ACCURACY ASSESSMENT OF HEIGHT COORDINATE USING UNMANNED AERIAL VEHICLE IMAGES BASED ON ORTHOMETRIC HEIGHT

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DEDICATION

To my beloved father and mother

My wife

My lecturers and

My friends

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All praises are belonging to Allah S.W.T, the Lord of the world, for His love, grace and guidance. May the blessing and peace of Allah be upon Prophet Muhammad S.A.W, his family members and companions.

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ABSTRACT

Most of the Unmanned Aerial Vehicle (UAV) images studies are focusing on the horizontal plane with minimal covered on its height values. This thesis will study about the accuracy assessment in height coordinates using UAV images processing based on orthometric height observation data. Apart from that, the accuracy of height coordinates using UAV images processing based on different number of ground control point (GCP) are also assess. In this study, Agisoft PhotoScan v0.9.0 and Global Mapper v15.2.3 are the software used for the processing and analysis. Ground control points and check points were established using Real Time Kinematic Global Positioning System (RTK-GPS) and leveling method. There are two photogrammetric products produced in this study such as orthophoto and digital elevation model (DEM). The analyses of the photogrammetric products were performed based on different number of GCP and different orthometric height observation data. The results of this study showed that the height accuracy of photogrammetric products using UAV images processing based on 10 GCPs produced better accuracy than 5 GCPs. RMSE values of check point height coordinates based on data from leveling method are ± 0.161 meter for 5 GCPs and ± 0.116 meter for 10 GCPs while RMSE values of check point height coordinates based on data from RTK-GPS method are ± 0.167 meter for 5 GCPs and ± 0.124 meter for 10 GCPs. The results also showed that photogrammetric products using UAV images processing based on leveling method provide more accurate height results than RTK-GPS method. The RMSE value of check point height coordinates based on RTK-GPS method is ± 0.148 meter (10 GCPs) and RMSE value of check point height coordinates based on leveling method is ± 0.116 meter (10 GCPs). As conclusion, UAV images can be used to generate DEM that give height coordinate values with sub-meter accuracy.

ABSTRAK

Kebanyakan kajian Kenderaan Udara Tanpa Pemandu (*UAV*) bertumpukan kepada satah mendatar dan kurang melihat kepada nilai ketinggian yang diperolehi. Kajian ini dibuat bagi menilai kejituan terhadap koordinat ketinggian menggunakan imej daripada *UAV* yang diproses berdasarkan data cerapan ketinggian ortometrik. Selain daripada itu, ketepatan koordinat ketinggian juga dinilai melalui imej *UAV* yang diproses berdasarkan bilangan titik kawalan tanah yang berbeza. Dalam kajian ini, perisian Agisoft PhotoScan v0.9.0 dan Global Mapper v15.2.3 digunakan untuk memproses imej *UAV* dan untuk membuat analisis. Titik kawalan tanah dan titik semak telah diwujudkan menggunakan kaedah Sistem Pendudukan Sejagat secara Kinematik Masa Hakiki (*RTK-GPS*) dan kaedah ukur aras. Terdapat dua hasil fotogrammetri dihasilkan iaitu ortofoto dan model ketinggian digital (*DEM*). Analisis terhadap hasil fotogrammetri dibuat berdasarkan bilangan titik kawalan yang berbeza dan juga berdasarkan kepada data cerapan ketinggian yang berbeza. Keputusan kajian ini menunjukkan kejituan ketinggian hasil fotogrammetri dari imej *UAV* yang diproses menggunakan 10 titik kawalan tanah memberikan ketepatan yang lebih baik berbanding 5 titik kawalan tanah. Nilai RMSE koordinat ketinggian titik semak berdasarkan data dari kaedah ukur aras adalah ± 0.161 meter untuk 5 GCPs dan ± 0.116 meter untuk 10 GCPs manakala nilai RMSE koordinat ketinggian titik semak berdasarkan data dari kaedah *RTK-GPS* adalah ± 0.167 meter untuk 5 GCPs dan ± 0.124 meter untuk 10 GCPs. Keputusan kajian juga menunjukkan kejituan ketinggian hasil fotogrammetri dari imej *UAV* yang diproses menggunakan kaedah ukur aras memberikan hasil ketinggian yang lebih tepat berbanding kaedah *RTK-GPS*. Nilai RMSE koordinat ketinggian titik semak berdasarkan data dari kaedah *RTK-GPS* adalah ± 0.148 meter (10 GCPs) dan nilai RMSE koordinat ketinggian titik semak berdasarkan data dari kaedah ukur aras adalah ± 0.116 meter (10 GCPs). Kesimpulannya, imej *UAV* boleh digunakan untuk menjana *DEM* yang memberikan nilai koordinat ketinggian sehingga ketepatan sub-meter.

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LIST OF ABBREVIATIONS

BM	-	Benchmark
CP	-	Check point
CIR	-	Color-infrared
DEM	-	Digital Elevation Model
DSM	-	Digital Surface Model
DTM	-	Digital Terrain Model
DGPS	-	Differential Global Positioning System
FVA	-	Fundamental vertical accuracy
GCP	-	Ground Control Point
GIS	-	Geographic Information System
GNSS	-	Global Navigation Satellite System
GPS	-	Global Positioning System
GSD	-	Ground Sampled Distance
LPS	-	Leica Photogrammetry Suite
NVA	-	Nonvegetated vertical accuracy
OTF	-	On-the-fly
RMSE	-	Root Mean Square Error
RTK	-	Real Time Kinematic
RTK-GPS	-	Real Time Kinematic Global Positioning System
SVA	-	Supplemental vertical accuracy

UAV	-	Unmanned Aerial Vehicle
UVS	-	Unmanned Vehicle System
VTOL	-	Vertical Takeoff and Landing Vehicles
VVA	-	Vegetated vertical accuracy

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

Photogrammetric technique becomes faster, simpler and lower cost due to rapid development of technologies in mapping. The development in digital technologies has increased the reliability in data captured. Research paper related to mapping using non-matrix camera become more popular due to their lower cost and time consuming. Although the Unmanned Aerial Vehicle (UAV) was found that capable in producing digital orthophoto and digital map, but most of the studies are focusing on the horizontal plane with minimal covered on its height values. There are many factors that can affect the height coordinates such as camera lens (Tahar, 2013), flying height (Tahar, 2013), image resolution (Zarco-Tejadaa *et al.*, 2014), digital camera format (Ahmad, 2011) and many more.

This thesis will study about the accuracy assessment in height measurement by using digital elevation model (DEM) generated from processed UAV images comparing with known height values of ground control points (GCP). The data of ground control points will establish using the GPS technique (RTK-GPS) along with leveling method. The study is expected to provide contribution for an easy and fast way in getting height points value other than using conventional method such as leveling. In this study, UAV is used as a platform to capture digital image using high resolution digital camera. The study area is surrounding the Universiti Teknologi Malaysia (UTM).

1.2 Problem Statement

There are many research related to the UAV techniques. UAV have used to produced slope map (Tahar, 2012), quantification of tree height (Zarco-Tejadaa *et al.*, 2014) and many more. Most of the researches give a good result in planimetry coordinates but little studies at the height coordinates. Tahar *et al*. (2012), in his study using UAV on production of slope map, he found that each coordinates of easting; northing and height recorded the RMSE value of ±1.342, ±1.660 and ±4.666 meters. The result shows a big error on height value. He deduces that a big error on height value might be caused by the auto tie points that were not well established, which were being effected due to the image resolution, color balancing and image quality itself such as blurring effects.

Tahar (2013), in his PhD research using micro UAV for large scale mapping, he found that the best flying height for UAV is 80 meters above the ground surface with scale 1:3000, but the result shows accuracies for height coordinates was ±3 meter and ±40 centimeter for easting and northing. He concluded that the error may be caused by limitation of camera lens.

Moreover, Ahmad (2011), in his research using low altitude UAV for digital mapping, the differences in height coordinates between ground height from GPS and ground height from Erdas Imagine software product reached 1.595 meters. In his research, he used a small format digital camera and high accuracy could be achieved by the large format metric camera.

In Tahar and Ahmad (2011) point of views, using UAV for photogrammetric survey in aerial terrain mapping also found that RMSE for fixed platform are ±0.002 m, ±0.001 m, ±0.214 m for coordinate x, y and z respectively and for mobile platform are ±0.002 m, ±0.002 m, ±0.223 m for coordinate x, y and z respectively. Although the result shows, the differences between the mobile and fixed platform are not significant but they decided that the different on ground control height might be an effect from the automated tie point that used image-matching technique.

Apart from that, Grenzdoerffer *et al*. (2008) in his study using UAVs in forestry and agriculture also get the accuracy in z is lower than in x and y. He concludes that this result might be the consequences of the systematic errors in the focal length. On the other hand, Zhang (2008) verifies that additional parameters are essential in aerial triangulation to increase the precision of height coordinate.

From the previous research, there are many factors that influence the height coordinate. The research question for this study is to determine the procedure of UAV to get the accurate value in the height coordinate.

1.3 Aim of Study

The aim of this study is to assess the accuracy of height coordinates using Unmanned Aerial Vehicle images processing based on different number of ground control point and different orthometric height data.

1.4 Objective of Study

The study objectives are:

a) To evaluate the capabilities of high resolution digital camera and UAV in generate values of height by produced digital photogrammetric product.
b) To determine the accuracy of height coordinate from digital photogrammetric product base on different number of ground control point.
c) To determine the accuracy of height coordinate from digital photogrammetric product base on height from leveling measurement and height from RTK-GPS technique.

1.5 Significant of Study

The findings of the study is expected to give contribution for determine the height value of the ground surface in easy and fast way. It is hope can become other alternative in obtaining the height value in surveying field.

1.6 Scope of Study

The study will be conducted at the main campus of Universiti Teknologi Malaysia (UTM) with several points of known height values around the campus area. The digital camera images using UAV platform are used to produce digital orthophoto and digital elevation model (DEM). Figure 1.1 illustrates the image which shows the study area that covered an area of 350 m x 290 m.

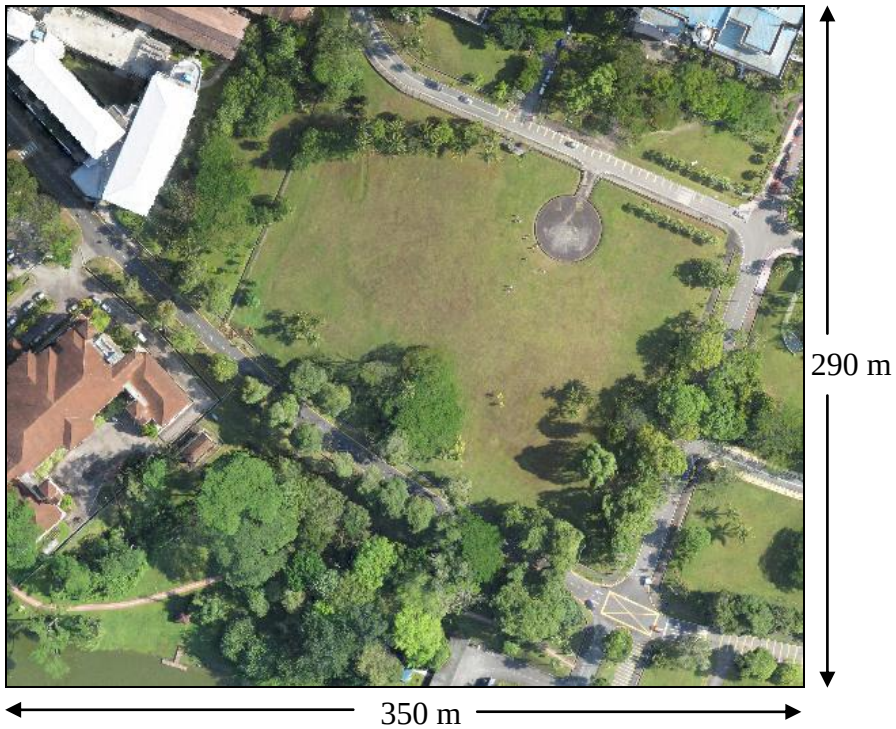

Figure 1.1: The study area

The digital images are captured by high resolution digital camera attached at the UAV. The ground control points (GCPs) will be established by GPS observation

(RTK-GPS method) and leveling. Although the GCPs will give three dimensional coordinates (East, North and Height), this study will emphasis accuracy assessment on height coordinates.

1.7 General Methodology

There are four phases covered in this study which are literature review related to the study and study preparation, the collection of the data, the processing of the data and data analysis.

The literature review will explain briefly about the photogrammetry and the development of UAV in many applications and mapping purposes. The study preparation give an explanation about the preparation should be done in collecting the data such as instrument used, flight planning and camera calibration of digital camera.

For the data collection phase, there are three main data should be collected that are ground control points (GCPs) established from RTK-GPS, camera calibration parameter from camera calibration and digital images captured by UAV at the study area. The determination of GCPs and Check Points (CPs) location must be well organized referred to UAV images for the study area.

In the processing stage, all the data will be processed using photogrammetric software to produce digital elevation model (DEM). The DEM then will be analyzed with GCPs and leveling to determine their accuracy by checking the value of root mean square error (RMSE).

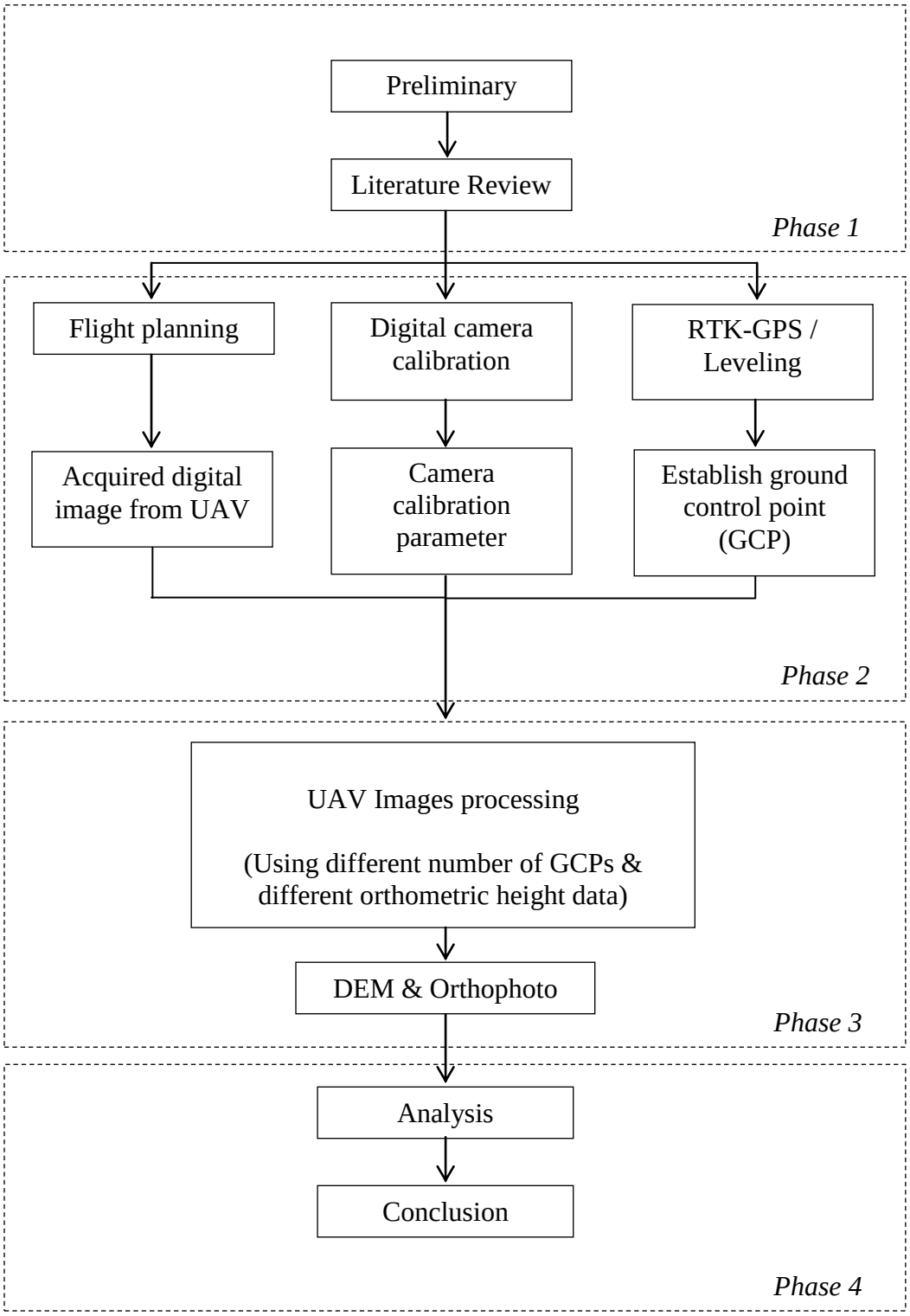

Figure 1.2: Research Methodology

1.8 Thesis Outline

The thesis is divided into five main chapters and the explanation of each chapter is described as follows:

Chapter 1 is the explanation about the introduction of the study. The chapter includes briefly explanation about the background of the research in briefly, the problem statement, objective of the study, significance of the study, scope of the study and general methodology to achieve the study objectives. This chapter also shows the flowchart of the research methodology in general that consists four main phases.

Chapter 2 is the literature review that review the previous research related to this study. The reviews are based on UAV system in aerial photogrammetry, UAV application especially in mapping, digital camera image resolution, digital image and ground resolution. This chapter describes the basic principle of aerial photogrammetry in determining photo scale, photograph overlap and photogrammetric control. Apart from that, this chapter also explains about the software used in processing and analyzing the UAV images. This chapter also describes the GPS ellipsoidal height, geoid height, orthometric height and MyGEIOD.

Chapter 3 is the research methodology that explained the flow of the study in more details. The methods used starting from data acquisition, data processing until the result will discuss in this chapter. The research methodology flowchart is included to show the method for this study. Besides that, this chapter also covers the software which has been used for processing the UAV images and field survey data. In this study, Agisoft Photoscan Version 0.9.0 and Global Mapper Version 15.2.3 were used to process UAV images. Topcon Tools Version 8.2.3 was used to convert the GPS ellipsoidal height to GPS orthometric height based on Malaysian Geoid Models (MyGEOID).

Chapter 4 explains the results and analysis of this study. This chapter discusses on the accuracy assessment of each result on height coordinates. The results are based on photogrammetric product such as digital elevation model (DEM) comparing with field survey data from RTK-GPS and leveling method. The analysis in this study will be shown in the form of graphic and graph presentation. The analysis of this study is based on quantitative and qualitative analysis with focusing on ground control points (GCPs) and check points (CPs).

Chapter 5 is the conclusion of the study. This chapter concludes the research finding of this study. This chapter also discusses the recommendation or suggestion for further improvement of the future study.

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