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Digital Mapping Using Low Altitude UAV

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ABSTRACT

Normally, topographic map is produced using aerial photogrammetry. The recent development in aerial photogrammetry is the use of large format digital aerial camera for producing topographic map, however, the cost of the camera is too expensive and many mapping organization around the world could not afford to purchase it. In certain application, there is a need to map small area with limited budget. This issue has been solved by using small format camera (i.e. conventional or digital) to produce digital map. This study concentrates on the use of unmanned aerial vehicle (UAV) for producing digital map. UAV has been widely used in military for reconnaissance, planning, combat, and etc. Today, UAV can be used by civilian for reconnaissance, monitoring, mapping, and others. The objectives of this study are to investigate the capability of UAV in producing digital map and assess the accuracy of mapping using UAV. In this study, a light weight fixed wing UAV was used as a platform and a high resolution digital camera was used to acquire aerial digital images of the study area. The aerial digital images were acquired at low altitude. After capturing the aerial digital images, ground control points and check points were established using GPS. Then the aerial digital images were processed using photogrammetric software. The output of the study is a digital map and digital orthophoto. For accuracy assessment, the root mean square error (RMSE) is used. Based on the assessment, the results showed that accuracy of sub-meter can be obtained using the procedure and method used in the study. In conclusion, this study shows that UAV can be used for producing digital map at sub-meter accuracy and it can also be used for diversified applications.

Keywords: Unmanned aerial vehicle, aerial photogrammetry, digital camera

INTRODUCTION

In aerial photogrammetry, normally the topographic map, orthophoto and other photogrammetric products are produced from the aerial photograph acquired using the large format aerial camera or commonly known as metric camera. The cost of acquiring the aerial photograph is very costly and need to be planned properly. Ideally, large format aerial camera is useful for mapping large area. This type of camera is not suitable and economical to be used for mapping small area. To overcome this problem, small format digital camera can be used to acquire aerial photograph. The small format digital camera has been widely used by many researches around the world for mapping purposes (Mills and Newton, 1996a, b; Ahmad, 2009). The aerial photograph acquired using small format digital camera is used not only for topographic mapping (Ahmad, 2006) but it could also be used for various applications such as for land slide (Ahmad *et al*., 2008), map revision in GIS, research

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work, and any application which does not require high accuracy. The digital camera offers several advantages compared to large format metric camera. Some of the advantages include ease of use, handy, cheap, the images are in digital form which is ready to be used and does not need special aircraft. The digital camera can be placed in a balloon, light aircraft such as the microlight, and other platform (i.e based on their application). The use of digital camera also has been reported by several researchers for different applications.

In this study, a small airplane in the form of a glider or known as unmanned aerial vehicle (UAV) equipped with a small format digital camera, Global Positioning System (GPS) and Inertial Navigation System (INS) which form data acquisition system is used to acquire aerial photograph of the study area. The objectives of the study are to investigate the suitability of the data acquisition system in acquiring the aerial photograph for mapping purposes and to produce digital map and digital orthophoto from the aerial photograph.

UNMANNED AERIAL VEHICLE

Unmanned Aerial Vechicle (UAV) was developed by the United State (US) military for surveillance and reconnaissance purposes back in World War 1 and World War 2 as a prototype form. UAV is widely used in early 20th century between the year 1960s to 1980s. The number of research on UAV done by US and other countries around the world is increasing. UAV is also known as drones, remotely piloted vehicle (RPV), remotely piloted aircraft (RPA), and remotely operated aircraft (ROA). Today, UAV is available in various shape, size, weight, and applications. UAV is a light aircraft that fly without pilot and uses aerodynamic power to fly, able to fly on its own based on pre-programmed flight plans or a complex dynamic automation system (UAV Forum, 2008). There are also operating UAV for remote sensing application such as photogrammetric task in recording archeology site (Eisenbeiss, 2004); precision agriculture (Herwitz *et al*., 2002); GPS remote sensing measurement (Gent *et al*., 2005), thermal and hyperspectral sensing, search and rescue, industrial and chemical plant inspection, emergency operation and production of 3D vector map (Haarbrink and Koers, 2008). Table 1 shows the category of UAV defined by Unmanned Vehicle Systems-International (UVS).

TABLE 1
Category of UAV [7]

Category name	Mass (kg)	Range (km)	Flying altitude (m)	Endurance (h)
Micro	<5	<10	250	1
Mini	<250/30/150	<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

In this study, the CropCam UAV deployed is a Canadian product that has weight of 2.7 kg (*Fig. 1*). Table 2 shows the specification of the CropCam UAV. The CropCam UAV together with Pentax Optio A40 digital camera is used to acquire aerial photographs. This CropCam UAV is launched manually and landed on the same spot where it was launched. *Fig. 2* shows the CropCam UAV component and ground control station.

Fig. 1: CropCam UAV

TABLE 2
Specification of Cropcam UAV

Lenght	1.22 m
Wing span	2.44 m
Mass	2.72 kg
Engine	2.46 cc / 0.15 cu in
Oil tank	6 oz
Altitude	Up to 2200 feet in Canada
Flight endurance / 160 acre	20 minute
Camera	Pentax Optio A40
Average speed	60 kmj^{-1}
Minimum temperature	–10°C

Fig. 2: CropCam UAV and ground station

RESEARCH METHODOLOGY

Acquisition of Aerial Photograph Using UAV

The photographs of Universiti Teknologi Malaysia (UTM) main campus were acquired using both the large format metric camera and small format digital camera Pentax Optio A40. For the large format metric camera, the Wild RC30 metric camera with wide angle lens was used to acquire the aerial photographs of UTM by Department of Surveying and Mapping Malaysia (DSMM). The photographs were acquired in 2005 with the scale of 1:10 000. After the photography, the colour film was developed and scanned at 1000dpi using the photogrammetric scanner in DSMM. In this study, the large format aerial photograph acquired using the Wild RC30 camera was used as reference image.

For the Pentax Optio A40 digital camera, the aerial photographs (in digital form) were acquired by placing the digital camera underneath the CropCam UAV's wing. The photographic session is carried out by a company and a series of digital images were acquired. The digital images were acquired at an approximate 60% overlapped and 30% sidelapped. Since the format of the digital camera is small, the ground coverage is small too. Many small format aerial photographs were acquired using several flight lines. After each flight session, the digital images were downloaded into the notebook at the ground control station. *Fig. 3* shows an example of the aerial photograph acquired using the small format digital camera.

Fig. 3: An example of aerial photograph of partial area of UTM campus acquired using the digital camera

Establishment of Ground Control Point

In photogrammetry, it is a common practice that the ground control points (GCPs) are established after the aerial photography session. There are several methods that can be used to establish the GCP such as traversing and Global Positioning System (GPS). For the large format photograph several GCPs were selected which enclosed the overlapped area. For the digital images, many GCPs are required. For the establishment of GCPs, rapid static method was used for both the large format and small format aerial photographs.

Calibration of Digital Camera

In this study, a test field was built at Faculty of Geoinformation Science and Engineering, UTM. This test field is a 3D test field which comprise of 36 targets that are fixed with retro-reflective target. The test field was used to calibrate the digital camera. For the purpose of calibration, 10 photographs of the test field were acquired from five (5) camera locations (*Fig. 4*). The focus of the digital camera was set at infinity focus and the automatic function was disabled. At each camera location, two photographs were acquired where one is in landscape position and the other one is rotated 90 degree from its' original position i.e portrait position. During photography the camera flash is switched on and a piece of tissue paper was used to block the flash light so that not much light will be transmitted. If the flash is not covered then 'over saturated' will occur which might cause deterioration of the calibration results. Also during photography, convergent photographs were employed where the optical axis of the digital camera always pointing towards the centre of the test field and the dimension of the test field should occupy the entire format of the digital camera. Convergent configuration was employed since it will strengthen the geometry and with the purpose to recover focal length successfully as recommended (Foyer, 1996). Photography was done within short period of time. The photographs of the test field were acquired after the acquisition of aerial photographs.

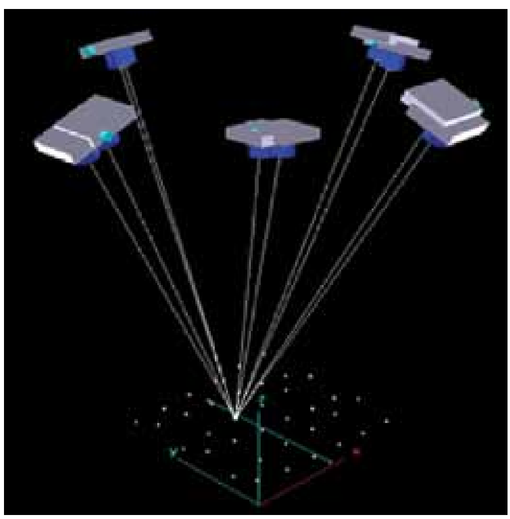

Fig. 4: Test field and location of digital camera

Processing Aerial Photograph

In this study, a digital photogrammetric software was used to process the digital images of the large format metric camera and the small format digital camera. The digital photogrammetric software was used to produce digital orthophoto and to produce digital map. For the large format aerial photograph, only a pair was used to generate the 3D stereoscopic model. In digital photogrammetric software, the 3D stereoscopic model was setup within short period. Then on screen digitizing is carried out to digitize some features (vectorization) in the stereoscopic model. The next step is to create DTM and subsequently create digital orthophoto. The vector and the orthophoto could be exported to other format such as CAD and GIS formats. The same procedure was repeated to process the aerial photograph from the small format digital camera.

Calibration of Digital Camera

After all the photographs from the digital cameras have been downloaded into the computer, image measurement is carried out. All the photographs of the test field were measured semi-automatically using close range photogrammetric software. This software can be used to determine the 3D coordinates of the points on the object (i.e retro-reflective targets) and the camera calibration parameters. The coordinates for the centre of the retro-reflective targets of the test field were determined using 'weighted mean' technique. The results of the camera calibration are tabulated in the following section.

RESULTS

From this study, two sets of results were produced. The first results comprised of camera calibration parameters obtained from calibrating the digital camera and the second results comprise of digital orthophoto obtained from the digital photogrammetric software.

Camera Calibration Parameters

Table 3 shows the estimated parameters together with their standard deviation. 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, p^3) lens distortion, "affinity"(b^1) and different in scale factor (b^1). All these parameters were then entered into the digital photogrammetric software for processing the aerial photograph except for affinity and scale factor parameters.

TABLE 3
Digital camera calibration parameters

Canon digital camera		
Parameter		Std. deviation
c (mm)	7.4753	4.511e-003
x_P (mm)	-0.0930	2.670e-003
y_P (mm)	0.1264	2.700e-003
k_1	4.17626e-003	1.004e-004
k_2	-9.22072e-005	2.088e-005
k_3	2.63634e-006	1.411e-006
p_1	2.05459e-004	1.802e-005
p_2	-6.14004e-004	1.841e-005
b_1	1.94918e-004	3.866e-005
b_2	7.89334e-005	4.294e-005 5

Digital Orthophoto

Before the production of the orthophoto, aerial triangulation is performed for the small format aerial photographs and followed by production of DTM. After the process of aerial triangulation, the 3D stereoscopic model is set up. From the 3D stereoscopic model, digitizing is carried out and check points were also digitized for the purpose of accuracy assessment. In this study, sub-meter accuracy of ±0.623m was achieved from the assessment. Table 4 shows the result of accuracy assessment.

Fig. 5 shows the mosaic of digital orthophoto produced from the digital photogrammetric software of the small format digital camera.

TABLE 4
Accuracy assessment

Pt ID	GPS (meter)			ERDAS imagine (meter)			Differences (meter)		
	X	Y	Z	X	Y	Z	ΔX	ΔY	ΔZ
1015	627391.613	171955.444	12.413	627391.651	171955.655	13.674	0.039	0.211	1.261
1016	627357.901	171945.050	11.724	627357.408	171944.646	12.185	0.493	0.403	0.461
1019	627420.304	171992.045	13.661	627420.573	171991.997	12.133	0.269	0.048	1.528
1020	627432.739	171995.588	13.805	627432.197	171995.647	12.890	0.542	0.060	0.915
1011	627313.775	172008.495	11.977	627313.570	172008.413	10.382	0.206	0.082	1.595
1012	627329.563	172008.759	12.015	627328.164	172009.035	10.589	1.399	0.277	1.426
						RMSE		**±0.623**	

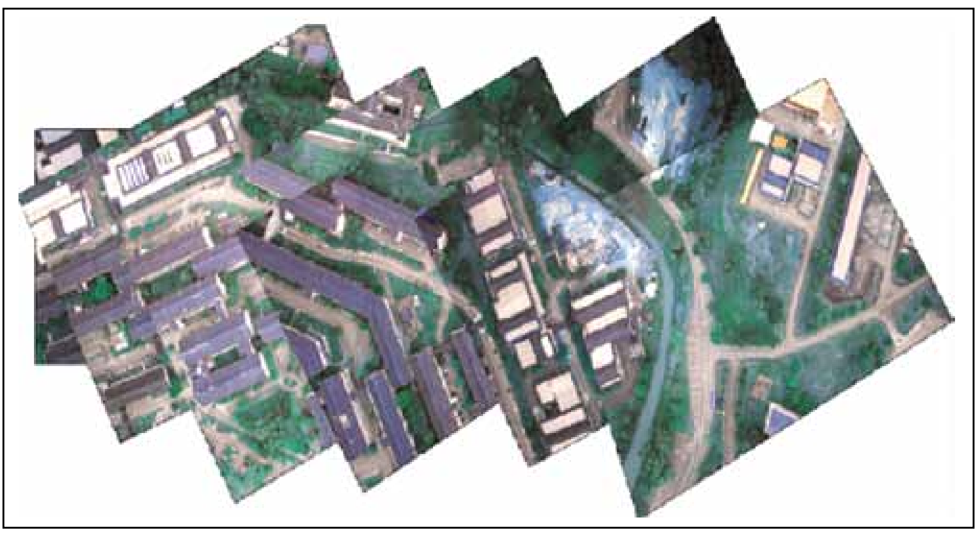

Fig. 5: Partial mosaic of UTM campus for the small format aerial photograph

CONCLUSION

From this study, it was found that the digital photogrammetric software is capable of producing digital orthophoto and digital map for both the large format metric camera and small format digital camera. However, the area covered by the digital camera is very small compared to the area covered by the large format metric camera. In this study, the digital orthophoto produced from the digital camera covers only a small area compared to the digital orthophoto produced from large format metric camera. For accuracy assessment, it cannot be denied that the accuracy for large format metric camera is superior. In another previous study, it was proved that high accuracy could be achieved by the large format metric camera compared to the accuracy achieved by the small format digital camera (Ahmad and Adnan, 2008). In this study, the accuracy achieved by the small format digital camera is at sub-meter level.

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