UNMANNED AERIAL VEHICLE LARGE SCALE MAPPING FOR COASTAL EROSION ASSESSMENT

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DEDICATION

This PhD Dissertation is dedicated

To my beloved husband (Mr. Hamdi Abdul Hamid), son (Muhammad Hadif Raziq Hamdi), parents (Andriana Mandehe & Darwin Dahlan), siblings (Hadri, Hisyam, Ecah, Patiroy & Ali), parents in law (Siti Hamidah Abdullah & Abdul Hamid Ahmad) brother & sister in law (Hamzee & Hamiza), supervisor (Assoc. Prof. Dr. Hj. Anuar Hj. Ahmad) and friends.

Who taught me to trust in Allah, believe in hard work and that so much could be done with little

Thank you very much

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ABSTRACT

Most of the time, many countries in tropical region are covered by cloud which obstruct the acquisition of high resolution optical image from satellite. Thus, the application of large scale mapping for coastal erosion assessment is difficult to be carried out. The unmanned aerial vehicle (UAV) can be used for acquisition of high resolution image due to its ability of flying at low altitudes and under cloud cover. This study aims to improve the methodology of data acquisition for assessing eroded coastal area by using UAV system designed for large scale mapping. The objectives of this study are (i) to improve the methodology of data acquisition for large scale coastal erosion assessment using UAV with rapid and low cost, (ii) to assess the accuracy of the digital photogrammetric products obtained with different ground control points (GCP) configurations and flying altitude, and (iii) to identify and assess coastal areas due to erosion based on the large-scale orthophoto produced. Two improved methods were introduced in this study: (i) rapid data acquisition and processing, low cost and accurate mapping using UAV, and (ii) modification of the end point rate (EPR) and linear regression rate (LRR) calculation methods by including two new parameters namely the sea water and wave level to detect coastline changes. The modified EPR and LRR methods in detecting the coastline changes of Crystal Bay, Alai, Melaka and Kampung Seri Pantai, Mersing, Johor were evaluated through statistical model, namely t-test and compared with other studies of similar area for validation and verification. Several configurations of GCP, check points (CP) and flying altitude were used to produce the digital elevation model (DEM) and orthophoto which were then processed photogrammetrically. Subsequently, the coastal erosion assessment was performed and the coastline changes of private properties, buildings and residential areas was identified. The results show that the best GCP configuration to produce coastal erosion mapping scale of 1:14000 is 25 points. Meanwhile, the best flying altitude is 300m with accuracies of ±0.002m, ±0.004m and ±0.389m in Northing, Easting and Height respectively. Furthermore, this study shows that most of the coastline, private properties, buildings and residential areas are affected by the coastal erosion. Based on the modified EPR and LRR calculation methods in determining the coastline changes, it is evident that the coastline change rate is significant. In conclusion, this study shows that the UAV system offers many advantages such as its ability to fly at low altitude, low cost, rapid data acquisition and processing in detecting coastline changes and accurate results.

ABSTRAK

Kebanyakan negara dalam kawasan tropika dilitupi oleh awan hampir sepanjang masa di mana ia menghalang perolehan imej optikal beresolusi tinggi daripada satelit. Maka aplikasi seperti pemetaan berskala besar bagi penilaian hakisan pantai sukar dilaksanakan. Pesawat udara tanpa pemandu (UAV) boleh digunakan untuk perolehan imej beresolusi tinggi kerana kebolehan ia untuk terbang pada altitud yang rendah dan di bawah litupan awan. Kajian ini bertujuan untuk menambahbaik metodologi pengumpulan data bagi menilai kawasan hakisan pantai menggunakan sistem UAV yang direkabentuk untuk pemetaan berskala besar. Objektif kajian ini adalah (i) untuk menambahbaik metodologi pengumpulan data bagi penilaian hakisan pantai berskala besar menggunakan UAV dengan pantas dan berkos rendah, (ii) untuk menilai ketepatan produk fotogrametri digital yang diperolehi dengan titik kawalan bumi (GCP) yang berbeza konfigurasi dan altitud penerbangan, dan (iii) untuk mengenalpasti dan menilai kawasan pantai yang terhakis berdasarkan ortofoto berskala besar yang dihasilkan. Terdapat dua penambahbaikan kaedah yang diperkenalkan dalam kajian ini iaitu: (i) kepantasan perolehan dan pemprosesan data, berkos rendah dan pemetaan yang tepat menggunakan UAV, dan (ii) pengubahsuaian dalam kaedah kadar titik akhir (EPR) dan kadar regresi linear (LRR) dengan memasukkan dua parameter baru iaitu paras air laut dan ombak untuk mengesan perubahan garis pantai. Kaedah EPR dan LRR terubah suai bagi mengesan perubahan garis pantai di Crystal Bay, Alai, Melaka and Kampung Seri Pantai, Mersing, Johor telah dinilai melalui model statistik iaitu ujian T dan dibandingkan dengan kajian lain bagi kawasan yang sama untuk pengesahsahihan dan penentusahan. Beberapa konfigurasi GCP, titik semakan (CP) dan altitud penerbangan telah digunakan untuk menghasilkan model ketinggian berdigit (DEM) dan ortofoto yang kemudiannya diproses secara fotogrametri. Seterusnya, penilaian hakisan pantai telah dilaksanakan dan perubahan garis pantai terhadap harta tanah persendirian, bangunan dan kawasan kediaman telah dikenalpasti. Hasil kajian menunjukkan bahawa konfigurasi GCP yang terbaik bagi menghasilkan pemetaan hakisan pantai berskala 1:14000 adalah 25 titik. Manakala ketinggian altitud penerbangan yang terbaik adalah 300m dengan ketepatan ±0.002m, ±0.004m and ±0.389m masing-masing bagi Utara, Timur dan Ketinggian. Selain itu, kajian ini menunjukkan bahawa kebanyakan garis pantai, harta tanah persendirian, bangunan dan kawasan kediaman mengalami kesan hakisan pantai. Berdasarkan kaedah kiraan EPR dan LRR terubah suai dalam penentuan perubahan garis pantai, ia menunjukkan bahawa kadar perubahan garis pantai adalah signifikan. Kesimpulannya, kajian ini menunjukkan bahawa sistem UAV menawarkan banyak kelebihan seperti ia mampu terbang pada altitud rendah, kos rendah, kepantasan pengumpulan dan pemprosesan data dalam pengesanan hakisan pantai dan hasil yang tepat.

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3D	-	Three dimensional
AT	-	Aerial Triangulation
CP	-	Check Point
CRP	-	Close Range Photogrammetry
DEM	-	Digital Elevation Model
DID	-	Department of Irrigation and Drainage
DSM	-	Digital Surface Model
DSMM	-	Department of Surveying and Mapping Malaysia
DTM	-	Digital Terrain Model
EPR	-	End Point Rate
GCP	-	Ground Control Point
GIS	-	Geographic Information System
GPS	-	Global Positioning System
GSD	-	Ground Sampling Distance
IMU	-	Inertial Measurement Unit
INS	-	Inertial Navigation System
InSAR	-	Radar Interferometry
LiDAR	-	Light Detection and Ranging

LRR	-	Linear Regression Rate
NAHRIM	-	National Hydraulic Research Institute of Malaysia
NDCDB	-	National Digital Cadastral Database
Pixel	-	Picture Element
RMSE	-	Root Mean Square Error
RTK	-	Real Time Kinematic
UAV	-	Unmanned Aerial Vehicle
WGS84	-	World Geodetic System 1984

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Coastal erosion is a natural disaster occurring from the interactions between natural processes and systems. It is widely believed that erosion occurs continuously along the coastline due to combination of both natural and human factors. These include wearing away of land and removal of beach or dune sediments by tidal currents or rise in sea level (Bruun, 1988, 1989; Douglas *et al.*, 2000; Nicholls and Tol, 2006; Schwartz, 1967; Teh and Voon, 1992; Yu and Chen, 2009), wave currents (Kearney *et al.*, 2001; Silvester and Hsu, 1997), or climate changes (Adger *et al.*, 2005; Feagin *et al.*, 2005; Zhang *et al.*, 2004). Additionally, waves generated by storms and winds may take the form of long-term losses of sediment and rocks, or merely the temporary redistribution of coastal sediments that could also cause erosion (Barnier, 1988; Yu and Chen, 2009). Moreover, human interference can also cause coastal erosion such as dredging in a bay, construction of structures in the coastal beach which could disturb the movement of the sediments, coastal reclamation and other factors (Leatherman *et al.*, 2000; Zhang *et al.*, 2004).

Coastal erosion is a global problem where at least 70 % of sandy beaches around the world are recessional (Bird, 1985). Tsunami causes the most severe effect of coastal erosion in the world, this is because tsunami affects several areas and exposes the coast to the open sea. In 2004, a large tsunami was generated by an earth-quake has affected most of the countries around the Indian Ocean, thus it was claimed as one of the world's worst natural disasters in decades (Szczuciński *et al.*, 2007). According to Stein and Okal (2005), the large tsunami happened when a plate-boundary, thrust-fault earthquakes becomes very large and enormously destructive and a huge area of the plate interface slips, generating seismic waves that can cause great damage near the earthquake. When the tsunami hit the northwestern states of Peninsular Malaysia on December 26, 2004, Malaysia experienced the worst natural disaster in the country's history (Ghazali *et al.*, 2013). Among the damages were severe loss of life, houses, transport, land, and major fishery equipment (Siwar *et al.*, 2006). In addition, 40 villages and approximately 4,000 people were affected (Ling *et al.*, 2006).

Due to the tsunami disaster, the importance of coastal erosion assessment is essential for the impacted countries. Geographically, Malaysia is surrounded by South China Sea (Figure 1.1) and has a long coastline. Malaysia is associated with coastal zone for about 4809 km (Abdullah, 1992) comprise of Peninsular Malaysia (2031 km) and Sabah and Sarawak (2778 km). The coastal zone area is the most valuable asset for marine and fish, wildlife and human's life which have a special socio-economic and environmental significance.

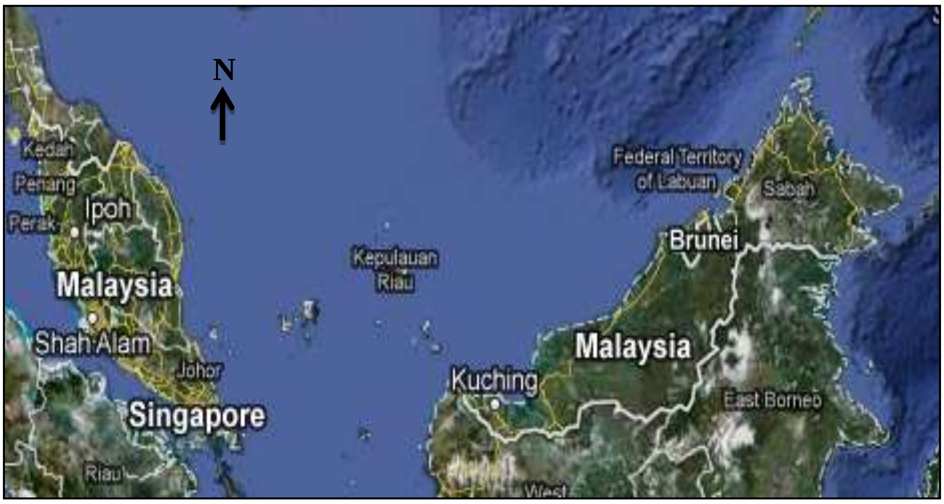

Figure 1.1: Malaysian is surrounded by Sea (Google Earth)

In Malaysia, the occurrence of coastal erosion is increasing and threatening those who are living close to coastal areas. Moreover, coastal erosion is causing losses along the coastal line due to economic activities encompassing urbanization, agriculture, fisheries, aquaculture, oil and gas exploitation, transportation, communication and recreation (Abdullah, 1992). According to Marfai (2011), coastal areas are also prone to environmental hazards such as erosion and sedimentation processes. These may cause loss of coastal land and damages to infrastructures and buildings.

During monsoon season the coastal areas are expose to erosion (Douglas, 1967; Husain *et al.*, 1995; Wong, 1990) and this may cause damage to mangrove trees, marine animals and human's life. This henceforth requires a severe attention by government and also local authorities. Meanwhile, it is important to identify the approximate magnitude of the overarching needs, set key policies, define possible implementation and financial mechanisms, and begin restoration activities wherever possible at the very early stage (Neuner *et al.*, 2006).

Therefore, Malaysian government has spent millions of Ringgit Malaysia (RM) in order to fix coastal areas, carry out research, development and management of coastal areas. National Hydraulic Research Institute of Malaysia (NAHRIM) is one of the departments that is responsible for coastal management. It was established in 1990 as a centre of coastal management and has started collaborative research development with local universities and research institute on coastal engineering (Othman, 2011). On the other hand, Department of Surveying and Mapping Malaysia (DSMM) survey has conducted surveying mainly to produce topographic mapping for any purpose demanded for coastal area by any agencies such as surveying organization, Department of Irrigation and Drainage (DID), Department of Environment (DOE) and etc. The Survey Departments and Topographic Departments have been established from year 1885 to 1957 until they merged into one department. In 1965, the government has officially approved the establishment of DSMM with the mandate to conduct surveying, mapping and performing geodesy works.

Furthermore, the upgrades of technology survey instruments help to produce maps and digital terrain models (DTM) easier, faster and at low-cost (Darwin *et al.*, 2014; Darwin *et al.*, 2014; Petzold *et al.*, 1999). A map is a representation and the reality of geography in the abstract, in which it is a mean to communicate and transfer the relevant geographic data in the form of visual or digital information as the end result. It can be seen that maps are not only used for positioning but also for surveillance, erosion monitoring, risk flooding area, erosion assessment and landslide. Conceptually, maps are defined as a representation, usually on a flat surface, of a whole or part of an area and also used to describe spatial relationships of specific features that the map aims to represent (Darwin *et al.*, 2014; Warnaby, 2008). There are two main types of topographic map namely special and specific purpose map. For examples, maps can display political boundaries, population, physical features, natural resources, roads, climates, elevation, and economic activities.

In the 90's, total station instruments were introduced for the purpose of surveying (Becker *et al.*, 2002). The instruments were used to accurately observe the bearing and distance of lines and also to deliver 2D plan. The conventional ways of data collection, data processing and results were replaced by more effective methods by using total station. According to Balenović *et al.* (2012) and Walstra (2006), there are several ways to produce maps by photogrammetric technique namely analogue photogrammetry (from about 1900 to 1960) and analytical Photogrammetry (1960 until end of 1990). However, recently the presence of digital photogrammetry in the photogrammetric industry has revolutionized the industry.

In general, for many countries around the world, the topographic map is produced by using photogrammetric technique (Debevec *et al.*, 1996). The large format aerial photographs were acquired and later undergo photogrammetric process and topographic process to produce topographic map (Aber *et al.*, 2010). Normally the coastal area will be included in the topographic map. The procedure to produce topographic map is lengthy and costly. For map updating, the cost of acquiring aerial photographs and the processes involved are costly too. The small format aerial photography become popular in 1980's (Aber *et al.*, 2002; Mills *et al.*, 1996). However, the cost of map updating is still expansive (Darwin *et al.*, 2014; Darwin *et al.*, 2014; Hashim *et al.*, 2013). In the last decade, the unmanned aerial vehicle (UAV) system has become popular. UAV system has been reportedly used for many non-photogrammetry applications by various studies conducted by Chiabrando *et al.*, (2011), Lingua *et al.*, (2009), and Remondino *et al.*, (2011).

This study focuses on coastal erosion assessment using small format aerial images obtained from micro UAV and based on low altitude. The imagery is natural color red green and blue (RGB) imagery which were collected for the areas impacted by coastal erosion. Many previous research have focused on UAV in the application on the 3D modeling, slope studies, video recording, agriculture, and archeology but there is lack of information related to coastal erosion assessment. Many small villages along coastal line are being impacted by coastal erosion and need to be assessed continuously. The novel method of UAV large scale mapping for coastal erosion assessment used in this study will be useful for the government and private agencies to evaluate the coastal area especially for decision making purposes and coastal erosion assessment.

1.2 Statement of Problem

Basically, there are several methods in geoinformation that could be used to map or monitor the coastal erosion such as aerial photogrammetry using manned aircraft (Crowell *et al.*, 1991; Kaichang *et al.*, 2003; Moore, 2000, Li *et al.*, 2004), remote sensing (Klemas, 2009; Moore, 2000), Light Detection and Ranging (LiDAR) (Moore, 2000; Olsen *et al.*, 2010), Global Positioning System (GPS) (Moore, 2000; Wozencraft and Millar, 2005) and Terrestrial Laser Scanning (TLS) (Alho *et al.*, 2009; Olsen *et al.*, 2009). These geoinformation technologies also assist engineers in protecting coastal erosion. Generally, remote sensing and aerial photogrammetry are widely used for mapping coastal erosion. Through remote sensing, the development of high resolution satellite imagery such as IKONOS, QuickBird and WorldView 2 enabled the mapping of coastal erosion. Similarly, high resolution satellite imagery from airborne or aerial images were obtained by utilizing several technologies (e.g. IKONOS, QuickBird, Spot and WorldView2) and manned aircraft technology (Li *et al.*, 2004).

However, there are some limitations or drawbacks of these methods for obtaining aerial images. For example, according to Al-Tahir *et al.* (2011), many countries in the tropical region are covered with clouds especially during the rainy and monsoon season, thus making it difficult to capture clear images. According to Biesemans *et al.* (2005) and Everaerts (2008), there are also limitations in using satellite and manned aircraft, which are high flight cost, low ground resolution and limited time frame. Hence, it is rather impractical to use these technologies to cover at lower altitude and small area. Table 1.1 shows the summary of the comparison between four methods namely manned aircraft, LiDAR, satellite image and UAV.

Table 1.1: Comparisons between Manned Aircraft, LiDAR, Satellite Image and UAV (Source: Kaichang *et al.*, 2003; Moore, 2000, Li *et al.*, 2004)

Method / Aspect	**Manned Aircraft**	**LiDAR**	**Satellite Image**	**UAV**
Flight Planning	Overlap and side lap need to be considered	More complex due to small strips and potential data voids	No	Overlap and side lap need to be considered
Flight restrictions	Must fly during day time and need clear sky	Less impact from weather, day/night, cloud condition	Most image in the tropical region cover with cloud	Must fly during day, clear sky time and under cloud
Cost estimation	Up to hundred thousand ringgit Malaysia	Up to hundred thousand ringgit Malaysia	Up to ten thousand	Up to thousand ringgit Malaysia
Production rate	Time consuming	Can be automated and faster	Depend on satellite which passes through the area	Can be automated and rapid

Coverage Area	Cover large area and not practical to cover small area	Cover large area	Cover large area	Cover small area based on micro UAV and cover large area based on long endurance UAV

Nowadays, aerial photogrammetry is often used for highway investigation, environmental, preliminary design and Geographic Information System (GIS). It is proven that the demand for aerial photogrammetry has increased especially after development of design, research and production of UAV platform (Chao *et al.*, 2010, Breckenridge and Dakins, 2011). Therefore, UAV system has expanded data capture opportunities for photogrammetry techniques. The micro UAV system uses the concepts of close range photogrammetry (CRP). The advantage of CRP is that it can survey the physical dimension of any structure and provide valuable insight for assessing the effects of surface changes since this has become a powerful and widely used tool for three-dimensional topographic modeling (Irvine-Fynn *et al.*, 2014; Westoby *et al.*, 2012). In CRP, the photography is acquired where the object-to-camera distance of less than 300m (Atkinson, 2001; Cooper and Robson, 1996; Smith, 1997; Wolf *et al.*, 2000). Moreover, numerous UAV have been developed by organization or individual worldwide including a complete set of UAV which uses high quality fibres as material for plane model (Baoping *et al.*, 2008). The development of this technology is very beneficial for monitoring purpose for limited time and budget. UAV has been practiced in many applications such as farming, surveillance, road maintenance, recording and documentation of cultural heritage (Bryson and Sukkarieh, 2009).

The UAV technology has been developed and progressed rapidly from year to year especially for mapping applications. Furthermore, UAV is the solution for low budget project with time constraints and few manpower rather than using satellites or manned aircraft with expensive flight costs, time consuming and weather-dependent data collection, restricted manoeuvrability, limited availability, limited flying time and low ground resolution in mapping process (Biesemans *et al.*, 2005). Moreover, three dimensional model can be generated by using UAV image after performing digital image processing.

Through the years, UAV has been modified to have the capabilities to capture low altitude aerial images. UAVs are used for several civilian and industrial applications and have the potential to be used in many diversified applications (Sarris and Atlas, 2001; Skaloud *et al.*, 2006; Valavanis, 2008),. For example, UAV has been used in slope mapping (Tahar, 2013), modeling of cultural heritage (Eisenbeiss, 2004; Eisenbeiss and Zhang, 2006; Eisenbeiss; 2009; Püschel *et al.*, 2008), documentation of archaeological sites (Bendea *et al.*, 2007), forest-fire monitoring (Zhou *et al.*, 2005), road monitoring (Egbert and Beard, 2007), vehicle detection (Kaaniche *et al.*, 2005), disaster management (Ambrosia *et al.*, 2003), and mapping urban and suburban areas (Spatalas *et al.*, 2006). In addition, the potential use of UAV has been investigated in producing orthophoto of coastal area (Darwin *et al.*, 2014; Delacourt *et al.*, 2009). The UAV systems are also employed in environmental, agricultural, and natural resources monitoring (Zongjian, 2008).

However, there is lack of research that study on producing large scale mapping of coastal erosion assessment using UAV platform including Malaysia. According to Hapke (2002), the issue of rapid coastal erosion assessment becomes a serious management problem for coastal communities as more and more country's population moves to coastal areas. In addition, the need for conducting coastal erosion assessment requires several weeks, months or even years. Rango *et al.* (2006) and Rango *et al.* (2009) recommended the use of lightweight UAV systems in acquiring high quality geospatial information and fast updating geo-information for resource management agencies, rangeland consultants, local authorities and private land managers.

The UAV system can be used for coastal erosion assessment since it provides rapid data collection, faster, lower cost and utilises less manpower. Moreover, the data processing is rapid and accurate results could be obtained. Hence, this study attempts to improve the methodology of producing large scale mapping for coastal erosion assessment using UAV technology. This technology can be used by government organizations, private agencies and local authorities for planning, making decision and research purpose. There are several research questions for this study as follows:

a. What are the potentials of UAV system in regards to mapping coastal erosion assessment?
b. Are there any limitations in using UAV technology?
c. Is UAV able to produce coastal map for coastal erosion monitoring?
d. What are the parameters affect the accuracy of photogrammetric output obtained from UAV?
e. Can UAV be used to improve the method of producing large scale mapping for coastal erosion assessment?

1.3 Aim and Objectives of Study

The aim of this study is to improve the methodology of data acquisition for the assessment on eroded area due to coastal erosion by using UAV system designed for large scale mapping. The following are the objectives of this study:

i. To improve the methodology of data acquisition for large scale coastal erosion assessment using UAV with rapid and low cost.
ii. To assess the accuracy of the digital photogrammetric products obtained with different ground control points (GCP) configurations and flying altitude.
iii. To identify and assess coastal areas due to erosion based on the large-scale orthophoto produced.

1.4 Significance of Study

Previously, aerial photogrammetry using manned aircraft has some limitations such as requirement of professional pilot on board, inability to fly on cloudy days, costly and need a large format film to be scanned before it can be processed using a photogrammetric software. The current aerial photogrammetry method i.e using a digital mapping camera used where direct digital image can be obtained. However the total cost of this current method including the operation cost is very expensive. Recently, Unmanned Aerial Vehicle (UAV) was introduced. UAV is an autonomous flying vehicle which does not require a pilot on board and suitable for covering small area. Thus work can be done within short period of time with small budget. Moreover, UAV technology is useful for many organizations in different areas such as job scope, research or project. Therefore, there are several important contributions expected from this study as follows:

i. To provide insight on UAV technique; which is very attractive and beneficial for small companies as sometimes their project or study area only cover a small area.

ii. To produce a large scale coastal mapping application especially for small area with limited budget, time and less manpower. This study provides the new knowledge on hardware, software, data acquisition method and data processing procedure to produce the final photogrammetric output for coastal erosion assessment.

iii. To provide an exposure and expertise in using UAV technology. In digital photogrammetry, UAV platform is a new technology especially for large scale mapping of coastal area. It can be utilized by any organization especially the Department of Surveying and Mapping Malaysia (DSMM), Licensed Surveying Firms, Department of Irrigation and Drainage (DID), Department of Environment (DOE) and other government agencies to apply the UAV technology in their projects including coastal engineering project.

iv. To provide an estimation cost by using UAV technology which utilizes digital cameras, GPS and other sensors.

v. To improve the data acquisition methodology for coastal erosion assessment using UAV system

vi. To improve the current method of calculating coastline change rate using orthophoto obtained from UAV system.

1.5 Scope of Study

There are many aspects to be considered in coastal mapping. To fulfil the aim and objectives of this study, the scope of the study was considered. The main scope of this study covers several aspects as follows:

1.5.1 Study Area

There are two types of study area. The first study area involves a small area which is suitable for large scale mapping. This area demonstrates an accurate measurement of mapping coastal erosion by using physical model and rotary wing UAV. The second study area was conducted to map the real coastal erosion area by using fixed wing UAV. This study concentrates on mapping and assessing two coastal erosion areas. The first is Crystal Bay, Alai, Melaka which is located on the west coast of Peninsular Malaysia (Figure 3.29). The second coastal erosion area is Kampung Seri Pantai, Mersing, Johor which is located in the east coast of Peninsular Malaysia (Figure 3.31).

The first coastal erosion area is at The Crystal Bay, Alai, Melaka which is located on the west coast of Peninsular Malaysia (Figure 3.19). The Crystal Bay coast is characterized by fine-grained sedimentary deposits, predominantly silt and clay that come from rivers. This coast can be classified as a “soft” coast. It has a broad gentle seaward slope, known as an intertidal mud flat where mangrove forest, saltmarshes, shrubs and other trees were found. Most erosion is generated by river damming that reduces sediment supply, diminishes vegetation cover (usually mangroves and saltmarshes) and exposes vegetation roots by lowering the mud flat.

The second coastal erosion area is Kampung Seri Pantai, Mersing, Johor. It is located in the east coast of Peninsular Malaysia (Figure 3.21). The coastal area in Mersing shows high hills terrain which is also known as cliff coast. According to Prasetya (2006), cliff coast can be classified as “hard” coast as it is formed from resistant materials such as sedimentary or volcanic rocks.

1.5.2 Coastline Identification

The study focus on producing large scale mapping from micro UAV platform on coastline using GIS software for digitizing and mapping. Then, the coastline identification was made by tides condition along the coast of the study area as shown in Figure 1.2 and Figure 1.3 for Crystal Bay, Alai, Melaka and Kampung Seri Pantai, Mersing, Johor, respectively.

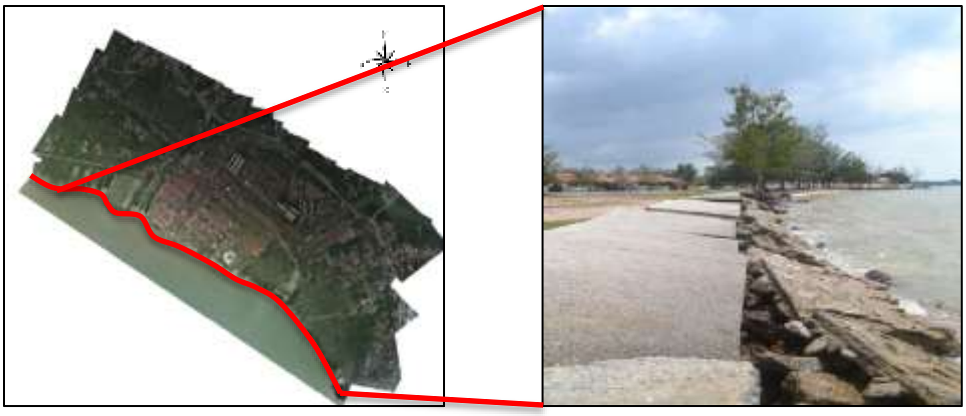

Figure 1.2: Coastline for Crystal Bay, Alai, Melaka

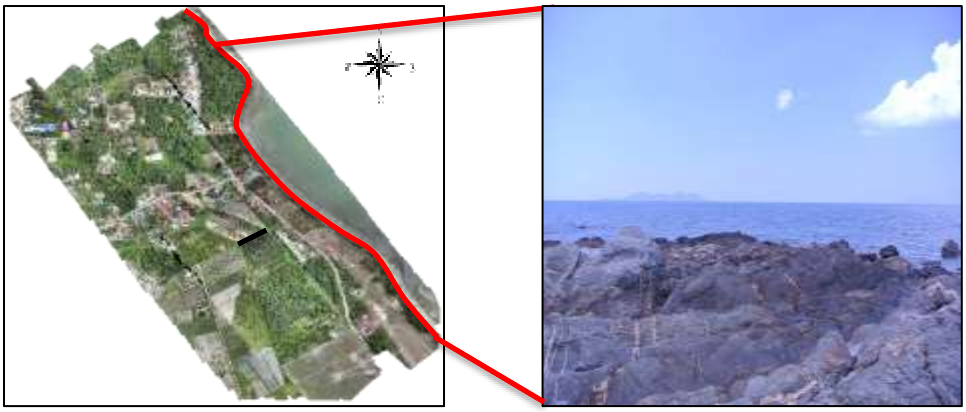

Figure 1.3: Coastline for Kampung Seri Pantai, Mersing, Johor

1.5.3 Effectiveness of system

In this study, there are two types of analysis were carried out. The analysis includes quantitative and qualitative assessment. For quantitative assessment, it was performed based on the Root Mean Square Error (RMSE) for the photogrammetry output obtained from UAV technology. The RMSE was used to compare the differences between 3D coordinates obtained from Erdas Imagine v8.6 software and 3D coordinates from ground survey measurement either based on total station or GPS techniques. For qualitative analysis, the potential use of UAV was compared to manned aircraft output and ground control survey (i.e. in term of manpower and time).

All the results were shown in this study. However, to see the effectiveness of this UAV large scale coastal mapping accuracy whether it was accepted or not, advanced statistical significant analysis was applied to validate whether both method of field data and UAV image are able to provide similar result of easting, northing and height coordinate accuracy value or not. There are two types of advanced statistical analysis that have been applied in this study which are t-test and Analysis of Variance test (ANOVA).

1.5.4 Limitations

Coastal erosion assessment in this study was limited to the real site coastal area which includes only the nearly eroded area. The coastal erosion assessment in large scale mapping using micro UAV platform could assess the coastline changes, private properties, building and residential area which is potentially affected by erosion. In this study, the end point rate (EPR) and linear regression rate (LRR) method were used to calculate the coastline changes. These methods were modified by including two new parameters namely mean sea level and wave.

1.5.5 Low-cost UAV with Altitude of ≤ 300 m

The study adopts low-cost data acquisition by using micro UAV to perform aerial photography through certain procedure and subsequently the data were processed to produce photogrammetry output such as digital map, digital elevation model and orthophoto of the coastal erosion study area. Low altitude UAV is preferable in this study (altitude of ≤ 300 m) because it focuses on large scale mapping and uses close range photogrammetry approach.

The altitudes of this study were divided into 200m, 250m and 300m that cover the real site study area. In addition, a series of digital images of coastal area were acquired by using a high resolution digital camera. The high resolution digital camera was attached to the UAV to provide small format images.

1.6 Hypothesis of Study

There are two hypotheses indicates in this study such as: (1) large scale mapping for coastal erosion assessment using existing methods is inefficient, time consuming and costly, and (2) the UAV approach provides an effective method in large scale mapping for coastal erosion assessment and enhances productive data on demand.

1.7 General Methodology

In Malaysia, the total coast line is 4809km and nowadays many states in Malaysia are facing problem of coastal erosion. The federal government and state government have spent millions of ringgit to overcome coastal erosion. In hard engineering, it is an expensive project to construct breakwater in the form of concrete or other material. Whereas in soft engineering such as planting mangrove tree, the cost is expensive too. This is because the trees need to be monitored after the plantation. This study concentrates on mapping the coastal erosion on the east coast of Peninsular Malaysia in Kampung Seri Pantai, Mersing, Johor and west coast of Peninsular Malaysia in Crystal Bay, Alai, Melaka. Recently, these areas are mostly affected by coastal erosion. This study comprises of several phases that include preliminary study, acquiring real data, processing the data, analyzing the data and finally, drawing the conclusion and providing recommendations.

In preliminary study, there are several steps that were performed. These steps are (a) Gathering and compiling related and crucial information on the proposed study from various sources such as articles, journals, books, the internet and previous theses; (b) Gaining better understanding in all aspects before data collection. It helps to understand more detail on types of UAV either long, medium or short endurance during the data collection; (c) Exploring the suitable UAV for this study especially for large scale mapping based on small format aerial photograph; (d) Choosing the suitable equipment for establishment of GCPs and CPs and software for data processing related to the proposed study.

Data acquisition is very important in any project or study. It needs to be done properly so that the objective of the study could be achieved. Data acquisition involves the following; (a) acquiring aerial photographs which are obtained from UAV system based on small format imagery; (b) Carrying out the camera calibration in order to recover the calibration parameter and later use it in digital image processing especially in the interior orientation process; (c) Establishing the GCPs by using GPS technique for absolute orientation or exterior orientation and to perform aerial triangulation. The CPs are also established by using GPS techniques and used for accuracy assessment.

Data processing was carried out after the required data were acquired successfully. In this study, the data processing involves the following; (a) The collected data were processed by using ERDAS Imagine software and ArcGIS software was employed to produce map either in softcopy or/and hardcopy; (b) The GCPs and CPs obtained from ground survey measurement (i.e total station) were processed by using Civil Design Software (CDS) software to obtain the 3D coordinates of these points. These points were then used for physical model. For real site coastal erosion study area (i.e. mapping and coastal erosion assessment), the GCPs and CPs were established by using GPS rapid static technique.

The results obtained for this study were analyzed using qualitative and quantitative analysis. The steps for data analysis are as follows; (a) The final results obtained from UAV system which include digital map, digital terrain model (DTM), contour line and orthophoto were analyzed in this phase; (b) It was evaluated in terms of point analysis (i.e. quantitative analysis based on RMSE) and visual analysis (i.e. qualitative analysis). The analysis of the coastal erosion assessment and discussion between two real site study areas (Crystal Bay, Alai, Melaka and Kampung Seri Pantai, Mersing, Johor) were analysed. The coastline change rate was calculated using both modified End Point Rate (EPR) and Linear Regression Rate (LRR). Furthermore, a method on large scale mapping for coastal erosion assessment using micro UAV approach was improved.

The final phase of research methodology is conclusion and recommendation. This phase involves the following; (a) whether or not the objectives of this study are achievable or vice-versa; and (b) recommendations are made based upon the final results and limitation of the study.

1.8 Thesis Organization

Chapter 1 is an introduction of this research study. This chapter consists of the background of the study, problem statement, objectives of study, significance of study, scope of study and research methodology.

Chapter 2 describes the fundamental part of the research which provides appropriate knowledge including the theories and applications employed in this study. This chapter reviews the existing research related to coastal erosion assessment and some useful references on photogrammetry and UAV system. The current coastal mapping which includes coastal management, coastal assessment and coastal erosion assessment are also explained in this chapter.

Chapter 3 consists of research methodology which covers field procedure, data collection and data processing in details for preliminary study and real site study area. The method of accuracy assessment is also discussed in this chapter. All the important details as well as obstacle before, during and after the data acquisition are included in this chapter.

Chapter 4 presents the results and the analyzed data. This chapter discusses on the accuracy assessment which consists of quantitative analysis and qualitative analysis for each results (e.g. orthophoto, DEM, and contours). The results cover two main photogrammetric results namely digital orthophoto and DEM for preliminary study and real site study area. It also discusses on the effect of GCP configuration, different flying height and different software capabilities. The results and relevant analysis are illustrated and elaborated in various forms such as table, graphic presentation, tabular form and graph presentation.

Chapter 5 contains coastal erosion assessment and discussion of the real site study area. This chapter discusses two different real site study area which are Crystal Bay, Alai, Melaka and Kampung Seri Pantai, Mersing, Johor. The discussion includes the qualitative assessment of large scale coastal mapping, coastal erosion assessment and map updating.

Finally, Chapter 6 delivers the concluding remarks and recommendations which are drawn from the study that has been carried out. This chapter concludes the research finding of this study and achievement of research objectives. Finally, this chapter discusses the suggestions or recommendations that can be used for future work.

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