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Development of Rapid & Low Cost Archaeological Site Mapping Using Photogrammetric Technique

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Abstract. In digital photogrammetry, unmanned aerial vehicle (UAV) platform is a new technology that can be used to capture digital images for large scale mapping with accuracy down to centimeter level from various waypoints for archaeological site documentation. UAV is one of the great alternatives to replace piloted aircraft and with combination of non - metric camera, thus it can be applied for small area such as cultural heritage building/ archeological site area. With the recent technology of non-metric cameras, this camera is capable of producing high resolution digital images. This study investigates the application of UAV images for documentation and mapping of a simulated archaeological sites. An archaeological site simulation modelwith dimension of 2.4m x 3.5m is used in this study. The accuracy for mapping the archeological sites based on the UAV system is evaluated and analyzed by performing the Root Mean Square Error (RMSE) derived from the differences of coordinates between reference value and the coordinates observed from photogrammetric output such as digital terrain model and orthophoto. In this application, a simulation model was used to simulate the archaeological site excavation. The results clearly demonstrate the potential and the capability of UAV and non-metric camera in providing the accuracy of centimetre level for this application. From this study, it can be concluded that the UAV and the photogrammetric technique procedure satisfied the needs of archaeological sites survey and documentation.

1. Introduction

Recently, the civilian application of unmanned aerial vehicle (UAV) has been increasingly used for mapping purposes. UAV have several advantages over satellites and piloted or manned aircraft which can capture aerial images from certain flying height and the flying height depends on the size and shape of the UAV. The UAV technologies have become popular among digital photogrammetry users as they are flexible in terms of flying mission and timing. The UAV is capable of flying at low altitude together with small format digital camera and it is suitable for small areas. The advantages of developing the technology of UAV for low altitude photogrammetric mapping are to perform aerial photograph at cloudy days, to get full image of objects from the top, and to supply a cheap and easy system for high frequency needs of aerial photogrammetric survey [1]. As well as their employment and development are cheaper than traditional platforms since the mini-UAV have a low weight (less than 5kg) and small dimensions. Therefore, the object that cannot be displayed clearly by piloted aircraft and satellites images can be obtained in detailed at sub-meter resolution.

Archaeological findings are instructive in explaining the socio-cultural aspects, as well as the placement of the pattern of life and social system of ancient societies [2,3,4]. In archaeological, documentation is one of the important sources for researchers to help then carry out research on

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an archaeological site. An archaeological site data should be collected quickly so as not to destroy the site or the original site conditions during the process of collecting data in the field. Therefore, a rapid method should be identified to facilitate this process because the excavation site may be exposed to hazards and debris due to soil conditions that might not be stable. Various methods are used for recording archaeological site such as ancient settlements, among them is through the use of GIS and spatial analysis [3]. Among the spatial technology information are remote sensing, Global Positioning System, aerial photo and GIS. These technologies have changed the discipline of geography by giving it the ability to analyze the whole information either quantitatively or qualitatively. Moreover most of the data are converted to numerical format due to the machine being used has a limited memory and limited analytical software [5]. In archaeology, the UAV system has been used to produce DSMs (digital surface model) of the settlement of Pinchango Alto in Peru which was the first archaeological site to be documented photogrammetrically using UAV [6]. Views of archaeological sites from the sky are always breathtaking [7]. Information technology has helped archaeologists in decision making. The overall field of the application of information technology to cultural heritage is rapidly developing. Hence archaeology has embraced virtual technology and known as virtual archaeology [8].

2. Preliminary Study

A preliminary experiment has been conducted in order to evaluate the capability of the UAV attached with digital camera for the purpose of mapping archaeological site. The dimension of the archaeological site simulation model is 2.4m x 3.5m. It consists of sand, some broken porcelains, and some artificial bones. The purpose of this study is to assess the digital camera for mapping archaeological site as well as to evaluate the accuracy that could be achieved by using close range photogrammetry technique.

2.1. Camera Calibration

Before a digital camera is used in photogrammetry, it must be calibrated to ensure that the internal geometry of the camera is known. The method of camera calibration used is self-calibration bundle adjustment. A camera calibration software was used to calibrate the digital camera. The results of the camera calibration are shown in Table 1. There are 8 parameters in camera calibration, which include focal length, principal point offset, radial, tangential and lens distortion.

Table 1. Result of camera calibration

Parameter	Canon PowerShot SX 230 HS
c	5.1274
x_p	3.054
y_p	1.7517
k_1	1.5940e003
k_2	-4.1140e005
k_3	6.9535e005
p_1	3.2327e004
p_2	3.5932e004

2.2. Equipment

In this study, Canon PowerShot SX 230 HS digital camera has been used in acquiring the simulation model images at resolutions up to 4000 pixels x 2248 pixels or about eight Megapixels. The camera was attached at the bottom of the Hexacopter which has been assembled with complete set gadgets such as GPS on board, pressure board, speed board, gyro and main board as shown in Figure 1. The Hexacopter is more stable and able to capture images from certain altitude.

Figure 1. Hexacopter equipped with Canon PowerShot SX 230 HS.

3. UAV System/Methodology

The Hexacopter uses the autonomous flight control system and controlled by two operators where one act as pilot on ground and the other in charge of monitoring flight mission at ground station. In this experiment, the Hexacopter was equipped with a Canon PowerShot SX 230 HS digital camera in acquiring the simulation model images. The specifications of the Hexacopter UAV are shown in Table 2.

Table 2. Hexacopter UAV Specification

Weight	1.2kg
Rotor	6 rotor
Endurance	Up to 36 minutes
Payload	1kg
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	Flexible camera holder

3.1. Fieldwork

The establishment of ground control point (GCP) and check point (CP) was performed after the acquisition of aerial image. The GCP and CP comprise of black and white target points placed throughout the simulation model in order to achieve the maximum effects of relating the measurements derived from the image with the 3D coordinate system. There are 35 GCPs and 6 CPs were established and were located in the simulation model. The 3D coordinates of these GCPs and CPs were determined using total station.

After the camera calibration and the establishment of GCPs and CPs completed, then the aerial images acquisition is carried out using the Hexacopter. For flight planning, the images must be acquired with the specifications coverage of 60% forward lap and 30% sidelap. The digital camera was used to acquire photographs of the simulation model at a constant distance of 3 meter from the model.

3.2 Image Processing

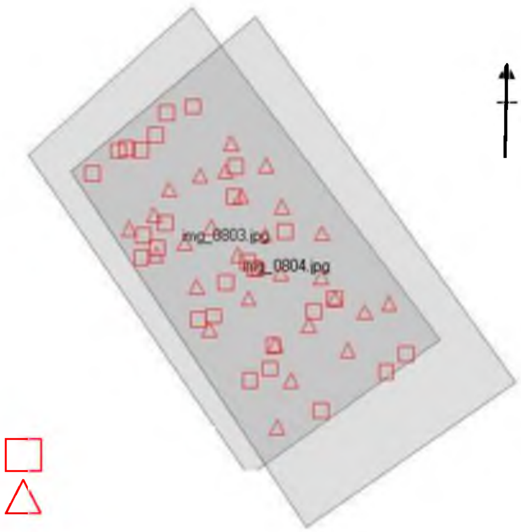
For photogrammetric image processing, all the images were processed using a digital photogrammetric software. The processing involved interior orientation which requires input camera calibration parameter of the digital camera. Also processing involved exterior orientation where GCPs are used in image processing. In aerial image processing, the bundle adjustment or triangulation is carried out and the result is shown in the form of root mean square error (RMSE). Ideally the RMSE value must be less than 1.0 to indicate good result. The RMSE of unit weight is displayed without unit. In equation (1)

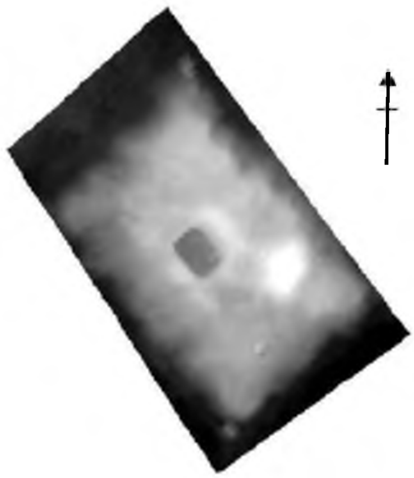
$$RMSE = \pm \sqrt{\frac{\sum_{i=1}^{n} (X_i - X_o)^2}{n-1}} \quad (1)$$

Where;
n = number of checkpoints
X_i = True value
X_o = Observed value

4. Result and Analysis

After the process of bundle adjustment or aerial triangulation ad the RMSE value is less than 1.0,the 3D stereo model has successfully been formed. Based on this 3D stereomodel, DTM and orthophoto are produced. The digital photogrammetric software allows user to display footprint of the processed aerial photograph. The footprint consist of two (2) overlapping photograph based on the most efficient and reliable means of providing stereoscopic coverage as shown in Figure 2. The aerial triangulation results shows that the result of the Canon PowerShot SX 230 HS digital camera is RMSE ± 0.0337. In this preliminary study, two main results were produced i.e DTM as shown in Figure 3 and orthophoto in Figure 3 respectively.





N

Tie

points

Control points

Figure 2. Footprint

Figure 3. Digital Terrain Model

The DTM was produced after aerial triangulation using GCP and later tie points were generated automatically. Then the individual orthophoto for each image was generated from the DTM as shown in Figure 4. Orthophoto product is free from any distortion and demonstrates the whole simulation model.

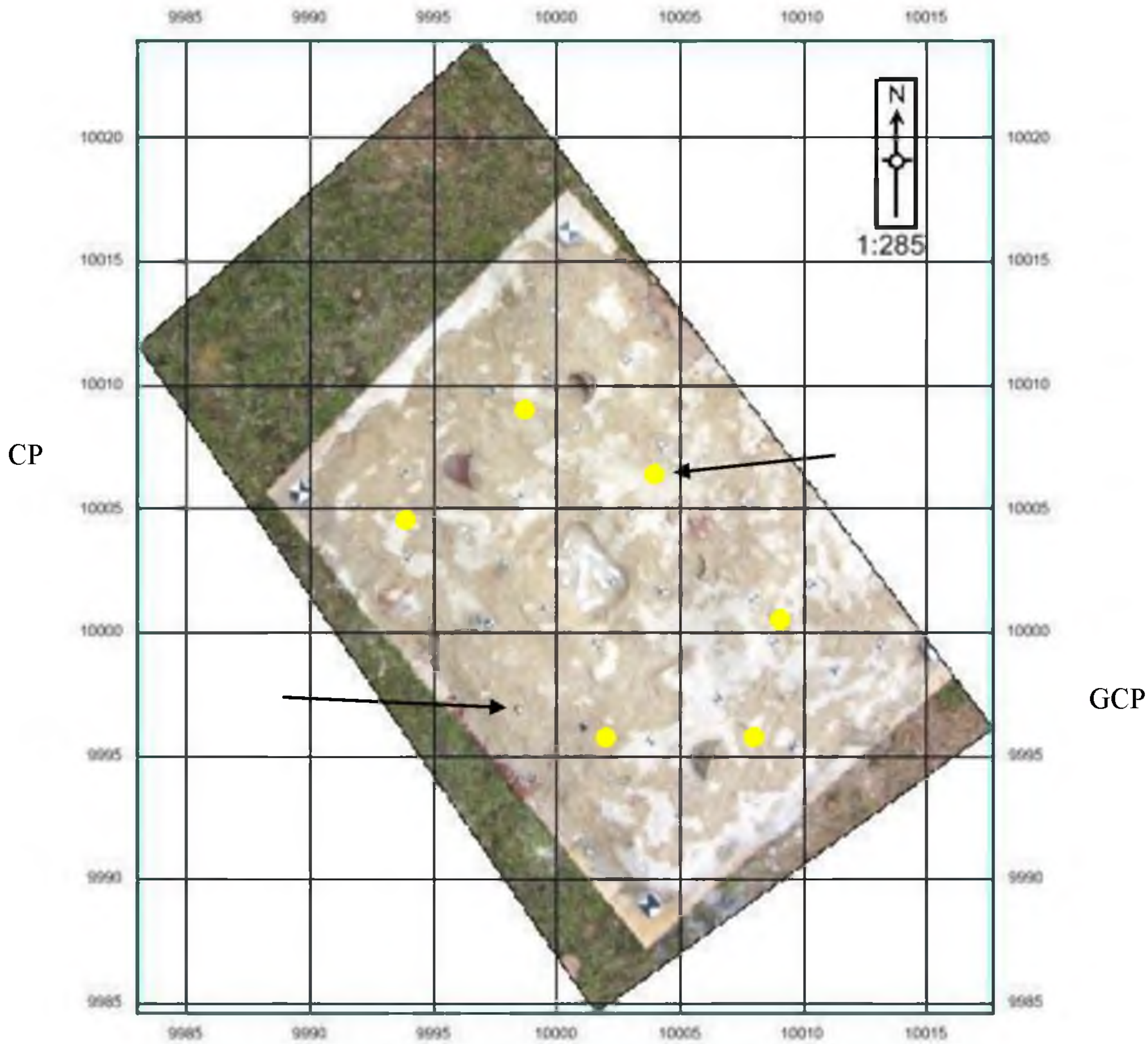


Figure 4. Orthophoto

From Table 3 it shows that the RMSE of differences in coordinates from the image processing software and total station were less than 1.0 which indicates the good results that were achieved in this study.

Table 3. Comparison of coordinates

Check Points	Erdas Imagine			Total station			Diff. in Coordinates		
	X(m)	Y(m)	Z(m)	X(m)	Y(m)	Z(m)	ΔX(m)	ΔY(m)	ΔZ(m)
C01	10010.687	9998.507	20.275	10010.783	9998.575	20.332	-0.096	-0.068	-0.057
C02	10009.475	9999.649	20.190	10009.559	9999.707	20.278	-0.084	-0.058	-0.088
C03	10009.719	9997.949	20.197	10009.782	9997.970	20.262	-0.063	-0.021	-0.065
C04	10010.130	9998.232	20.246	10010.188	9998.319	20.319	-0.058	-0.087	-0.073
C05	10008.896	9999.169	20.154	10008.953	9999.266	20.213	-0.057	-0.097	-0.059
C06	10009.937	9999.477	20.199	10009.962	9999.533	20.314	-0.025	-0.056	-0.115
						RMSE	0.171	0.173	0.204
						Average		0.183	

5. Conclusion

For future work real archaeological site will be determined and the aerial image will be captured using fixed wing UAV. Then the digital images will be processed using similar procedure where the GCPs, CPs and camera calibration parameters will be used for digital processing to produce the photogrammetric product. Then the results from these two platforms will be compared for archaeological site. In this preliminary results show that there is no doubt that good result could be produced from the UAV system using photogrammetric technique.

References

[1] Lin Zong Jian 2008 *UAV for Mapping-Low Altitude Photogrammetric Survey The International Archives of the Photogrammetry* Remote Sensing and Spatial Information Sciences, Part B1 XXXVII 1183-1186

[2] Witschey W R, and Brown C T 2000 *Building a GIS System of Ancient Lowland Maya Settlement*. Society for American Archaeology Annual Meeting

[3] Van Der Leeuw S E 2004 *Why Model? Cybernetics and Systems*: An International Journal, 35(2-3) pp 117-128

[4] Okabe A 2006 1- *Introduction. In A. Okabe, GIS-Based Studies in the Humanities and Social Science* (Boca Raton: CRC Press, Taylor & Francis Group) pp 1-18

[5] McPheerron S P, and Dibble H L 2002 *Using Computers in Archaeology: Practical Guide* (USA: McGraw-Hill Companies)

[6] Lambers K, Eisenbess H, Saurbier M, Kupferschmidt D, Gaisecker T, Sotoodeh S, and Hanusch T 2007 *Combining photogrammetry and laser scanning for the recording and modeling of the Late Intermediate Period site of Pinchango Alto, Palpa, Peru.* Journal of Archaeological Science, 34(10): pp 1702-1712

[7] Gerster G, and Trumpler C 2005 *The past from above: Aerial photographs of archaeological sites* J. Paul Getty Museum Series (Getty Trust Publications, Los Angeles)

[8] J A, Forte M, and Sanders D H 2000 *Virtual Reality in Archaeology* (ArcheoPress Oxford) British Archaeological Reports International Series pp 843

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