UNIVERSITI PUTRA MALAYSIA

UAV-BASED EXTRACTION OF TOPOGRAHIC AND AS-BUILT INFORMATION BY OBJECT-BASED IMAGE ANALYSIS TECHNIQUE

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UAV-BASED EXTRACTION OF TOPOGRAHIC AND AS-BUILT

INFORMATION BY OBJECT-BASED IMAGE ANALYSIS TECHNIQUE

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Chairman : Associate Professor Helmi Zulhaidi Bin Mohd Shafri, PhD
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The advancement of airborne technology without pilot, unmanned aerial vehicle (UAV) systems utilises the minimal cost of function for future mapping purposes. The utilisation of UAV data from visible red, green, blue (RGB) bands is limited to the visualisation of orthophoto for planning and monitoring applications. Thus, this study explores the potentials of UAV data based on RGB camera for topographic and as-built information for features extraction using OBIA (object-based image analysis) technique. The main objective of this study is to assess the capability of UAV data in providing reliable topographic and as-built data information. More specifically, this study aims to extract topographic and as-built information such as land cover and geometry of infrastructure classes in urban area using eBee Sensefly UAV imagery. In this frame of study, The National Land and Survey Institute in Tanjung Malim, Perak, Malaysia was chosen as the area of interest. A robust Taguchi method was used in optimising the segmentation process. In accordance with the image classification process, different supervised OBIA classifiers such as KNN, normal Bayes (NB), decision tree (DT), random forest (RF), and support vector machine (SVM) were tested by tuning each of their parameters to quantify the performance of each classifier in favour of using UAV image data. Results showed that SVM obtained the highest percentage of overall accuracy, followed by RF, NB, DT, and KNN at 97.20%, 95.80%, 93.14%, 86.01% and 77.62%, respectively. The optimal OBIA parameters for each classifier are as follows: SVM with their C was 100,000 and Gamma 0.001. Meanwhile, the maximum depth parameter for RF and DT was 15 and 20 respectively. KNN classifier with K parameter was 5. The dimensional assessment on features that was extracted using OBIA showed that the error was in the range of less than 20 cm. Meanwhile, the positional accuracy based on root mean square error (RMSE) result gave the error of horizontal and vertical axes of less than 0.5 m. This result indicated that the UAV image data have a big potential to be utilised for topographic mapping and as-built information.

Moreover, the OBIA technique also contributes to efficient features extraction compared to the manually practiced technique.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

ASAS UAV BAGI PENGEKSTRAKAN MAKLUMAT TOPOGRAFI DAN LUKISAN BINAAN DENGAN TEKNIK ANALISIS IMEJ BERDASARKAN OBJEK

Oleh

HAIRIE ILKHAM BIN SIBARUDDIN

Jun 2018

Pengerusi : Professor Madya Helmi Zulhaidi Mohd Shafri, PhD
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Kemajuan teknologi sistem pesawat udara tanpa pemandu (UAV) untuk tujuan pemetaan dapat digunakan dengan kos yang minimum pada masa hadapan. Kebiasaannya, penggunaan data UAV dari jalur Merah, Hijau, Biru (RGB) hanya terhad kepada visualisasi ortofoto bagi aplikasi perancangan dan pemantauan. Justeru itu, kajian ini dibuat bagi mengenalpasti potensi data UAV dengan menggunakan kamera RGB bagi pengekstrakan ciri maklumat topografi dan lukisan binaan menggunakan teknik analisis imej berdasarkan objek (OBIA). Objektif utama kajian ini adalah untuk menilai keupayaan data UAV bagi menyediakan maklumat data topografi dan maklumat binaan. Secara khususnya, kajian ini bertujuan untuk mengekstrak maklumat topografi dan butiran seperti ciri-ciri geometri infrastruktur bagi kawasan bandar dengan menggunakan UAV eBee Sensefly. Dalam rangka kajian ini, Institut Tanah dan Ukur Negara (INSTUN) di Tanjung Malim, Perak, Malaysia telah dipilih sebagai kawasan tumpuan kajian. Kaedah Taguchi telah digunakan untuk mengoptimumkan proses segmentasi. Bagi proses klasifikasi imej, kaedah OBIA berpenyelia seperti pengelas K-Nearest Neighbours (KNN), Normal Bayes (NB), Random Forest (RF), Decision Tree (DT) dan Support Vector Machine (SVM) telah diuji dengan menilai parameter masing-masing menggunakan data imej dari UAV tersebut. Keputusan analisis menunjukkan pengelas SVM memperolehi peratusan ketepatan keseluruhan tertinggi, diikuti oleh RF, NB, DT dan KNN iaitu 97.20%, 95.80%, 93.14%, 86.01% dan 77.62%. Parameter optimum OBIA yang digunakan untuk setiap pengelas adalah seperti berikut; SVM dengan parameter C adalah 100,000 dan Gamma 0.001. Manakala parameter kedalaman maksimum untuk RF dan DT masing-masing adalah 15 dan 20. Bagi pengelas KNN, parameter optimum bagi K ialah 5. Penilaian dimensi mengenai ciri-ciri yang telah diekstrak menggunakan OBIA menunjukkan bahawa ralat ketepatan berada dalam lingkungan kurang

daripada 20 sm. Sementara itu, ketepatan kedudukan berdasarkan keputusan RMSE memberikan ralat paksi mendatar dan menegak kurang daripada 0.5 m. Secara keseluruhannya, data imej UAV mempunyai potensi besar digunakan untuk tujuan pemetaan topografi dan informasi lukisan binaan. Di samping itu juga, melalui teknik OBIA ini telah menyumbang kecekapan ciri-ciri pengekstrakan berbanding kaedah secara manual.

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I certify that a Thesis Examination Committee has met on 29 June 2018 to conduct the final examination of Hairie Ilkham Bin Sibaruddin on his thesis entitled “UAV-based extraction of topographic and as-built information by object-based image analysis technique” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of master of science

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LIST OF ABBREVIATIONS

ASPRS	Association Society for Photogrammetry and Remote sensing
AT	Aerial Triangulation
BM	Benchmark
C	Cost
CAMS	Computerized Mapping System
CATMAPS	Computer Assisted Topographic Mapping System
CP	Check Point
DCA	Department of Civil Aviation
DEM	Digital Elevation Model
DSM	Digital Surface Model
DSMM	Department of Survey and Mapping Malaysia
DT	Decision Tree
DTM	Digital Terrain Model
FGDC	Federal Geographic Data Committee
FSO	Feature Space Optimization
GCP	Ground Control Point
GCS	Ground Control Station
GDAS	Geospatial Data Acquisition System
GDM 2000	Geocentric Datum of Malaysia 2000
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSD	Ground Sampling Distance
GT	Ground Truth
EDM	Electronic Distance Measurement
HB	Higher is Better
INSTUN	The National Land and Survey Institute
ISPRS	International Society for Photogrammetry and Remote Sensing
KC	Kappa coefficient
KNN	K-Nearest Neighbour
LIDAR	Light Detection and Ranging
LW	Lower is better
NB	Normal Bayes
NRE	Ministry of Natural Resources and Environment
NSDI	National Spatial Data Infrastructure
OA	Overall Accuracy
OBIA	Object Based Image Analysis
POF	Plateau Objective of Function
RADAR	Radio Detection and Ranging
RBF	Radial Basis Function
RF	Random Forest
RGB	Red Green Blue
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SN	Signal to Noise

SVM	Support Vector Machine
UAV	Unmanned Aerial Vehicles
UTM	Universal Traverse Mercator

CHAPTER 1

INTRODUCTION

1.1 Preamble

The Department of Survey and Mapping Malaysia (DSMM) is the pillar agency in addressing the preparation, supply and dissemination of geospatial data quality to meet the needs of stakeholders (JUPEM, 2015). One of their primary operation is to measure, process and manage topographical detail data that exist on the ground for the purposes of mapping. In Malaysia, the topographical mapping activities are dated back since 1885 (JUPEM, 2010). The large-scale topographical mapping precedented for supporting the nationwide development especially on detail spatial planning. The entire of these activities had gone through a process of rapid technological development neither on management nor working methods in the field to ensure the implementation of the work process is robust and efficient.

The topographic survey measurement is dedicated for the preparation and updating topographic maps and the national topographic database for entire Malaysia (JUPEM, 2012). The presence of the topographical land surveys provides an accurately measured plan of a site, which covers the whole range of various features information. Typically, it is used as a skeleton for design work before a construction project begins to address the need of land survey, urban planning, as-built planning, hazard preparedness assessment, or disaster risk management. The data for these surveys was attained and collected using several surveying equipment and techniques such as total station, digital levelling, Global Positioning System (GPS), terrestrial laser scanning, manned aircraft platform, remote sensing satellite data, Radio Detection and Ranging (RADAR), Light Detection and Ranging (LiDAR) which measured every point individually or accumulatively.

1.2 Justification

The growth and capacity development of the urban areas in Malaysia such as Kuala Lumpur, Klang Valley, Shah Alam, Johor Bahru, Penang and Ipoh continue to increase rapidly in the recent years. According to the World Bank, (2015) Malaysia is among the urbanised countries in the East Asia region. Malaysia presented the fourth-largest amount of built-up land in East Asia as of 2010. Between 2000 and 2010, the urban land grew from about 3,900 square kilometres to 4,600 between an average annual growth rate of 1.5%. As of 2010, the Kuala Lumpur urban area was ranked the eighth largest in the region. It is larger than some megacity urban areas like Jakarta, Manila, and Seoul despite the smaller capacity population.

The expansion of the urban area is quantified by deriving the high intensity of the built-up, population and infrastructure for that area as escalated by the World Bank (2015). Consequently, quick and frequent updates of information for such urban area with topographic mapping is required to deliver the information pertaining to the area accurately. The urban mapping must provide accurate information on features, structures and geography as well as on the relationship between features in urban and suburban areas (Shafri et al., 2012).

Remote sensing technology plays an important role in providing a useful source of data with the up to date and wide area information about the spatial extent. It generates a digital data of the spatial and spectral features of the earth's surface at the time of the image acquisition (Yang, 2011). Remotely sensed data is available from a range of sources and data collection techniques. Generally, the data can be acquired from ground-base, aerial and satellite platform (Gopi et al., 2007). It is not always easily found within the public domain. This is because most of this data is acquired by equipment that is too expensive to build and maintain. With the advancement of technology, the preparation of accurate and precise data showing the spatial distribution and relationship between the different earth features has become possible, especially in areas which are difficult to access.

Simultaneously, with the deployment of Unmanned Aerial Vehicle (UAV) system which operates without a human operator, is becoming a famous technology in recent years within public coverage (Tahar, 2012). The UAV segment has experienced the fastest growing sector in the market for aerospace (Mastor et al., 2013; Goebel & Saha, 2015). UAVs for the civilian science applications recently have received more emphasis to a greater extent by border security, environmental monitoring, and other application domain compared to previous application which was driven primarily by the military community mainly for shooting targets and for surveillance (Everaerts, 2008).

Nowadays, the UAV becomes an invaluable data capture tool for the survey industry. A huge quantity of data points can be captured in just one short time covering a large area, and added with the tendering major cost efficiency to the user needs (Sona et al., 2014). It is advanced compared to the traditional methods which have limitations in certain areas of interest (inaccessible), tedious and have a long dependency of time to acquire the data in the site areas. Normally, the survey process by a land surveyor consumes several days to complete by targeting for each point, area or feature (Nex & Remondino, 2014).

Technological advancements have resulted in the development of topographic maps and in future will become more innovative, interesting and useful for users. The potential of producing these maps with low technological costs (Dustin, 2015), high image resolution, and the relevant data is attainable. The UAV become more prominent in various disciplines due to their availability of high spatial resolution data, lightweight of sensors and platforms, incorporation of flexibility of flight planning and deployment, and removal of the long dependency, leading to a growing interest for this technology (Hardin & Hardin 2010; Laliberte & Rango, 2009). UAV could also obtain timely imagery of areas that are difficult or dangerous to access by traditional means. In addition, it can predict the acquisition points and possibly perform a direct geo-referencing (Nex & Remondino, 2014).

Acquaintance on the current area distribution of such urban or built-up land, agriculture land, forest land, water and rangeland as well as information on their changing proportions is required. With the technology and capabilities used to collect the survey data, it is possible to generate highly detailed plans for the interest of the stakeholders. This is due for determining better land use policy, future development in sustaining an effective and efficient management for a particular area.

1.3 Problem Statement

The rapid development of Malaysia especially in the main city area sprawling over the landscape of land use and land cover. Therefore, there is a need for an existing technology that can be used rapidly without the constraint of cost, time, and can update the current land topography regularly. Mostly, the current technology and system utilised are highly costly and inefficient in the technology provided. This is due to the limitation and circumstances of lack of technology available. The restriction of this technology spoiled the demand and defaced the stakeholders' trust. The land use and land cover data information are highly required in addressing the need of civil engineers, planners, contractors, architect and surveyors.

In recent years, the increasing demand for digital orthophotos has been pushing researchers to improve the data quality and reduce the production costs. Advances in the resolution of satellite imagery have increased its use in terrace mapping particularly on small scales. High costs indirectly impact on small project, in which the use of large format aerial photographs as the main source of data is less appropriate in implementing the project.

Aerial manned aircraft provides better perspective with the capability to cover an extensive area and focus the spot area on the current investigation. However, it cannot be flown in bad weather, or area which is potentially unsafe for the operators. In addition, the factor of cloud cover would affect the quality of imagery during the time the image were taken. The current system that had been used is highly costly with the high interoperability of the data risk. It needs more man power and human capacity during the data acquisition.

According to Yatim, 2015, the former Director General of Survey and Mapping Malaysia said that the department was spending high rental costs on aircraft expenses for data acquisition using manned aircraft. The expenses are almost

RM200,000 up to RM300,000 for a 15-day flight time monthly for data acquisition. Therefore, there is a need for an advanced, efficient and current technology of data acquisition as an alternative to reduce the flight rental cost, which can save the government expenses for the purposes of DSMM for data collection in producing and publishing the maps.

Satellites are likely to be used and perform well in a given specific area. More expensive satellites offer wider and regular coverage of a specific target. However, the influence of atmospheric conditions in moist and tropical regions cannot be neglected and they are often an obstacle for capturing the high-quality data using satellites. In regards, the location of Malaysia which is near the equatorial admit to the hot, humid and rainy conditions throughout the year. In addition, any forms of cloud may spoil the image data. Therefore, it is beneficial to have multiple sources of sensor data that operate efficiently.

The pixel-based image analysis is becoming less important for high resolution imagery classification. The pixel-based image analysis algorithm is based on binary theory. In this theory, one pixel is labelled to a class or is not assigned properly. For overlapping pixels, such pixel will be labelled in one or two classes showing affinity in object-based technique. The per pixel-based classification does not have the capability overcome this problem due to the image is classified according to the spectral information and the pixels in the overlapping region will be misclassified.

1.4 Objectives of Study

The general objective of this study is to extract topographic and as-built information using UAV. Specifically, this study's objectives are;

(i) To determine the most optimal Object-Based Image Analysis (OBIA) parameters through the process of segmentation and classification to deliver the required information from UAV data;
(ii) To extract the topographic and as-built information such as land cover, infrastructure geometry, dimensions from UAV data; and
(iii) To assess the accuracy of the extracted information from UAV data.

1.5 Scope and Limitation of the Study

This study is expected to produce a suitable topographic map and as-built data by extracting the information from UAV orthophoto by using OBIA method. The information generated by this study is believed to supply and provide beneficial information to the target group especially for the purposes of land management and development. Formerly, the conventional ground survey regarding the data acquisition for mapping was very time consuming. Therefore, with the potential use and availability of the UAV technology, it gives an alternative for solving this problem.

The image had been generated into orthorectified and pre-processed using Pix4D software. The limitation of this study is the use of visible RGB (Red Green Blue) band for further image classification with OBIA method. The study area is limited for up to 36 hectares consisting of seven (7) classes only that represent the main land cover data. The landscape of this area was surrounded by detailed classes likes soil/sand, urban tree, building/roof, impervious surface, water and shadow. The features were extracted for as-built geometrical assessment and were limited to man-made features such as buildings, drainage and roads.

1.6 Organisation of Thesis

Chapter 2 encompasses the literature of the main topic and sub topic related to this study. This section coherently explains about the basic of remote sensing data, UAV technology availability, topographic map with the representing of land use and land cover and a core aspect on OBIA technique. In detail, the OBIA technique involved several processes such as segmentation, classification, feature selection and accuracy assessment. Then, the gaps of this research will be highlighted at the end of this chapter based on thorough findings from previous journals and references. The gaps of the research are vital to fulfil the potential research scope and are directly investigated through the entire of study.

Chapter 3 highlights the section of the methodology of the research. This chapter includes the background of the study area and the sources of data set being used. The important part of this chapter is the workflow of the research conducted. The research flow involved three phases. The first phase is the initial pre-processing of UAV data using photogrammetry method and software. Then, the second phase is the initiation of the pre-analysis on validation of pixel-based and OBIA comparison. Afterwards, the third phase is on OBIA process, comprises of segmentation process, features selection and classification. The last stage of research comprises accuracy assessment for image classification and geometrical assessment to validate the output map.

Chapter 4 focuses on the results, analysis and discussion of the entire research. The analysis is considered the important part of this study with the elaboration of the findings that had been experimented before. This chapter explained the results derived from the methodology of research. The results for each phase were explained and demonstrated through this chapter. The analysis covered the preliminary segmentation results using Taguchi experimental cases for optimising the segmentation. Next, the analysis focused on how the data contributed by the impacts of size of training and testing sample for classification. It also showed the great impacts of the performance of the classifiers by setting the tuning parameter to get the reliable parameter for each classifier. The results for accuracy validation based on classification were also highlighted. Finally, the last analysis was on the dimensional assessment and checking.

The last chapter of this research draws the summary and conclusion from the entire study. An overview and implications of the findings, as well as the limitations and benefits of this research were discussed. The suggestion and recommendation from the whole study is also highlighted in this chapter in a way of improving for the future research.

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