital aerial images. It involved the determination of 60% side lap and 30% end lap. A well-organized image requires an essential arrangement because it is vital for data processing and analysis.

### 2.3. Establishment of Ground Control Point and Check Point

The GCP and CP were established before the aerial photography mission. About 33 white crosses were painted as GCP which enclosed the study area. The GCPs were fixed along both side of the stream flood plain and coordinated by Total Station. Twenty-three (23) points were used as GCP with full 3D (XYZ) coordinates points and ten (10) points were used as CPs.

### 2.4. Camera calibration

Camera calibration is carried to recover camera calibration parameters that are needed for interior orientation before performing digital image processing. It is done by capturing convergence image of a test field which comprises of several targets and scale bar. The method used is self-calibration bundle adjustment method. After data acquisition of the test field, the images were processed using a camera calibration software to recover the camera calibration parameters as shown in Table 1. The camera calibration parameters consist of the focal length ( $c$ ), principal point offset ( $x_p$ ,  $y_p$ ), radial ( $k_1$ ,  $k_2$ ,  $k_3$ ) and tangential ( $p_1$ ,  $p_2$ ) lens distortion, "affinity" ( $b_1$ ) and different in scale factor ( $b_2$ ).

**Table 1.** Camera Calibration parameters of Sony NEX-5N digital camera

Parameter	Value
C (mm)	16.6364
$x_p$ (mm)	0.0123
$y_p$ (mm)	0.449
$k_1$	2.60490e-004
$k_2$	-1.22048e-006
$k_3$	-1.16336e-009
$p_1$	-9.24742e-005
$p_2$	-1.47364e-004
$b_1$	-8.37144e-005
$b_2$	-1.52412e-004

### 2.5. Data acquisition

The digital aerial imagery was collected using a Sony Alpha NEX-5N digital camera with wide angle lens digital camera mounted on Y6 UAV. The aerial photographs were acquired in a straight line and form a series of digital aerial photograph. Flying height and speed were fixed, with variation in flying

altitude of 40m, 60m, 80m and 100m. A timing interval was determined in order to obtain consistent flying height with 60% overlapping. One strip of the images in JPEG (Joint Photographic Experts Group) for four different flying altitudes was captured. Then the images were transferred to the notebook for image processing.

### 2.6. Data processing

A digital photogrammetric software was used to perform data processing, generating digital terrain model (DTM) and producing orthophoto of the stream. This software requires camera information such as pixel size, focal length, radial lens distortion and tangential distortion to carry out interior orientation. The GCPs were used to perform the aerial triangulation in order to produce 3D stereoscopic model. GCPs were also used to geo-reference images to the local coordinate system. The step is continued by generating DTM and orthophoto of the digital aerial imagery. The generated orthophoto was used for accuracy assessment and visualization.

### 2.7. Data analysis

Last stage of the study comprises of qualitative and quantitative analysis. The qualitative is done by analyzing the quality of the generated orthophoto and DTM. Meanwhile, the quantitative analysis is performed by using Root Mean Square Error (RMSE). The CPs derived using Total Station were compared with similar points estimates established by photogrammetry. The RMSE is carried out by using the equation shown in Equation 1.

$$\text{RMSE} = \pm \sqrt{\frac{\sum(n_1 - n_2)^2}{N - 1}} \dots\dots\dots (1)$$

where,

n1 = differences value between two parametres

n2 = mean differentiation

N = total no. of points

## 3. Results

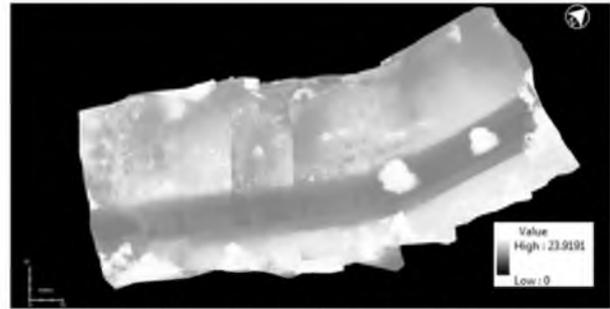
In this study, two photogrammetric results were generated after performing interior orientation, exterior orientation and aerial triangulation such as digital elevation model and digital orthophoto based on variation flying altitude using the UAV.

### 3.1. Digital Terrain Model

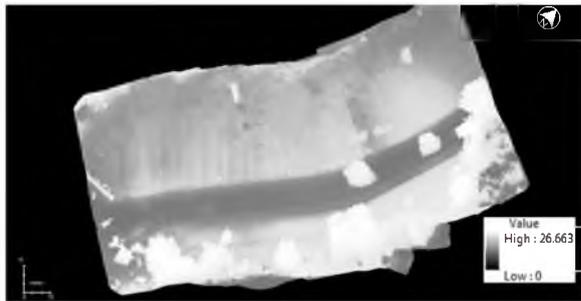
DTM is the necessary data sets that useful for the generation of 3D renderings of any location in the study area. The DTM generated based on aerial triangulation process as shown in Figures 5, 6, 7 and 8 respectively using different altitude. A module in the digital photogrammetric software was used to generate DTM. This module uses a hierarchical feature based matching algorithm that incorporates both pyramid image layers and an epipolar constraint to reduce the search time for conjugate points in image pairs. The DTM is in raster form. White colour shows higher terrain elevation such as trees along the stream while grey colour displays the lower terrain elevation of stream. The highest value of DTM is 30.1834 and it is shown together with the generated DTM of 100m flying altitude. Besides, the visualization of all different height of DTMs is almost similar.



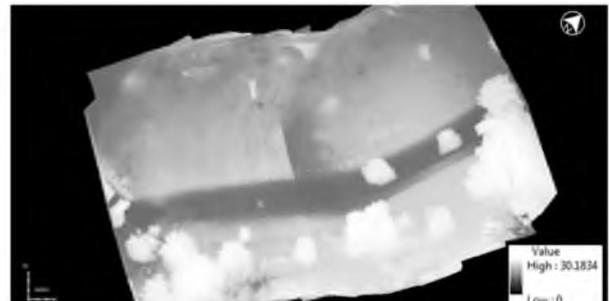
**Figure 5.** DTM extracted from Y6 UAV imagery (40m altitude).



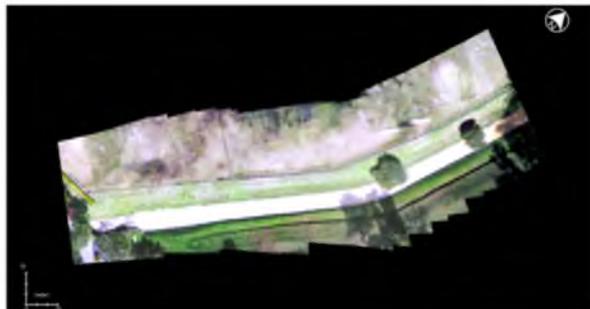
**Figure 6.** DTM extracted from Y6 UAV imagery (60m altitude).



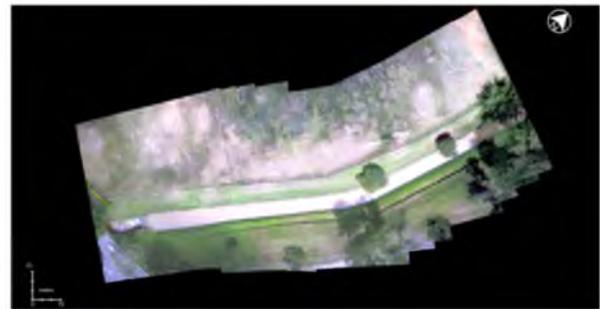
**Figure 7.** DTM extracted from Y6 UAV imagery (80m altitude).



**Figure 8.** DTM extracted from Y6 UAV imagery (100m altitude).



**Figure 9.** Orthophoto of stream (40m altitude)



**Figure 10.** Orthophoto of stream (60m altitude)



**Figure 11.** Orthophoto of stream (80m altitude)



**Figure 12.** Orthophoto of stream (100m altitude)

## 4. Analysis

### 4.1. Qualitative analysis

Based on the generated orthophoto of four different flying altitudes, it can be concluded that there are no gaps or error in overlapping image regions but there are some technical difficulties of matching process such as spatial continuity or edge matching and radiometric consistency. For spatial

continuity, features that appear on more than a single image patch must be continuous. Channel stream must form a continuous straight line and show no jumps at the original photo edges where the images are connected. In the case of radiometric consistency, different photographs may have different contrast and brightness resulting from lack of uniform conditions during the photographic processing or from changes in illumination conditions.

#### 4.2. Quantitative analysis

All the orthophoto generated was analyzed by comparing the CPs with total station coordinates. However, an assumption was made where 3D coordinates obtained from total station being reference value and used for comparison with 3D coordinates derived from photogrammetric measurement. The smaller the RMSE calculated, the higher the accuracy of the orthophoto. Hence, the accuracy of orthophoto is influenced by the RMSE value. Table 2 shows that the results of accurate assessment of digital orthophoto based on RMSE and mean sample dataset after digital image processing.

**Table 2.** RMSE of digital aerial imagery orthophoto based on variation in flying altitude

Flying altitude	Aerial Triangulation	RMSE (m)			MEAN (m)
		X(m)	Y(m)	Z(m)	
40m	10 check points	±0.411	±0.156	±0.178	<b>±0.249</b>
60m	10 check points	±0.415	±0.159	±0.212	<b>±0.262</b>
80m	10 check points	±0.410	±0.163	±0.287	<b>±0.287</b>
100m	10 check points	±0.415	±0.149	±0.324	<b>±0.296</b>

Based on the Table 2, it can be seen that the values of average RMSE for minimum and maximum flying altitude are slightly different which shows 0.047m. The best result is ±0.249m and it was obtained by averaging the planimetry and vertical RMSE of orthophoto of 40m flying altitude. This result might be affected by image matching algorithm that was used in the same software during image processing. The error was usually caused by different flying height during image acquisition, image matching during image processing and motion movement such as omega, phi, and kappa.

## 5. Conclusion

Based on this study, the digital aerial imagery of rotor wing Y6 UAV can be used for large scale stream mapping. The sub-meter accuracy produced by four set data based on variation in different flying height is relevant for various applications with low cost expenditure and less manpower. Besides, the flexibility and high efficiency of the Y6 UAV flight would be a solution for real-time mapping. It is because UAV can take-off and landing at limited open area with autopilot controlling. The configuration of the photographs acquired has a direct impact upon the production of DTM and orthophoto. Besides that the achievable accuracy was found to be dependant upon other photogrammetric digital controls such as camera calibration and control point coordinates related to the grounds station network. This study is more extensive if compared to the previous work done by [5] where a rotor wing Hexacopter UAV was employed.

## References

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