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Mapping of a river using close range photogrammetry technique and unmanned aerial vehicle system

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Abstract. Photogrammetry is a technique that can be used to record the information of any feature without direct contact. Nowadays, a combination of photogrammetry and Unmanned Aerial Vehicle (UAV) systems is widely used for various applications, especially for large scale mapping. UAV systems offer several advantages in terms of cost and image resolution compared to terrestrial photogrammetry and remote sensing system. Therefore, a combination of photogrammetry and UAV created a new term which is UAV photogrammetry. The aim of this study is to investigate the ability of a UAV system to map a river at very close distance. A digital camera is attached to the Hexacopter UAV and it is flown at 2 m above the ground surface to produce aerial photos. Then, the aerial photos are processed to create two photogrammetric products as output. These are mosaicked orthophoto and digital image. Both products are assessed (RSME). The RSME of X and Y coordinates are ± 0.009 m and ± 0.033 m respectively. As a conclusion, photogrammetry and the UAV system offer a reliable accuracy for mapping a river model and advantages in term of cost-efficient, high ground resolution and rapid data acquisition.

1. Introduction

Generally photogrammetry refers an art, science and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena [1]. In other words, photogrammetry is a technique or method used to record the physical information (e.g.: hill, river, house etc.) on the earth's surface without direct contact to them. Photogrammetry can be divided into four categories. Each category is recognized based on the ways photo or image is taken. The photo can be taken from different heights or altitude. If the photo or image taken from height more than 300 m, it called aerial photogrammetry. For the photo or image taken from a height less than 300 m, it can be classified as close range photogrammetry (CRP). Besides, a photo taken near to the ground is called terrestrial photogrammetry. The photo taken in the space then it is called outer space photogrammetry or commonly known as remote sensing [2]. Photogrammetry can be used for various applications such as topographic mapping, engineering, military, architecture, geology, crime, environment and much more. Today, the field of photogrammetry is growing rapidly and became as one of the important field in the world especially in developed countries.

Unmanned Aerial Vehicle (UAV) is one of the branches in the photogrammetric field. It is considered as close range photogrammetry (CRP). A UAV is a model of an aircraft that does not need a pilot onboard to control it. It is equipped with a high technology system which is capable to fly without a pilot on board. It is controlled from the ground control station (GCS) [3]. According to [4] UAV is an uninhabited and reusable motorized aerial vehicle. UAV can be flown in several modes which is autonomous, semi-autonomous, remotely controlled or combination one of them. Generally,

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there are many terms used to describe a UAV as remotely piloted vehicle (RPV), remotely operated aircraft (ROA) or remotely piloted. But UAV is the most commonly used term in fields like computer science, robotics and artificial intelligence and also in photogrammetry and remote sensing communities. The UAV was developed by military during World War I and II for reconnaissance and surveillance purposes [5]. Today, civilians are able to operate a UAV for photogrammetry applications. According to [6], 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 aerial view, and to supply a cheap and easy system for high frequency needs of aerial photogrammetric survey.

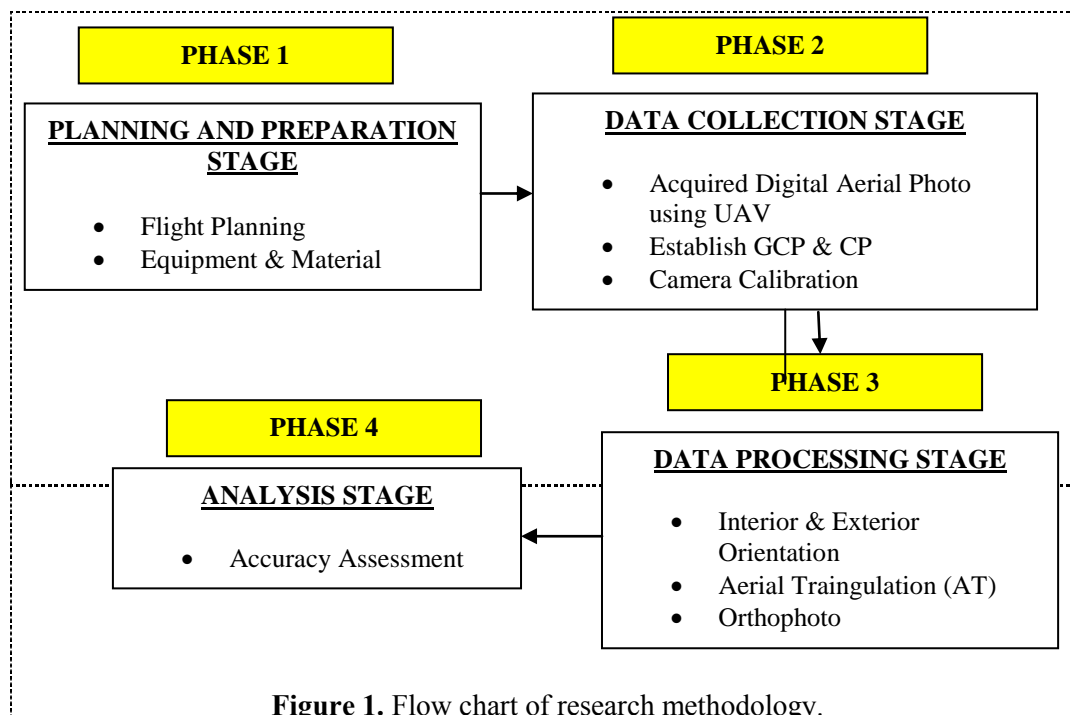
There are several types and categories of UAV. Each category is grouped based on mass, range, flight altitude and endurance. Table 1 shows the categories of UAV and the description of each category [7].

Table 1. Categories of U_s.

Category Name	Mass (kg)	Range (km)	Flight altitude (km)	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		>3000	>6

2. Research methodology

Methodology is the most important element in this research because it affects the success of the research. Methodology in this study has been divided into four phases. Figure 1 shows the flow chart of the research methodology.



2.1. Planning and preparation

Phase one is the initial phase in this study. There are two processes involved in this phase which are flight planning and preparation of equipment and materials. The flight planning is important and must

be implemented carefully and neat because any mistake occurs during flight planning will cause the UAV crashed and interrupt the flow of the entire study. Several elements need to be considered during formulating the flight planning such as flight height, waypoints, speed and others. All these elements need to be set correctly to ensure that all the aerial photos are successfully acquired. For example, the aerial photo should 60% overlap side lap and 30% overlap end lap. Other process involved in the first phase is preparing the relevant equipments and materials that are required in this study such as digital camera, total station, Hexacopter-UAV and exacta.

2.2 Data collection

The second phase involves data collection of aerial photograph, establishment of ground control point (GCP) and check point (CP). Aerial photo is captured using a digital camera which is installed on the Hexacopter-UAV. There are 21 aerial photos successfully acquired during a flight mission, but only 3 aerial photo used for the data processing. In addition, about 40 GCP's and 6 CP's are established using total station. The GCP are used in exterior orientation while CP's are used for accuracy assessment. The GCP are also used to perform aerial triangulation (AT). The camera also needs to be calibrated in order to obtain the camera parameter and these data are used for interior orientation. There are many methods can be used to calibrate the digital camera and the method used in this study is bundle adjustment.

2.3 Data processing

Data processing involves the interior and exterior orientation and performing AT. All the processes are carried out using AgiSoft software. Interior and exterior orientation must be executed sequentially. Generally, the purpose of interior orientation is to create the ray geometry projection precisely as an original geometry [8]. Meanwhile, the exterior orientation is carried out to eliminated y-parallax and formation of 3D stereoscopic model. After the formation of 3D stereoscopic model, DTM could be generated. Subsequently, the orthophoto could be generated. In this study, three individual orthophoto were generated and later all of them were mosaicked to form a single (Figure 3). This is an orthophoto which covers the whole river.

2.4 Accuracy assessment

$$RSME = \pm \sqrt{\frac{\sum(n_1 - n_2)^2}{N - 1}} \quad (1)$$

where,

n1 = observed value

n2 = reference value

N = total no. of points

The last phase is accuracy assessment where each result is analyzed in terms of quantitative and qualitative. Qualitative analysis was used to visualize the result (i.e. orthophoto) while quantitative analysis involves the use of root mean square error (RSME) as shown in equation 1[8].

3. Results and analysis

There are two major results produced in this study which comprise of orthophoto mosaic and digital map of the river model. Figure 2 and figure 4 show the mosaic orthophoto and digital map respectively.



Figure 3. Mosaic Orthophoto.

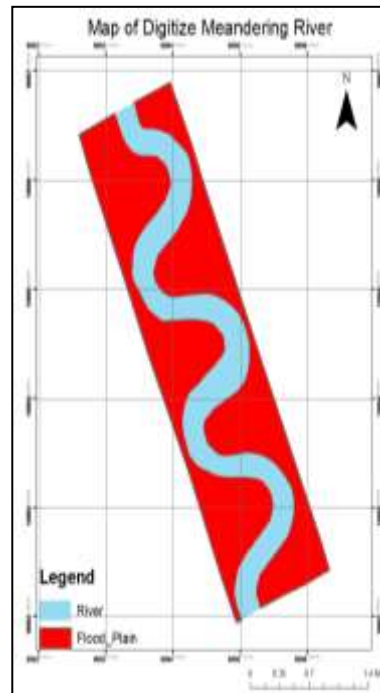


Figure 4. Digital Map of Meandering River Model.

Based on Figure 3, there are three individual orthophoto that were mosaicked by using Agisoft software. In addition, the digital map of meandering river model as shown in Figure 2 is produced by digitizing the orthophoto using ArcMap 10 software.

Other than that, digitize image of river model also generated in this study as shown in Figure 2. Digitize images is produced by making a mosaic orthophoto as a references and digitizing process done by using ArcMap10 software.

Table 2. Accuracy assessment.

GCP ID	AGISOFT		Total Station		Difference	
	X (m)	Y (m)	X (m)	Y (m)	X (m)	Y (m)
CP A21	9994.121	10006.640	9994.128	10006.638	-0.007	0.002
CP B19	9995.244	10002.075	9995.253	10002.074	-0.009	0.001
CP A01	9995.552	10002.202	9995.546	10002.205	0.006	-0.003
CP B01	9993.850	10006.429	9993.843	10006.431	0.007	-0.002
CP B10	9995.094	10004.534	9995.102	10004.616	-0.008	-0.082
CP A13	9994.348	10005.114	9994.336	10005.134	0.012	-0.020
				RMSE	0.009	0.033
				Average	±0.0021 m	

Table 3 shows the comparison between the coordinates measured using Agisoft software and the coordinates observed using total station. The coordinates from the total station were used as reference value. There are six CP's are used for accuracy assessment. Table 3 also shows the root mean square error X-Coordinate and Y-Coordinate which are ±0.009 m and ±0.033 m respectively. The RMSE

shows the quality of the orthophoto. The RSME of Y-Coordinate is higher than X-Coordinate and the average RSME is ± 0.0021 m.

In this study, ArcMap 10 software was also used to measure the length, area and width of any the river model. The measurements made on the orthophoto can be used for comparison with the measurement on the river model to evaluate accuracy. All the measurements made on the river model and by ArcMap 10 software were shown in Table 3.

Table 3. Comparison between Measurement on the river model and ArcMap 10.

Method	Length (m)	Width (m)	Area (m ²)
Tape Measurement	4.845	1.210	5.862
ArcMap 10	4.844	1.181	5.719
Difference	0.001	0.029	0.143

From Table 4, the differences in length, width and area are 0.001 m, 0.029 m and 0.143 m respectively. The differences of width is higher than length which is 0.029 m and can be considered as a acceptable. The differences between measurement on the ground and ArcMap 10 is small and the quality of orthophoto produced from Agisoft can be considered as accurate.

4. Conclusion

CRP and UAV system can be used and is suitable for large scale mapping to create a river model. This is because both techniques can give a result with reliable and good accuracy. Also these techniques have advantages in terms of cost, time and high ground resolution [10].

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