CAPABILITIES OF LOW COST AND FAST IMAGE ACQUISITION USING MICRO FIXED-WING UNMANNED AERIAL VEHICLE SYSTEM

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ABSTRACT

Fast image acquisition is most important part for societal impact of a developing country. This paper aims to demonstrate the potential use of micro fixed wing unmanned aerial vehicle (UAV) system attached with high resolution digital camera for coastal mapping. In this study, a strip of aerial images of simulation models of coastal area was captured using a high resolution compact digital camera known as Canon Power Shot SX230 HS and it has 12 megapixel image resolution. The low cost supplying of micro fixed wing UAV can be used in various applications including mapping coastal area. The UAV equipped with an autopilot system and automatic method known as autonomous flying, can be utilized for data acquisition. In this study, the UAV system has been employed to acquire aerial images of a simulation model at low altitude. From the aerial images, photogrammetric image processing method is completed to produce mapping outputs such a digital terrain model (DTM), contour line and orthophoto. In term of the accuracy, of measurement, a milimeter-level is reached by ground control point (GCP) and check point (CP) using conventional ground surveying method (i.e accurate Global Positioning System (GPS)). For accuracy assessment, the coordinates of the selected points in the 3D of stereomodel were compared to the conjugate points observed using GPS and the root mean square error (RMSE) is computed. From this study, the results showed that the achievable RMSE are ± 0.018m, ± 0.013m and ± 0.034m for coordinates X, Y and Z respectively. It will anticipate that the UAV will be used for coastal survey and improve current method of producing with low cost, fast and good accuracy. Finally, the UAV has shown great potential to be used for coastal mapping and others applications that require accurate results or products using high resolution camera.

KEYWORDS: UAV; Photogrammetry; Coastal Area

INTRODUCTION

Basically, there are several methods in geoinformation that can be used to map the environmental sites such as aerial photogrammetry, remote sensing, LIDAR (Light Detection and Ranging), GPS (Global Positioning system), TLS (Terrestrial Laser Scanning) and total station. The geoinformation technology could also be used in environmental survey and could assist the developers for societal impact in the developing country. The remote sensing and aerial photogrammetry is widely used for mapping environmental sites. For remote sensing, with the existing of high resolution satellite imagery such as Ikonos, QuickBird and WorldView 2, it can be used for environmental survey. On the other hand, the development of remote sensing technology where the satellites can capture high-resolution imagery with the capability of producing stereo imagery using IKONOS satellite images [5].

However, there are some limitations or draw back for these methods. The problem related to this technology is the difficulties of possessing clear image of the study area. According to [5], the limitation of satellites and manned aircraft are flight costs, slow and weather-dependent data collection, limited availability, limited flying time, low ground resolution. In aerial photogrammetry, the aircraft can be flown under the cloud and imagery can be obtained much easier than satellite imagery.

Digital photogrammetry in the photogrammetric industry has revolutionized the industry. Nowadays, most countries in the world have produced their topographic map using aerial photogrammetry. Recently, digital photogrammetry has embraced UAV technology known as UAV photogrammetry. According to [7], UAV photogrammetry can be understood as a new photogrammetric measurement tool. UAV photogrammetry opens various new applications in the close range domain, combining aerial and terrestrial photogrammetry, and also introduces low-cost alternatives to the classical manned aerial photogrammetry.

PROBLEM STATEMENT

UAV system has been used to produce digital map and orthophoto of UTM Johor Bahru ([1]-[4]). In the study carried out, fixed wing UAV was used to acquire the digital aerial photograph at low altitude of approximately 300m. The output of the study showed that the digital map was produced at large scale and accurate. Therefore, UAV system has expanded data capture opportunities for photogrammetry techniques. Usually, the UAV system uses the concepts of close range photogrammetry (CRP). In CRP, the photography is acquired where the object-to-camera distance is less than 300m (Cooper and Robson, 1996; Wolf and Dewitt, 2000). Moreover, [5] stated that numerous UAV had been developed by organization or individual worldwide including a complete set of UAV which used high quality fibers as material for plane model. The development of this technology is very beneficial for monitoring purpose for limited time and budget. It is supported that UAV has been practiced in many applications such as farming, surveillance, road maintenance, recording and documentation of cultural heritage [6].

Therefore, this study were used two main hardwares which comprise of micro fixed-wing UAV and high resolution digital camera. Low altitude UAV is preferable in this study because it focuses on simulation model which covered small area only. The compact digital camera provides small format images. Figure 1 show examples of UAV known as Hexacopter and compact digital camera used in this study.

(a) (b)

Figure 1: (a) Micro fixed-wing UAV; (b) Compact digital camera

In this study Canon Power Shot SX3 digital camera has been used in acquiring simulation model images. This digital camera has 14x optical zoom lens and 2.0” LCD screen. Table 1 depicts the compact digital camera specification.

Table 1: Canon PowerShot XS230 HS digital camera specifications

Specification	
Maximum Resolution	4000 x 3000 pixels
Effective pixels	12.10 megapixels
Lens	14.00x zoom, f3.1-5.9, 28-392mm (35mm equivalent)
LCD size	3”
Sensor size	1/2..3”, 460K dots/None
Sensor type	CCD
Dimensions	4.2 x 2.4 x 1.3 in. (106 x 62 x 33 mm)
Weight (Body)	218g includes batteries
Shutter	15-1/3200
ISO	100-3200
Memory type	SD/SDHC
File formats	JPEG (conforms to Exif 2.2), conforms to DCF2.0, DPOF, PRINT Image Matching III, AVI (Motion JPEG), with WAV (PCM), mono

In this study, micro fixed-wing UAV (Figure 1) has been used in acquiring images of the simulation model. The specification of the rotary wing used in this study is shown in Table 2.

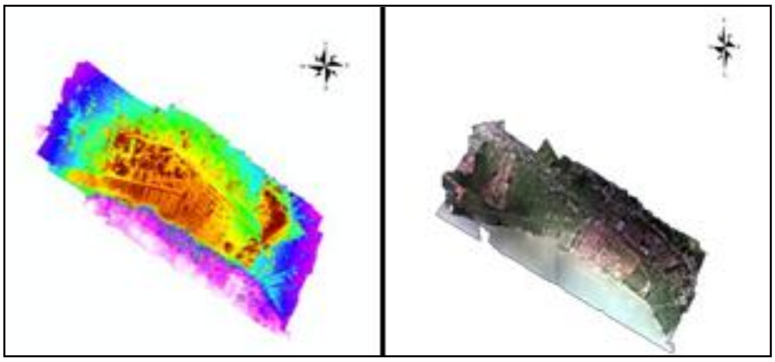
Table 2: Hexacopter Specification

Specification	
Weight	2-3 kg with Lithium-polymer battery
Rotor	No
Endurance	45 min -1h with a 5000 mAh Li-po
Payload	130g – 500g for one to three cameras
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 and autonomous
Camera stand	No flexible camera holder
Flight altitude	<450m

RESULTS AND ANALYSIS

In this study, two main results were produced. First is the Digital Terrain Model (DTM) and second is the Orthophoto. DTM is an essential data set which useful for the generation of 3D renderings at any location in the simulation model. DTM consists of X, Y and height information. It also can be used for generating contours automatically for volume computation, multi engineering design work, geodesy and surveying, geophysics, and geography. In digital photogrammetric, digital orthophoto is identified as one of the outputs. An orthophoto is a product that has pictorial quality of a photograph and correct planimetric characteristics. Orthophoto is produced through the process of differential rectification whereby photo tilt, lens distortion, and relief displacement have been eliminated and adjusted. Apart from that, the scale is uniform where the orthophoto has the same characteristics. Hence, it can be used on measuring true distances, coordinates and angles because of its accuracy on earth's surface representation. Figure 2 (a) shows the result of Digital TM and 2 (b) shows the orthphoto result of this study.



(a) (b)

Figure 2 : (a) Digital Terrain Model (DTM); (b) Orthophoto

The root mean square error (RMSE) was used to assess the accuracy of the outputs based on orthophoto from rotary and fixed wing UAV. Therefore, the RMSE formulae to compute RMSE for check points of the orthophoto in equation 2a and 2b. Table 3 shows the comparison of coordinates between ground survey (total station) and image processing software using hexacopter rotary-wing UAV.

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

$$RMSE_{(z)} = \pm \sqrt[2]{\sum_{i=1}^{i=n} \frac{(z_i - z_o)^2}{n}} \qquad (2b)$$

Where;
x_i, y_i, z_i = measured value
x_o, y_o, z_o = true value
n = number of dataset

Table 3 shows the comparison of check points between coordinates from ground survey (i.e total station) and coordinates obtained from image processing software, where the calculated RMSE is ± 0.004, ± 0.006 and ±0.002 meter (<1 meter) for coordinate x, y and z respectively. It can be seen that the accuracy can be achieved using rotary-wing UAV system based on the one strip of digital aerial photograph for simulation model. Meanwhile, Table 4 shows the comparison coordinate of GPS observation and image processing software using fixed-wing UAV. The smaller the RMSE calculated, the higher the accuracy of orthophoto produced. The smaller the RMSE, the better orthophoto could be produced. It can be concluded that the higher the GCPs was, the better the RMSE. Hence, the accuracy of orthophoto is influenced by the RMSE value.

Table 3: Comparison of coordinates based on micro fixed-wing UAV

Check Point	Total Station			Image Processing Software			Differences		
	X	Y	Z	X	Y	Z	ΔX (m)	ΔY(m)	ΔZ(m)
01	10013.262	9993.894	20.155	10013.284	9993.909	20.130	0.022	0.015	-0.025
02	10013.017	9995.136	20.108	10012.995	9995.121	20.133	-0.023	-0.015	0.025
03	10011.993	9994.318	20.183	10012.016	9994.338	20.169	0.023	.020	-0.014
04	10011.835	9994.314	20.157	10011.847	9994.329	20.137	0.012	0.015	-0.020
05	10011.188	9995.444	19.972	10011.174	9995.453	20.001	-0.014	0.009	0.029
06	10010.346	9994.063	20.086	10010.330	9994.044	20.061	-0.016	-0.019	-0.025
07	10009.942	9996.762	19.847	10009.965	9996.777	19.862	0.023	0.015	0.015
						RMSE	±0.004	±0.006	±0.002

SUMMARY AND CONCLUSION

Nowadays with the development of digital camera, analysis can be carried out for the small format digital camera attached to UAV. A small format photograph from digital camera has the potential to be used in aerial photogrammetry and analysis can be carried out for the product of aerial photogrammetry such as orthophoto, DTM, contour line and digital map. Based on the data collection, it is clear that photogrammetric micro fixed-wing

UAV technology has the potential to be used for coastal studies in terms of data collection and data analysis. In general, micro UAV system and photogrammetric software is easy to use and need more experience in order to understand how the micro fixed-wing UAV work especially in research purpose. The micro UAV provides more advantages compare to conventional method due to the use of less manpower, limited budget and time constraint in order to produce map in sub meter accuracy.

This study proves that photogrammetric micro UAV has a potential to be used for mapping and monitoring coastal erosion. With this technology, many problems could be solved for various applications especially project with limited budget and small coverage area. As a conclusion, micro UAV platform is very helpful and economical for large scale mapping.

ACKNOWLEDGMENT

The authors would like to acknowledge the support of Faculty of Geoinformation & Real Estate in conducting this study. The authors also would like to express their great thanks to Ministry of Higher Education Malaysia and Universiti Teknologi Malaysia for guidance and supporting this study.

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