HIGH RESOLUTION DIGITAL ELEVATION MODEL GENERATION BY SEMI GLOBAL MATCHING APPROACH

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This thesis dedicated to my parents,
Shaffie bin Man & Kalsom Binti Ahmad.
My siblings Mohd Rizuan bin Shaffie, Mohamad Naziman bin Shaffie
Mohamad Khoshi bin Shaffie and Siti Hajar bin Shaffie
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ABSTRACT

The photogrammetric point cloud is a revolutionary product that represents an important breakthrough in Photogrammetry. The purpose of this research is to establish the workflow in the generation of Digital Elevation Model (DEM) from the photogrammetric point cloud. The photogrammetric datasets were acquired using Digital Modular Camera 01 (DMC 01) over the Putrajaya area. The main steps for Digital Elevation Model generation using the digital photogrammetric software were involved post processing image and Global Positioning System (GPS) and inertial measurement unit (IMU), aerial triangulation, and photogrammetric point cloud generation, point cloud editing and surfacing. The whole process was successfully performed and the output was delivered in the raster DEM format. The generated Digital Elevation Model were statistically compared with DEM's available from airborne Light, Detect and Ranging (LiDAR) technique and ground control points (GCP's) to measure the accuracy of DEM produced by Semi Global Matching(SGM) using Root Mean Square Error (RMSE) and F-test analysis. Based on the analysis, horizontal accuracy meets the expected accuracy; 0.5-1.0 Ground Sampling Distance (GSD) of images and sub-meter accuracy were obtained for vertical accuracy. In closing, elevation data generated from the SGM approach with this accuracy meet the standard practice of Department Survey and Mapping Malaysia (DSMM) for vertical direction (height) requirement.

Key words: DEM, DMC01, GPS, IMU, LiDAR, GCP's, RMSE, GSD

ABSTRAK

Awanan titik fotogrametri adalah produk revolusi yang melambangkan satu kejayaan penting dalam bidang Fotogrametri. Tujuan kajian ini adalah untuk mengkaji aliran kerja di dalam penjanaan model ketinggian digital daripada awanan titik-titik Fotogrametri. Data-data Fotogrametri telah dicerap dengan menggunakan kamera DMC01 dan Putrajaya telah dipilih sebagai kawasan kajian. Langkah-langkah utama yang terlibat semasa proses penghasilan model ketinggian digital dengan menggunakan perisian digital Fotogrametri adalah seperti berikut; pasca-pemprosesan imej dan GPS/IMU (pembetulan kedudukan dan orientasi), penyegitigaan udara, penjanaan awanan titik-titik fotogrametri, penyuntingan awanan titik-titik dan penghasilan permukaan model ketinggian digital Keseluruhan proses telah berjaya dilaksanakan dan hasil disimpan di dalam format raster model ketinggian digital. Model ketinggian digital yang telah dijana secara statistiknya dibandingkan dengan model ketinggian digital yang lain dimana ia diperolehi daripada kaedah bawaan udara LiDAR dan cerapan titik kawalan bumi bagi mengukur ketepatan model ketinggian digital yang dihasilkan daripada teknik Pemadanan Separa Global dengan menggunakan kaedah analisis RMSE dan Ujian-F. Berdasarkan analisis, ketepatan mendatar memenuhi jangkaan ketepatan yang diperlukan iaitu 0.5-1.0 resolusi imej dan ketepatan sub-meter telah diperolehi untuk ketepatan menegak. Sebagai penutup, ketinggian data yang dijana melalui pendekatan Pemadanan Separa Global dengan ketepatan yang diperolehi ini memenuhi amalan standard Jabatan Ukur dan Pemetaan Malaysia untuk keperluan arah menegak (ketinggian).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS	TITLE
2D	2 Dimensional
3D	3 Dimensional
ABM	Area Based Matching
APM	Automatic Point Measurement
ASCII	American Standard Code for Information Interchange
ASPRS	American Society for Photogrammetry and Remote Sensing
AT	Aerial Triangulation
AAT	Automatic Aerialt Triangulation
BSQ	Band Sequential
CCD	Charge Coupled Device
CVA	Consolidated Vertical Accuracy
CORS	Continues Reference Station
DEM	Digital Elevation Model
DMC	Digital Modular Camera
DSM	Digital Surface Model
DTM	Digital Terrain Model
EGM	Earth Gravitational Model
EO	Exterior Orientation
FBM	Feature Based Matching
FVA	Fundamental Vertical Accuracy

GCP	Ground Control Point
GIS	Geographical Information System
GSD	Ground Sampling Distance
GPS	Global Positioning System
ISAE-EXT	ImageStation Automatic Elevation Extended
IMU	Inertial Measurement Unit
INS	Inertial Navigation System
IO	Interior Orientation
ISAT	ImageStation Automatic Triangulation
JPEG	A lossy compression technique for color images
JUPEM	Department of Survey and Mapping Malaysia
LAS	Log ASCII Standard
LAZ	Compressed Log ASCII Standard
LSM	Least Square Matching
LiDAR	Light, Detect and Ranging
MS	Multi Spectral
MSL	Mean Sea Level
NIR	Near Infra-Red
NMAS	National Map Accuracy Standard
NSSDA	National Standard for Spatial Data Accuracy
NDVI	Normalized Difference Vegetation Index
RGB	Red, Green & Blue Band
RGBN	Red, Green, Blue and Near Infra-Red Band
RM	Relational Matching
RMS	Root Mean Square
RMSD	Root Mean Square Deviation
RMSE	Root Mean Square Error
RTK	Real-Time Kinematic
SAR	Synthetic Aperture Radar
SCP	Surface Control Points
SGM	Semi Global Matching
SRTM	Shuttle Radar Topography Mission
SVA	Supplemental Vertical Accuracy

TIFF	Tagged Image File Format
TIN	Triangular Irregular Network
UAV	Unmanned Aerial Vehicle
VMAS	Vertical Map Accuracy Standard

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

This study presents about the generation of Digital Elevation Model (DEM) from the photogrammetric point cloud using Semi Global Matching (SGM) approach. According to Hirschmüller (2005), SGM can be defined as the stereo matching method that is founded on a pixel-wise matching, held by a global smoothing function that is optimized along multiple paths. It holds a regular algorithmic structure and uses simple operations and is thus well suited for parallel implementation of the CPU using vector commands as well as on the GPU (Ernst and Hirschmüller, 2008) and FPGA (Hirschmüller, 2011). It normally does not require parameter tuning, this method is rather insensitive to the choice of parameters.

DSM's and DEM's do play a major role in mapping purposes. At present, several different methods are being available for DSM's and DEM's generation in the mapping industry. Both of these elevation types can be generated from topographic maps obtained by ground terrestrial laser measurements, airborne photogrammetric data or remote sensing expertise. Based on our nation trend, airborne LiDAR has become the key technology and an alternative to supply data for DSMs and DEMs in the utmost few years in the mapping industry. Precise, high density and high sampling 3D geometry data of the earth's surface can be delivered by airborne LiDAR. It's been turning the choice method for large scale acquisition of nationwide DEM.

Hitherto, motivation from digital Photogrammetric always impending into the industry. For instance, the presence of a digital metric camera like ADS80, RCD30, DMC, and Ultra-cam has been shown to construct multiple stereo coverage. And then, the pixel base method is kept in DSM and DEM derivation. The innovation of the existing stereo construction, it creates new data types, called as Photogrammetric Point Cloud using Vision community technique, Semi Global Matching approach. In some systems, SGM point clouds begin to return accuracy levels achieved by a mobile LiDAR in open hard surfaces.

Hence, this study presents the SGM approach for DMC camera and compares the results with LiDAR datasets and ground control points – in terms of DSM/DEM resolution and accuracy. And likewise a question can be asked is which method better than others.

1.3 Problem Statement / Motivation

Referable to the increasing of innovative technology in Photogrammetry now and will continue ahead to impact the geospatial industry, SGM looks can replace LiDAR with bargain pricing on point clouds. Multiple stereo coverage capabilities of the digital frame camera are a fundamental of the pixel-based DSM/DEM derivation where the image matching techniques at the present time be able to deliver very dense point clouds. Given the situation, it is high affording that our mapping agencies take serious effort in studying the goodness that may contributed from this useful branch technology. Hence, this study is conducted to analyze the accuracy of terrain from SGM technique, so that it can be recommended as an alternative source of elevation besides as a primary choice for ultra-dense surface extraction images, in case LiDAR technologies are not available and to save additional flight costs of the department. Initial presumption is SGM accuracies are motivated by the triangulation accuracies of the block imagery, typically 0.5 GSD horizontally and 1.5 GSD vertically.

1.4 Objective of Study

The objectives of this study are:

1. To study a workflow of generation Photogrammetric Point Cloud (Digital Surface Model) data using Semi Global Matching approach.

2. To assess the accuracies of terrain elevation and surface height generated from Semi Global Matching technique compared to airborne LiDAR data and ground control point.

1.5 Significance of Study

Although currently in Malaysia there is no concrete evidence shows the photogrammetric point clouds may leads to digital elevation data generation, the findings of the study are important to prove that this type of elevation data can be bottom next after LiDAR technologies or might be proposed as alternative if we don't have LiDAR data in the department. For instance, in recent years, we can see an increasing natural disasters in our countries such as floods, earthquakes, landslides so on. In further disaster analysis scenarios, it's significant to know the conditions before, current and after the disaster came so we can compare and do .real-time updating it to horizontal and vertical conditions following requirements. Imagine that if we don't have LiDAR data from earlier? By having this product, 3D True Ortho model can be shaped and from that we can quantify the alteration between two temporal datasets from the Photogrammetric Point Cloud.

1.6 Scope

The focus of this project is to identify the workflow of DSM generation, SGM and DEM extraction from photogrammetric technique, from an existing post processing LiDAR technique. Other techniques in the creation of DSM and DEM will not discuss in this study. The data of this survey were confined to large-format airborne digital frame camera, Digital Modular Camera (metric-camera), which are flown 2500 above mean sea level and it's having the capability to make more than 60% stereo overlapping per models. Once the data is ready, it will be processed using digital photogrammetric workflows and digital image matching technique will be necessary along the generating of DSM. Stereo environment is replaced by point cloud profile editing and extraction in order to generate raster DEM. Point's interval of point cloud is 18 cm which is same with the spatial resolution of aerial photograph. LiDAR dataset and ground control points (GCP's) are utilized as reference data for this project.

1.7 Methodology

1.7.1 Instrumentation

The instrumentation for this study was involved hardware and software applications. The hardware components include Digital Modular Camera (DMC 01) and GNSS/IMU equipment (Trimble POS AV), whereas the processing software, including Z/I Mission Planning, Z/I Inflight, Z/I Post Processing Software (PPS), Waypoint Inertial Explorer, ImageStation Family Product, ERDAS Imagine Professional and Geomedia GRID.

1.7.2 Study Area

The study area is an administrative center of Malaysia. Located in Putrajaya, Malaysia, the study area extended by land features like vegetation area, water bodies, residential area and open spaces. The base height of study area is about 15 meters to 110 meters above sea level. Because the conditions of terrain, features surrounding this area besides the reference data for this study are available is a key factor the research area is preferred.

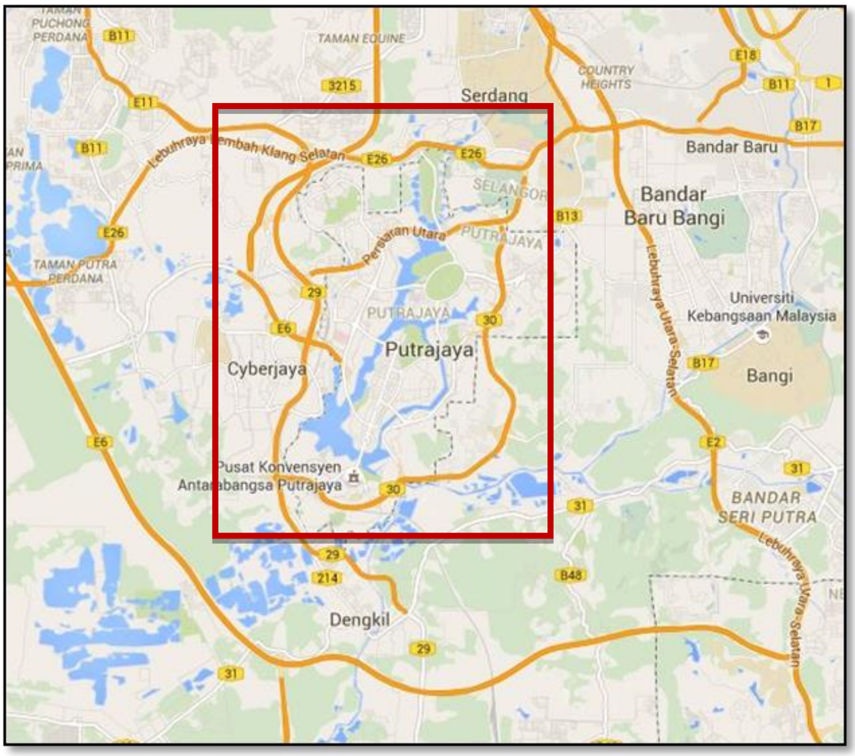

Figure 1.1 Location map of Study Area

(Source: Google Map, 2015)

1.7.3 Outline of Methodology

In brief, the general sequences that will be involved in this study are:

a) Flight Mission Planning uses the Z/I Mission Planning. A mission planning is designed based on terrain, and conditions of the research field.

b) Field Data Acquisition that involved image data capturing using DMC01 camera and GPS/INS recording using Trimble POS AV. Z/I Inflight software is used to record the exposure stations information during the mission.

c) Post-processing images using the Z/I Post Processing Software to output out of RGB images

d) GPS/IMU Data Processing uses Waypoint Inertial Explorer software to generate Exterior Orientation ((EO) parameter that consisted East, North, Height, Omega, Phi and Kappa values.
e) Aerial triangulation process for registration and orientation of exposure stations by ImageStation Automatic Triangulation software.
f) Point cloud generation using a SGM technique by ImageStation Automatic Elevation Extended software.
g) 3D Viewing of Photogrammetric Point Cloud.
h) DEM extraction and generation by performing the classification, filtering, and manual editing of point clouds, and interpolation of terrain elevation.
i) Quality Assurance with LiDAR and ground control points.
j) Present the result through the table's analysis.

The detail explanation every methodology sequence in this study will be discussed in Chapter 3, Research Methodology.

1.8 Outline of Chapters

In short, Chapter 1 exposes to the research proposal that present a clear knowledge of the subject and explain the methodology. Chapter 1 starts with a background study that concerned about the ways of the DSM and DEM generation from Photogrammetry techniques, followed by a section of the different contents of proposal, namely, problem statement or motivation, objective of the study, the significance of the study and scope. The chapter proceeds with a methodology process that the author plans to use to collect the data that substantiate the thesis statement and achieved the stated aims. The chapter ends with the outline of the methodology and outline of chapters to summarize the thesis action.

In Chapter 2, some note and literature reviews from previous study or journals that highlighted about the SGM approach in order to generate a point cloud or DSM that conducted by other researchers will be reviewed. Also, in this chapter attached a theoretical base of the research to illustrate and justify the motivation of this study from existing studies. This chapter ends with the summary of the DSM and DEM generation, verification questions to integrate to the next chapter.

Chapter 3 demonstrates a research methodology on how to gather aerial photogrammetric data for this research. This chapter begins with an introduction of research methodology, followed by elaboration of the steps in general Photogrammetry data methodology workflow, which include the data collection that involved mission planning and field data acquisition, airborne data processing which are separated by two parts namely, post processing images and GPS / IMU processing. Then, followed by data processing in order to achieve the first objective which are involved project management, aerial triangulation and bundle block adjustment, point cloud generation by SGM approach and ended with DEM extraction by editing DSM. When all workflows are completed, data analysis and quality assurance will be executed. The chapter also covers the discussion, research instruments from airborne to ground that involved hardware and software used along with this subject area. Simple briefing about supporting data, LiDAR and GCPs were explained in this chapter.

Chapter 4 will focus on result and analysis description. The chapter starts with the introduction section which sum up the aim, previous chapter response and DSM discussion. The chapter continues with the height analysis of surface and terrain, which a core section of project writing. The description of height analysis embraces the background information, explanation of results, positive or negative support, contradict reference to previous research and suggesting general hypotheses and implications based on research findings. In clearly and effectively result presentation, the illustration and diagrams will be employed to demonstrate the findings besides statement analysis. The chapter ends with the summary of the short height analysis and review the findings.

Lastly, the emphasis on Chapter 5 is about making conclusion of the research findings. According to another chapter, this chapter will begins with an intro, accompanied by an overview of the summary of findings and end with the recommendations based on findings and for future research. Some other element in conclusion of this research includes restatement of the objectives, implications of findings, limitations of the research and recommendations and suggestions for the following studies.

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