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Assessment of Photogrammetric Micro Fixed-Wing Unmanned Aerial Vehicle (UAV) System For Image Acquisition of Coastal Area

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Graphical abstract

Abstract

Fast image acquisition is the 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, six strips of aerial images 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. From the aerial images, photogrammetric image processing method is completed to produce mapping outputs such a digital elevation model (DEM) and orthophoto. 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 that require accurate results or products using high resolution camera.

Keywords: Micro fixed-wing UAV; Digital camera; Coastal area

Abstrak

Perolehan Imej udara secara pantas adalah perkara paling penting bagi sesebuah negara yang membangun. Kertas kerja ini bertujuan untuk membuktikan potensi penggunaan sayap tetap system pesawat udara tanpa pemandu (UAV) dipasangkan dengan kamera digital beresolusi tinggi bagi pengambilan imej udara kawasan pantai. Dalam kajian ini, enam (6) jalur imej dari udara bagi kawasan pantai telah ditangkap menggunakan kamera digital beresolusi tinggi yang dikenali sebagai Canon Power Shot SX230 HS dan memiliki resolusi imej 12 megapik sel. Kesemua imej udara diproses menggunakan kaedah fotogrametri untuk menghasilkan model ketinggian digital (DEM) dan ortofoto. Untuk penilaian ketepatan, koordinat titik dipilih dalam model stereo 3D yang terhasil dan dibandingkan dengan titik konjugat dari Sistem Penentudududukan Sejagat (GPS) dan punca ganda dua terkecil (RMSE) dikira. Hasil kajian ini menunjukkan bahawasa RMSE yang dicapai adalah ±0.018m, ±0.013m, ±0.034m bagi koordinat X, Y dan H. Ini menunjukkan bahawa UAV sesuai digunakan untuk kajian pantai dan memperbaiki kaedah perolehan imej udara yang cepat, jimat dan mempunyai ketepatan yang baik. Secara kesimpulannya, UAV sayap tetap telah menunjukkan pemetaan kawasan pantai menggunakan UAV sayap tetap adalah berguna yang memerlukan ketepatan yang baik dengan menggunakan kamera digital beresolusi tinggi.

Kata kunci: UAV sayaptetap; Kamera digital; Kawasanpantai

■1.0 INTRODUCTION

Basically, there are several geoinformationmethods which can be utilizedforenvironmental sites mappingsuch as aerial photogrammetry, remote sensing, LIDAR (Light Detection and Ranging), GPS (Global Positioning system), TLS (Terrestrial

Laser Scanning) and total station.The geoinformation technology canalso be used for environmental survey which then able to assist the development of societal impact in a developing country. The remote sensing and aerial photogrammetry has beenwidely used for the purposes of mapping environmental sites. In remote sensing, the current high resolution satellite imagery such as Ikonos, QuickBird and WorldView 2 can be used for environmental survey where the satellites are able to capture high-resolution imagery and also has the capability of producing stereo imagery when using IKONOS satellite images [1].

However, there are some limitations or draw back in this method. The problem related to this technology is the difficulties of possessing clear image in anarea of study. In addition, the limitation of satellites and manned aircraft capabilities are flight costs, slow and weather-dependent data collection, limited availability, and limited flying time [1]. In aerial photogrammetry, the aircraft can be flown under the cloud and the imagery can be obtained much easier than satellite imagery.

The introduction of Digital photogrammetry in the photogrammetric industry has revolutionized the geoinformationindustry. Nowadays, most countries in the world have produced their topographic map by using aerial photogrammetry. Recently, digital photogrammetry has embraced UAV technology which then been known as UAV photogrammetry.UAV photogrammetry can be explained as a new photogrammetric measurement tool[2]. UAV photogrammetry opens new various applications in the close range domain, combining aerial and terrestrial photogrammetry, and also introduces low-cost alternatives to the classical manned aerial photogrammetry.

■2.0 PROBLEM STATEMENT

The UAV system has been used to produce digital mapping and orthophoto of UTM Johor Bahru[3-7]. In this study, fixed wing UAV was used to acquire the digital aerial photograph at low altitude of approximately 300m. The study output showed that the digital map has produced large scale with minor error mapping when using Micro UAV.Consequently, the 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 if the object-to-camera distance is less than 300m [8]. Moreover, numerous UAV have been globally developed either by an organization or individual which also included a complete set of UAV that used high quality fibers as material for plane model[1].The development of this technology is very beneficial formonitoring project that has time constrain and with limited budget. It is supported that UAV has been practiced in many applications such as farming, surveillance, road maintenance, recording and documentation of cultural heritage [9].

Therefore, this study used two main hardwaresfor image acquisitionwhich is the micro fixed-wing UAV and high resolution digital camera. Low altitude UAV is preferable in this study because it focuses and onlycovered a simulation model in a small area. The compact digital camera provides small format images. Figure 1 show the example of UAV (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 was used for acquiring images of coastal area. This digital camera has 14x optical zoom lens and 2.0" LCD screen. Table 1 depicts the compact digital camera specification detail.

Table 1 Canon PowerShot XS230 HS digital camera specifications

Specification	
MaximumResolution	4000 x 3000 pixels
Effectivepixels	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 includesbatteries
Shutter	15-1/3200
ISO	100-3200
Memorytype	SD/SDHC
File formats	JPEG (conforms to Exif 2.2), conforms to DCF2.0, DPOF, PRINT ImageMatching III, AVI (Motion JPEG), with WAV (PCM), mono

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

Table 2 Micro fixed-wing UAV Specification

Specification	
Weight	2-3 kg withLithium-polymerbattery
Rotor	No
Endurance	45 min -1h with a 5000 mAh Li-po
Payload	130g – 500g forone to three cameras
GPS onboard	Yes
Specialfunction	Automaticallyreturn to home location (1st point)
Stabilizer	Inbuiltstabilizer to dealwithwindcorrection
Capture data	Using software to reachedwaypoints
Flight control	Manual and autonomous
Camera stand	No flexible camera holder
Flight altitude	<450m

■3.0 METHODOLOGY

Basically, the research flowchart for the study area which located at the Crystal Bay, Alai Malacca has been divided into five (5) phases. For the first phase, a flight plan was constructed using mission planner v1.0 open sources with the dimension of 4km x 1.5km for coastal area. In the second phase, the acquisition of aerial images was done by using micro fixed-wing UAV and the data acquisition process needs to be carried out on site. The third phase is image processing whichneeds to be performedin order to produce the results. This work process involved aligns of photos, build geometry and build texture using Agisoftphtoscan software. Results of this study are based on generated digital elevation model (DEM) and digital orthophoto. The fourth phase is the result and image assessment. This section analyzed the accuracy of the output for aerial images of coastal area using digital camera attached to micro fixed-wing UAV. Figure 2 shows the flowchart of the research methodology for coastal study area. Lastly, the fifth phase is the conclusion of the study area obtained from UAV together with the high resolution digital camera.

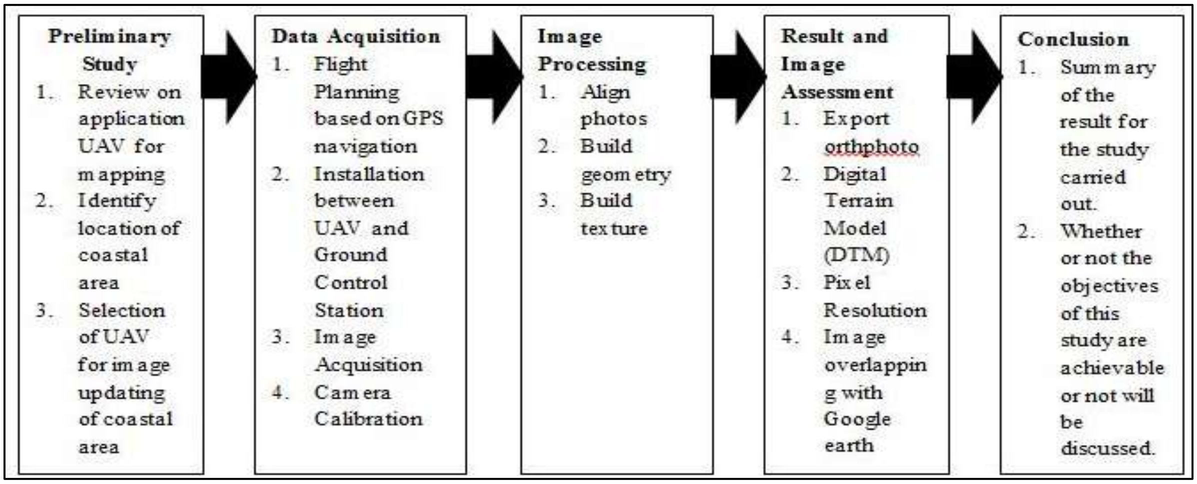
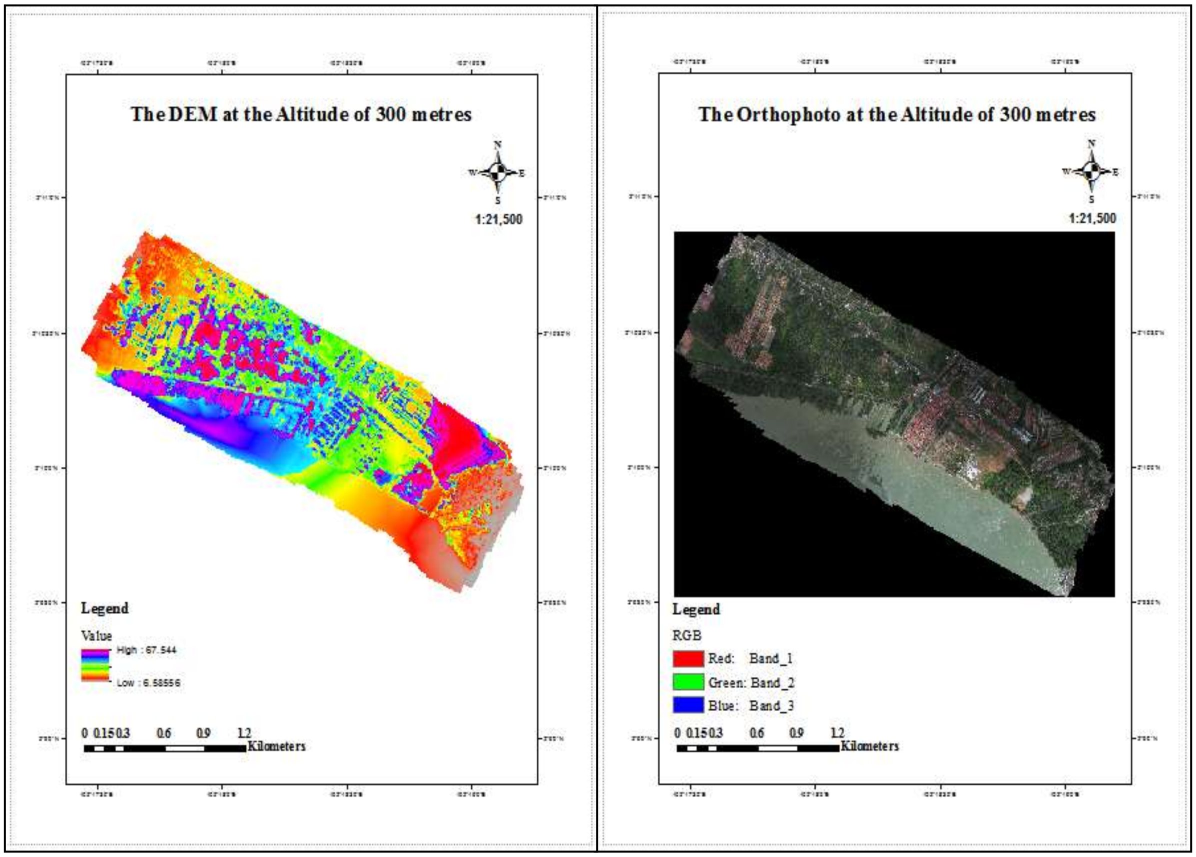


Figure 2 Research methodology of the study

■4.0 RESULTS AND ANALYSIS

In this study, two main results were produced. First is the Digital Elevation Model (DEM) and second is the Orthophoto. DTM is an essential data set which proves 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, 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 whichhave been eliminated and adjusted. Apart from that, the map scale and theorthophotohave the same characteristics. Hence, it can be used for measuring true distances, coordinates and angles because of its accuracy on earth's surface representation. Figure 3 (a) shows the result of Digital Elevation Model (DEM) and 3 (b) shows the orthphoto result of this study.



(a) (b)

Figure 3 (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 micro fixed wing UAV. Therefore, the RMSE formulae to compute RMSE for check points of the orthophotoas shown in equation 1a and 1b. Table 3 shows the comparison of coordinates between ground survey (total station) and image processing software using micro fixed-wing UAV[10].

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

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

Where;

xi, yi, zi = measured value
xo, yo, zo = true value
n = number of dataset

Table 3 shows the comparison of check points between coordinates from ground survey (i.eGlobal Positioning System (GPS)) and coordinates obtained from image processing software, where the calculated RMSE is ± 0.018, ± 0.013 and ±0.034 meter (<1 meter) for coordinate x, y and z respectively. It can be seen that the accuracy can be achieved using micro fixed-wing UAV system based on the one strip of digital aerial photograph for coastal area. 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	GPS Coordinate			Image Processing Coordinate (Orthphoto)			Coordinate Different		
	Northing (m)	Easting (m)	Elevation Height (m)	Northing (m)	Easting (m)	Elevation Height (m)	dN (m)	dE (m)	dH (m)
1	239943.465	478689.248	5.182	239943.485	478689.233	5.124	0.020	-0.015	0.058
2	239926.316	478856.084	4.877	239926.286	478856.104	4.890	-0.030	0.020	-0.013
3	240017.424	478732.621	5.182	240017.388	478732.637	5.192	-0.036	0.016	-0.010
4	240164.666	478859.538	4.877	240164.705	478859.508	4.802	0.039	-0.030	0.075
5	239827.757	478831.213	4.572	239827.717	478831.241	4.590	-0.040	0.028	-0.018
6	239900.227	478642.831	3.658	239901.762	478642.833	3.670	0.015	-0.030	-0.012
7	239890.097	479242.283	4.267	239890.117	479242.257	4.280	0.020	-0.026	-0.013
8	239658.698	479112.149	3.962	239658.640	479112.191	3.942	-0.058	0.042	0.020
9	239787.509	478837.331	2.438	239787.538	478837.316	2.428	0.029	-0.015	0.010
10	239724.009	478985.556	3.658	239724.036	478985.544	3.000	0.027	-0.012	0.658
11	239944.471	478633.628	5.486	239944.461	478633.653	5.442	-0.010	0.025	0.044
12	239942.893	478460.584	5.791	239942.941	478460.604	5.752	0.048	0.020	0.039
13	239960.789	478408.08	5.486	239960.815	478408.130	5.450	0.026	0.050	0.036
14	240015.397	479053.982	3.962	240015.412	479054.002	3.959	0.015	0.020	0.003
15	240039.701	478225.58	5.486	240039.720	478225.560	5.467	0.019	-0.020	0.019
16	240060.379	478161.03	5.486	240060.349	478161.070	5.468	-0.030	0.040	0.018
17	239923.661	478985.861	3.962	239923.685	478985.831	3.942	0.024	-0.030	0.020
18	240146.335	478593.767	3.962	240146.403	478593.787	3.943	0.068	0.020	0.019
19	240157.795	478531.984	4.267	240157.785	478531.993	4.259	-0.010	0.009	0.008
20	240220.894	478245.325	16.706	240220.906	478245.317	16.706	0.012	-0.008	0.000
21	240168.636	479075.846	14.572	240168.659	479075.864	14.530	0.023	0.018	0.042
22	240222.629	478717.485	14.267	240222.639	478717.465	14.250	0.010	-0.020	0.017
23	239968.602	479325.834	13.353	239968.573	479325.852	13.345	-0.029	0.018	0.008
24	240110.087	479199.358	4.267	240110.067	479199.382	4.249	-0.020	0.024	0.018
25	240260.199	478052.567	5.182	240260.229	478052.542	5.175	0.030	-0.025	0.007
26	240082.713	478018.922	4.877	240082.753	478018.872	4.869	0.040	-0.050	0.008
27	240264.128	478896.77	14.572	240264.100	478896.800	14.582	-0.028	0.030	-0.010
28	240077.244	478782.153	15.182	240077.274	478782.123	15.190	0.030	-0.030	-0.008
29	240295.675	478754.677	13.962	240295.705	478754.693	13.979	0.030	0.016	-0.017
30	239978.084	478547.159	15.182	239978.128	478547.219	15.190	0.044	0.060	-0.008
						Mean Square Error	**0.018**	**0.013**	**0.034**
						Total of Root Mean Square Error (RMSE)	**0.030**		**0.034**

■5.0 CONCLUSION

Nowadays, with the development of digital camera, analysis can be carried out for the small format digital camera attached to the 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 and DEM. 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.

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