The Potential of Unmanned Aerial Vehicle for Large Scale Mapping of Coastal Area

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Abstract. Many countries in the tropical region are covered with cloud for most of the time, hence, it is difficult to get clear images especially from high resolution satellite imagery. Aerial photogrammetry can be used but most of the time the cloud problem still exists. Today, this problem could be solved using a system known as unmanned aerial vehicle (UAV) where the aerial images can be acquired at low altitude and the system can fly under the cloud. The UAV system could be used in various applications including mapping coastal area. The UAV system is equipped with an autopilot system and automatic method known as autonomous flying that can be utilized for data acquisition. To achieve high resolution imagery, a compact digital camera of high resolution was used to acquire the aerial images at an altitude. In this study, the UAV system was employed to acquire aerial images of a coastal simulation model at low altitude. From the aerial images, photogrammetric image processing was executed to produce photogrammetric outputs such a digital elevation model (DEM), contour line and orthophoto. In this study, ground control point (GCP) and check point (CP) were established using conventional ground surveying method (i.e total station). The GCP is used for exterior orientation in photogrammetric processes and CP for accuracy assessment based on Root Mean Square Error (RMSE). From this study, it was found that the UAV system can be used for large scale mapping of coastal simulation model with accuracy at millimeter level. It is anticipated that the same system could be used for large scale mapping of real coastal area and produces good accuracy. Finally, the UAV system has great potential to be used for various applications that require accurate results or products at limited time and less man power.

1. Introduction
Coastal mapping techniques are changing and improved from time to time. Photogrammetric technique can be employed to map the tide-coordinated coastline from aerial photographs that are taken when the water level reaches the desired level. Aerial photographs taken at this water level are more available to obtain water level information than remote sensing (RS) imagery.

In aerial photogrammetry, recently the unmanned aerial vehicle (UAV) has been popularly used for large scale mapping and involves low budget. UAV systems showed advantages in several mapping applications in recent years especially in surveying. The UAV systems could be mounted on either high or low altitude platforms. Low-altitude systems have advantages in conducting photogrammetric surveys at cloudy days, providing different views and tilted images of the surveyed

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objects, low-cost supplying and easy-to-maintain for engineering applications systems such as topographic either large or small scale mapping.

According to [1], 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 the top, and to supply a cheap and easy system for high frequency needs of aerial photogrammetric survey. UAV system is not limited by human on aircraft for data collection in dangerous of hazardous environment without risk of pilot.

In this study, two main hardware were used which comprise the light weight rotary-wing UAV and high resolution digital camera. Low altitude is preferable in this study because it focuses on large scale mapping of coastal simulation model which involved small area only. In addition, the compact digital camera provides small format images. Figure 1 and 2 shows an example of rotary wing UAV (Hexacopter) and compact digital camera.

![Figure 1. Hexacopter](image1.png) ![Figure 2. Digital Camera](image2.png)

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. In this study, the micro UAV also known as Hexacopter (Figure 1) has been used in acquiring images of the simulation model. The rotary wing UAV known as Hexacopter used in this study. This rotary wing has flexible camera holder, autonomous flight control, GPS onboard.

2. Coastal Terms

Coastal terms are used in coastal engineering and shoreline management. Generally, coastal environmental is the area is lying between land and sea [2]. The coastal zone is a difficult geographical area that needs to manage due to temporal issues (i.e. tides and seasons [3]). According to Figure [4], the definition of coastal terms has been identified such as (1) backshore; (2) bar; (3) beach or shore; (4) beach berm; (5) beach park; (6) breaker zone; (7) closure depth; (8) coast; (9) coast erosion; (10) coast protection/defense; (11) coastal area; (12) coastal hinterland; (13) coastal zone; (14) coastline; (15) coastline retreat; (16) development activity; (17) dune; (18) Environmental Impact Assessment (EIA); (19) erosion or profile erosion; (20) foreshore or beach face. The definition of the coastline can be defined as the line that forms the boundary between the coast and the shore, i.e. the foot of the cliff or the foot of the dunes. Malaysia has a total coastline of 4809 km, including Sabah and Sarawak. The peninsular Malaysia has a coastline 2031 km long while Sabah and Sarawak 2778 km long. [5] has claimed that the coastal erosion and reclamation in Malaysia can be linked to the demands and impacts of development in the coastal zone where 70% of the Malaysian population centred.

2.1. Mapping of Coastal Area

The coastal zone area is the most valuable asset for marine and fish, wildlife and human lives. In Malaysia, the occurrence of coastal erosion is increasing, threatens the people living close to coastal area and caused losses along the coastal line. However, coastal areas are also prone to environmental hazards such as erosion and sedimentation processes that may cause loss of coastal land and damage infrastructures and buildings as mentioned by [6]. The physical and environmental impacts of the tsunami in the affected areas were unquestionable. Among the damages were severe loss of life, houses, transport, land, and major fishery equipment [7]. More than 40 villages were involved,
affecting approximately 4,000 people [8]. Hence, coastal topographic is the principal variable that affects the movement of the tsunami wave on land. It is highlighted that the land surface elevation data are critical to a tsunami model for computing extent of inundation. Conceptually, map is defined as a representation, usually on a flat surface, of a whole or part of an area. In addition, map is also used to describe spatial relationships of specific features that the map aims to represent.

3. Experimental Result – Simulation Model
In this study, a rotary wing UAV was employed to acquire aerial images of a simulation model of coastal area that experienced coastal erosion. The dimension of this simulation model is 2.4m x 7.2m. It is made of sand and the simulation was done before and after erosion. The following section discusses the experiment conducted in this study.

3.1. Ground Control Station & Pilot Station
Since the development of UAV is autonomous flight, two main stations known as ground control station (GCS) and pilot. Generally, flight planning shows a flight map which consists of waypoints on a topographic map that shows the starting and ending points of each flight line. Flight planning encompasses calculation of boundary of the study area, number of strips required, pixel size, photo scale, flying height and percentage of end lap and side lap. The aerial photographs should overlap at least 60 percent and side lap at least 30 percent. Before any observation start, first step that need to be done is to properly install the instruments. There are few important components of the system in autonomous fly that should be installed such as internet connection, battery and digital camera attach to hexacopter UAV.

3.2. Camera Calibration
The self-calibration bundle adjustment was adopted in this simulation study. Normally, the digital camera needs to be calibrated to obtain camera parameters such as interior orientation parameters as shown in Table 1 shows the recovered camera calibration parameters after the self-calibration bundle adjustment method based on a camera calibration software.

| Table 1. Camera Calibration Parameter |
|--------------------------------------|
| Canon Powershot XS230 HS              |
| Parameter    | Value            |
| e (mm)       | 5.1274           |
| x_p (mm)     | 3.054255         |
| y_p (mm)     | 1.751686         |
| k_1          | 1.594 x 10^-3    |
| k_2          | -4.114 x 10^-5   |
| k_3          | 0.00000000      |
| p_1          | 6.071 x 10^-4    |
| p_2          | 4.965 x 10^-4    |
| b_1          | 4.54346 x 10^-7  |
| b_2          | 3.28513 x 10^-4  |

3.3. Data Acquisition
The digital images were acquired in small format according to the non-metric camera. Apart from that, a Canon Power Shot SX3 HS digital camera with wide angle lens and 12.10 megapixel resolutions was used to capture the aerial photography at the height of 3 meter. The GCPs were collected using total station through closed traverse. This technique can provide the position of Northing, Easting, and Elevation (N,E, and H) using the Civil Design and Survey (CDS) software. Using this software, a
accuracy of 10mm could be achieved. The check points (CPs) were also established using total station on the simulation model.

3.4. Image Processing and Results
All the images were processed using digital photogrammetric software. The process comprises of interior orientation, which requires the camera calibration parameter (table 1) and exterior orientation which require the registration of GCPs and auto generation of tie points. Each pair of photographs has 60 percent overlapped and eight (8) photographs which form a strip of photograph were processed for the whole simulation model. The footprint of a simulation model is shown in Figure 3. Meanwhile, the generated digital orthophoto for simulated model is shown in Figure 4.

Figure 3. Footprint for 8 photographs of the GCPs and tie Points

Figure 4. Digital orthophoto

The scale of the simulation model is 1:500 and the ground resolution is 4.0mm. Based on the image processing, there were 267 points, which covered 37 GCPs and the rest covered 230 tie points. There were two photogrammetric results generated after performing interior orientation, exterior orientation and aerial triangulation such as DTM and digital orthophoto. the visualization of DEMs is shown in Figure 5.

Figure 5. Digital Terrain Model (DTM)

3.5. Analysis and Discussion
This study utilizes UAV system for large scale mapping of coastal area for simulation model. The main important part in mapping is the accuracy of the output. This study investigates the accuracy of the output based on the average RMSE by using the GCP in aerial triangulation. Figure 6 shows the graph of RMSE versus the number of Ground Control Points (GCPs) used.

In point analysis, the results of the RMSE was below 1 meter which indicate that the orthophoto has sub meter accuracy. The smaller the RMSE, the better the result of the orthophoto. It can be conclude that the higher the GCPs, the better the RMSE.

![Average RMSE vs GCPs](image)

Figure 6. Triangulation Summary

This study has been carried out prove that UAV have a potential use for mapping coastal erosion. With this technology, many problems could be solve for various applications especially project with limited budget and covered small area. Table 2 shows the comparison of the time taken for data acquisition, processing and man power for the simulation model. As a conclusion, UAV platform is very helpful and economical for large scale mapping.

| Method       | Conventional                  | UAV Technology               |
|--------------|-------------------------------|------------------------------|
| Fieldwork    | Traversing – 30 minutes       | UAV setup – 20 minute        |
|              | Tacheometry - 1 hours (48 hours) | Flight – 30 minute           |
| Processing   | Generate the topographic plan – 1 days | Image processing until Map production – 2 hours |
| Man power    | 4 person                      | 1 professional pilot + 1 person |

From Table 2, it can be concluded that UAV system and photogrammetric software is easy to use and need more experience in order to understand how the UAV work. The equipment especially UAV give more advantage compare to conventional method because of the less manpower, limited budget and time constraint in order to produce map in sub meter accuracy.

4. Conclusion

In conclusion, this study has proven that the light weight rotary-wing UAV was successfully used for capturing the images of the simulated model for large scale mapping. UAV is an autonomous flight without any pilot onboard, suitable for cover small area and limited time and budget. Previously, aerial photogrammetry using manned aircraft has some limitation such as need professional pilot onboard, cannot fly at cloudy day, high cost and large format film needs to be scan before it can be processed.
using photogrammetric software. Recently, UAV technology showed the contribution for any organization in their job scope, research or project.

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