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Fast Data Acquisition of Aerial Images using Unmanned Aerial Vehicle System

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ABSTRACT

The present work discusses the technique and methodology of analysing the potential of fast data acquisition of aerial images using unmanned aerial vehicle system. This study utilizes UAV system for large scale mapping by using digital camera attached to the UAV. UAV is developed from the low-altitude photogrammetric mapping to perform the accuracy of the aerial photography and the resolution of the image. The Ground Control Points (GCPs) and Check Points (CPs) are established using Rapid Static techniques through GPS observation for registration purpose in photogrammetric process. The GCPs is used in the photogrammetric processes to produce photogrammetric output while the CP is employed for accuracy assessment. A Pentax Optio W90 consumer digital camera is also used in image acquisition of the aerial photograph. Besides, this study also involves image processing and map production using Erdas Imagine 8.6 software. The accuracy of the orthophoto is determined using the equation of Root Mean Square Error (RMSE). The final result from orthophoto is compared to the ground survey using total station to show the different accuracy of DEM and planimetric survey. It is discovered that root mean square errors obtained from UAV system are ± 0.510, ± 0.564 and ± 0.622 for coordinate x, y and z respectively. Hence, it can be concluded that the accuracy obtained from UAV system is achieved in sub meter. In a nutshell, UAV system has potential use for large scale mapping in field of surveying and other diversified environmental applications especially for small area which has limited time and less man power.

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1. INTRODUCTION

According to [5], photogrammetry is based on the processing of images that gives the main products such as Digital elevation Models (DEM), Digital Surface Models (DSM), Orthoimages, 2D and 3D reconstruction and classification of real world objects, and visualization (virtual models). Therefore, the demand for aerial photogrammetry has increased especially after development of design, research and production of UAV platform ([6]; [13]). According to [1], numerous UAV have been developed by organizations or individuals worldwide. These include a complete set of UAV which uses high quality fibers as material for plane model. UAV has been practiced in many applications such as farming, surveillance, road maintenance, recording and documentation of cultural heritage [9].

Unmanned Aerial Vehicle (UAV) systems have advantages in several mapping applications. This is apparent in comparison to conventional aerial surveying which offers accurate maps, but very expensive and have limited endurance for only a few hours. The UAV systems could be mounted on either high or low altitude platforms. Low-altitude systems have advantages in conducting photogrammetric surveys in cloudy days, providing different views and tilted images of the surveyed objects, low-cost supplying and easy-to-maintain for engineering applications systems such as topographic, either a large or a small scale mapping. These systems can be utilized in several applications such as modelling of cultural heritage ([3]; [4]; and [10]), documentation of archaeological sites, forest-fire monitoring [15], and mapping urban and suburban areas [14]. The UAV systems are also employed in environmental, agricultural, and natural resources monitoring [8]. Moreover, [11] recommended on using light weight UAV systems in acquiring high quality geospatial information for resource management agencies, rangeland consultants, and private land managers.

The UAVs have several potentials such as low cost operation, simple manipulation, high resolution, flexibility and others. According to [7], the advantages in developing the technology of UAV for low altitude photogrammetric mapping are to perform aerial photography at cloudy day, to get full image of object from the top, and to supply a cheap and easy system for high frequency needs of aerial photogrammetric survey. UAV system is not limited by human on aircraft when collect data in dangerous environment without risk of pilot. Conceptually, these UAV are equipped with devices such as camera, sensors, communication tools and other payloads to perform certain activity. UAV can be classified depending on their size, endurance, range and flying altitude that are clearly defined by Unmanned Vehicle Systems International Association. It is because UAVs are not burdened with the physiological constraints of human pilot that it can be planned for maximized on-station times. Table 1 shows the different types of UAVs based on their endurance.

Table 1. UAV Categories defined by UVS international

Category name	Mass [kg]	Range [km]	Flight attitude [m]	Endurance [hours]
Micro	<5	<10	<250	1
Mini	<25/30/150	<10	150/250/300	<2
Close Range	25 - 150	10 - 30	3000	2 – 4
Medium Range	50 - 250	30 - 70	3000	3 – 6
High Alt. Long Endurance	>250	>70	>3000	>6

(a) (b)

Figure 1. (a) Cropcam UAV; (b) Pentax Optio W90

In this study, two hardware were used. They were the Fixed Wing UAV and high resolution digital camera. Low altitude UAV was preferable in this study because it focused on large scale mapping which involved small area only. UAV is the most potential equipment and very low cost budget for capturing aerial photograph of small area. Apart from that, digital camera with high resolution images was attached at the UAV. The digital camera also provides small format images. Figure 1 shows an example of UAV (Cropcam) and digital camera (Pentax Optio W90).

Pentax Optio W90 has been used in acquiring the images. This digital camera has 5x zoom lens and 2.7" LCD screen. In this study, Fixed Wing UAV also known as Cropcam UAV (Figure 1) has been used in acquiring images that covered study area. The Cropcam is highly efficient and user friendly for the commercial market. It is a Radio Control (RC) glider plane equipped with a Pentax digital camera, controlled by an autopilot from the pre-programmed ground control software. This Cropcam also will work with a RC transmitter for manual control of the plane. It is utilizes an autopilot for navigation and control of the camera and RC parts (wings, servos, propellers, glow fuel or batteries) that can purchased locally. The specification of the Cropcam UAV used in this study is shown in Table 2.

Table 2. Cropcam specification [2]

Specification	
Weight	6 lbs./2.42 kg
Wing span	8 feet/2.44 meter
Length	4 feet/1.22 meter
Endurance	Up to 55 minutes
Payload	1 pound/0.373kg
GPS on board	Yes
Special function	Automatically return to home location (1st point)
Stabilizer	Inbuilt stabilizer to deal with wind correction
Capture data	Using software to reached waypoints
Flight Control	Manual or autonomous
Camera Stand	Flexible camera holder
Average Speed	60 km/h

Therefore, this paper discusses the technique and methodology of analysing the potential of fast data acquisition of aerial images using unmanned aerial vehicle system. The main objective of this paper is to proposed of fast data acquisition of aerial images using unmanned aerial vehicle system.

2. RESEARCH METHOD

In this study, the methodology has been divided into several phases including preliminary study, data acquisition, result and discussion. The dimension of the study area approximately five hundred meter by one hundred meter only. Thereby, few aspects involved in preparation such as flight planning and properly install the instruments installation that needs be considered, which contributes to the quality of data acquisition. Flight Planning involves calculation of study area, number of strips required, pixel size, photo scale flying height and percentage of end lap and side lap. In general, the aerial photographs should be overlapped at least 60 percent and side at least 30 percent. This requirement needs to be fulfilled to make sure quality photogrammetry results could be obtained. Figure 2 represents flowchart of the research methodology.

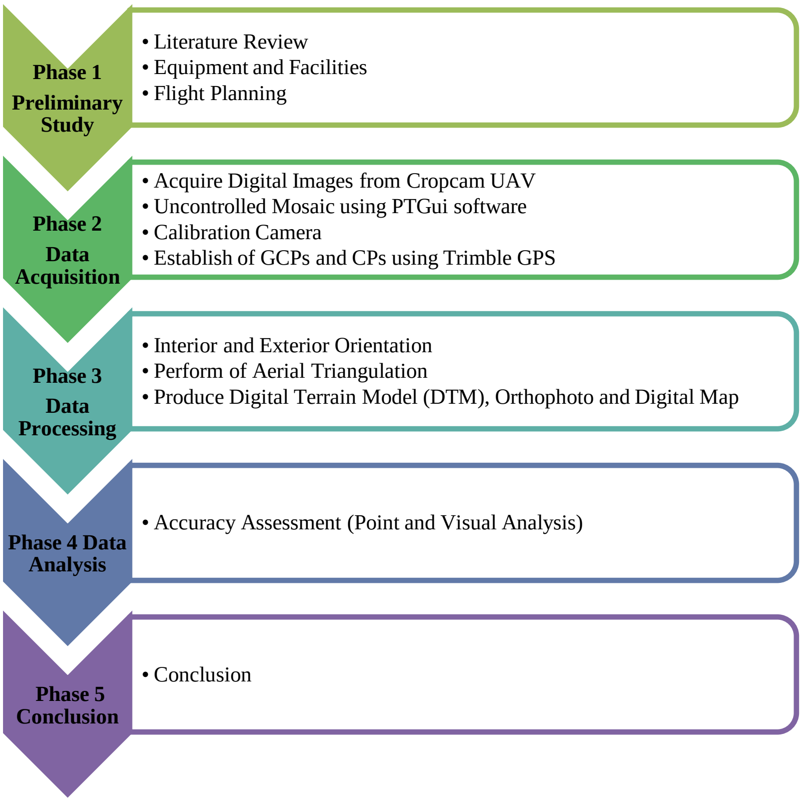

Figure 2. Flowchart of research methodology

2.1. Data Acquisition

After installation and flight plan already sent to the autopilot UAV's, hand launched systems was carried out to start fly the UAV. The crew ground control station would informed pilot for the altitude and position from time to time until UAV fly accordance to the waypoints. Pilot will change from the Position Hold into Coming Home (CH) for landing. For aircraft landing, it needs to be on clear area and CropCam will landed at the started point. Figure 3 represents how the Cropcam UAV and Ground Control Station were carried out. Figure 4 shows the study area and two strips of overlapping aerial photograph captured using the pentaxoptio W90 digital camera of 12 megapixel resolutions.

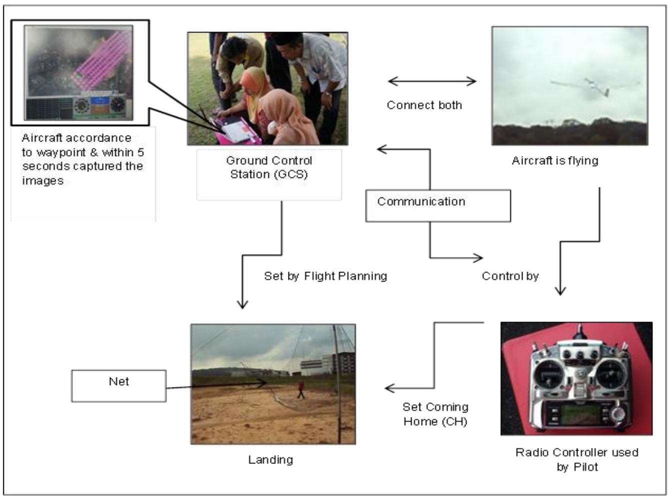

Figure 3. Cropcam UAV and Ground Control Station

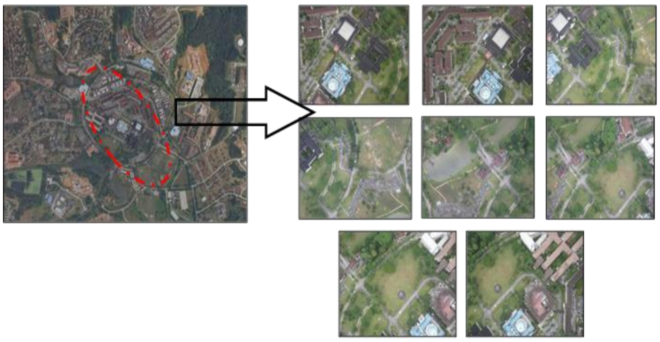

Figure 4. Study area (left) and example for two steps of aerial images (right)

2.2. Establishment of GCPs and CPs

The GCPs were collected using GPS observation through Rapid Static technique. This technique can provide the position information includes Northing, Easting, and Elevation (X, Y, and Z) with the post processing by using the Trimble Total Control (TTC) software that gives accuracy at 0 to 10 centimeter level. This technique only takes 5 until 20 minutes. Any point on the earth has been identified on aerial photographs such as road corner, building, drain and etc. were considered as GCPs measured towards the coordinate. Minimum four GCPs were established in order to register during exterior orientation. There are two equipments involved in this field, both of the same brands (Trimble Ground Plane), one which acts as the reference station and the other one which acts as the rover (GCPs and CPs). The reference stations were ISKANDARnet1, ISKANDARnet2 and ISKANDARnet3 was completely installed at their designated location and has accurately coordinated the stations. In addition, ISKANDARnet was also operational for data logging and streaming. Figure 5 represents the distribution of GCPs and CPs was measured by using the rapid static technique. After the GPS observation was carried out, the data need to be downloaded and converted it to the rinex file. After that, the data need to process in order to get the coordinate by using the TTC software. The coordinate obtained after processing in Geocentric Datum of Malaysia (GDM2000). It needs to be converted to RSO using GDTS software. For this study, the RSO coordinate system was used to process the small format aerial photograph using ERDAS Imagine software.

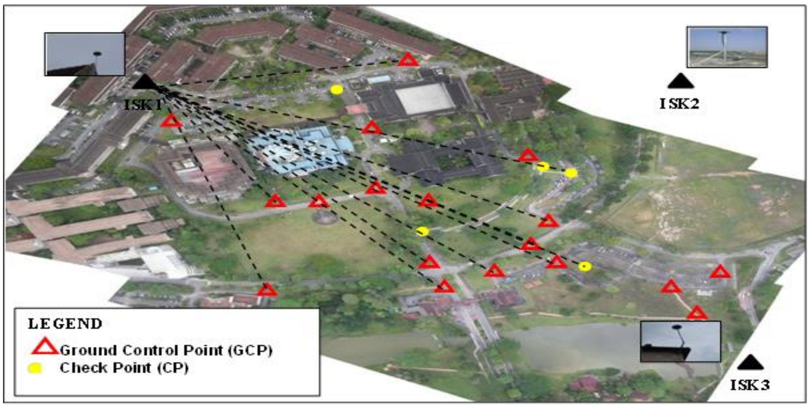

Figure 5. GCPs and CPs distribution

3. RESULTS AND ANALYSIS

After data acquisition has been completed using Cropcam UAV, all acquired images and GCPs have been processed using photogrammetric software i.eErdas Imagine software. Besides that, the results will be presented in the form of digital map or hardcopy. Erdas Imagine software required camera information such aspixel size, focal length, radial lens distortion and tangential distortion to carry out interior orientation. A total of 19 GCPs have been registered during exterior orientation. Erdas Imagine software required six tie points or three points for each pair of the overlapped photographs.

After computing and adjusting the aerial triangulation measurement, a report on the aerial triangulation results must be prepared. The report should include the photogrammetric block layout and a diagram showing the location and names of all points that participated in the adjustment. The RMSE of aerial triangulation based on 19 ground control points and 5 for the check points in the two strips of the small format aerial photograph and the RMSE calculated automatically is + 0.0168 meter.

3.1. Result

In this study, there were three photogrammetric results which have been generated after performing interior, exterior orientation and aerial triangulation. The photogrammetric results generated were the Digital Terrain Model, the Orthophoto and the digital map. The result of Digital Terrain Model is shown in Figure 6.

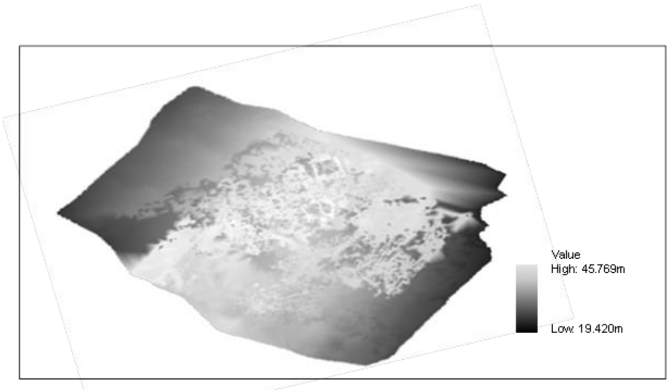

Figure 6. Digital Terrain Model

The result depended on the accuracy of GCPs. If the quality of ground control points was not good, the result of digital orthophoto and digital terrain models was also less accurate. The result of digital orthophoto for small format aerial photo, about eight non-metric imagery including digital image from the digital camera are used to cover the study area and the aerial triangulation procedure has to be carried out for the small format aerial photo. After producing the orthophoto, ERDAS Imagine then generates a mosaic image for it. The mosaic image comprised of eight resulting orthophotos, whereby all of them are joined together to form an image. Figure 8 shows the digital orthomosaic which was generated based on the invidualorthophoto together for the two strips of small format aerial photograph. ERDAS Imagine then generates a mosaic image for it. The mosaic image comprised of eight resulting orthophotos, whereby all of them are joined together to form an image. Figure 7 shows the digital orthomosaic which was generated based on the invidualorthophoto together for the two strips of small format aerial photograph.

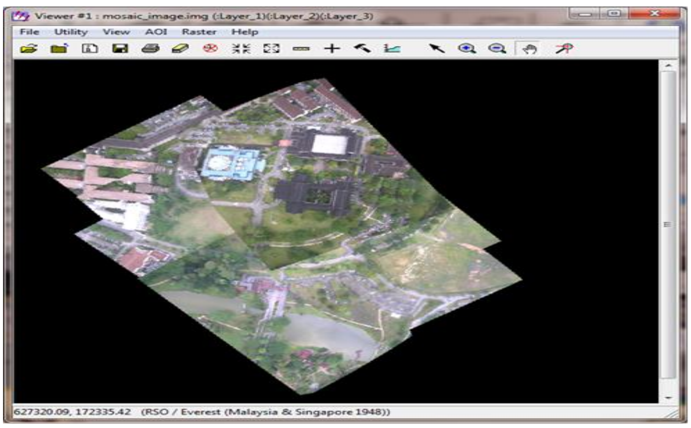

Figure 7. Digital Orthophoto

3.2. Analysis

For this study, analysis of point accuracy of ERDAS Imagine software generated orthophoto was carried out based on the orthophoto coordinates and the GPS control points' coordinates as shown in equation 1 and 2 represents the RMSE formulae to compute RMSE for accuracy of the orthophoto.

$$RMSE_{(x,y)} = \pm \sqrt[2]{\sum_{i=1}^{i=n} \frac{(x_i - x_o)^2 + (y_i - y_o)^2}{n}} \;..... \quad (1)$$

$$RMSE_{(x,y)} = \pm \sqrt[2]{\sum_{i=1}^{i=n} \frac{(z_i - z_o)^2}{n}} \;..... \quad (2)$$

Table 3 shows the comparison of check points between ground survey (GPS) and coordinates obtained from ERDAS Imagine, where the calculated RMSE is + 0.565 meter (<1 meter). It can be seen that the accuracy could be achieved using UAV system based on the two strips of aerial photograph. The smaller the RMSE calculated, the higher the accuracy of orthophoto produced. Hence, the accuracy of orthophoto is influenced by the RMSE value.

Table 3. Comparison of check points

Check Point	Trimble 4800			ERDAS Imagine v8.6			Diffrences		
	X(m)	Y(m)	Z(m)	X(m)	Z(m)	Z(m)	ΔX(m)	ΔY(m)	ΔZ(m)
209 (CP1)	626930.568	172270.152	37.372	626930.362	172270.037	37.889	0.015	0.206	-0.517
210 (CP2)	626927.058	172248.999	33.485	626926.554	172249.541	34.725	-0.542	0.504	-1.240
3 (CP3)	626877.725	172485.731	43.343	626876.069	172485.459	42.179	0.272	1.656	1.164
211 (CP4)	626779.969	172254.677	34.128	626779.776	172256.085	35.060	-1.408	0.193	-0.932
212 (CP5)	626879.374	172115.487	23.096	626880.344	172115.124	23.505	0.363	-0.970	-0.409
					RMSE		±0.510	±0.564	±0.622

Table 4. Comparison of time estimation and man power

Method	Tacheometry method	Manned Air-Craft	UAV Technology
Fieldwork	Traversing – 1 days (24 hours) Tacheometry - 2 days 948 hours)	Traversing, Pre-Marking and Flight Planning – 4 days	UAV setup – 20 minute Flight – 30 minute
Processing	Generate the topographic plan – 1 days	Image scanning and Processing – 1 months	Image processing until Map production – 4 hours
Man power	4 person	2 pilot onboard + 2 person on the ground	1 professional pilot + 1 person

In general, UAV system and ERDAS Imagine software were easy to use and required more experience in order to understand how the UAV work. The equipment especially UAV give more advantage compared to conventional method because it used less manpower, low budget and minimal time constraint in order to produce map in sub meter accuracy. Table 4 shows the comparison of the time taken for data acquisition, processing and man power for 500m x 200m. The processing parts were positioned step by step such as interior orientation, exterior orientation, DTM extraction and finally orthophoto production. Next, it was run automatically and users just have to follow each step thoroughly. Finally, the results of orthophoto were analyzed in two ways which are point and visual analysis. In point analysis, the RMSE below than 1 meter, shows that the orthphoto having a sub meter accuracy.The smaller the RMSE that's mean the better of orthophoto. While for the visual analysis, the vector map obtained from UAV technology were compared to the ground survey measurement that does not overlapping hundred percent but still the overlaid images were quite matched and acceptable.

From Table 4, it could be concluded that the UAV technology give more advantages in terms of time and man power. While the conventional method which are tacheometry and manned aircraft have disadvantage in fieldwork stage and data processing. In conclusion, UAV technology together with camera is very helpful in large scale mapping especially in small area.

4. CONCLUSION

This study demonstrates that the Cropcam UAV together with the digital camera was capable of acquiring the aerial photograph successfully for large scale mapping. The photogrammetric outputs such as DTM and orthophoto were successful and generated too. These results have been analyzed using the Root Mean Square Error (RMSE). With the new technology, Unmanned Aerial Vehicle could solve problems in many applications especially in small area. It has been proven that UAV platform was very suitable for the project that has limited time and man power. This technology could be adopted in photogrammetric work, which requires up to date information in a short time. This technology could be used by any agency or ministry related with environmental studies. For the future, it is also hope that this study could be expanded at large and different flying height to determine the accuracy and cost involve for data acquisition.

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