UNIVERSITI PUTRA MALAYSIA

OBJECT-BASED IMAGERY ANALYSIS FOR AUTOMATIC URBAN TREE SPECIES DETECTION USING HIGH RESOLUTION SATELLITE IMAGE

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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 Doctor of Philosophy

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Chairman : Assoc. Prof. Helmi Zulhaidi bin Mohd Shafri, PhD
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Sustainable management and monitoring the urban forest is an important activity in an urbanized world and subsequently operational approaches requires information about the status to determine the best strategic. In spite of availability of some traditional methods which imposes difficulties for tree species identification in larger urban areas, there is a demand for a fast, sensitive, that is expected to facilitating improvement of monitoring involve remote sensing technologies and image analysis techniques for urban forest inventory, urban tree species detection and ecology management. The main goal of this research is to build generic rule from World View-2 satellite imagery in conjunction with spectral, spatial, color and textural information, which is extracted from available training data for tree species detection. After segmentation, the most important step was feature selection, which is used for dimensionality reduction and discrimination between different attributes. The attribute evaluator method, which performed in this study, was CfsSubsetEval. Result of attribute selection indicates that 26 attributes were extracted from 56 attributes of the WorldView-2 image. In this research, most of satisfactory results achieved from the generic model and proves it can be easily performed to different WorldView-2 images from different areas and provided the high accuracy through algorithms for tree species detection namely, *Mesua Ferrea*, *Samanea Saman*, and *Casuarina Sumatrana* without using any training data. This study also explores the use and comparison of object-based classification, and two common pixel-based classification methods namely, maximum likelihood and support vector machines based on WorldView-2 satellite imagery to evaluate the potential of the object-based in compare to pixel-based to detect urban tree species. The method of maximum likelihood classification and support vector machines leads to the lowest classification accuracy since these algorithms extract only the spectral information of each pixel and consequently fail to utilize spatial, color and textural information.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

ANALISIS IMEJ BERASASKAN OBJEK UNTUK PENGESANAN SPESIS POKOK A BANDAR SECARA AUTOMATIK MENGGUNAKAN IMEJ SATELIT RESOLUSI TINGGI

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Pengurusan mampan dan pemantauan hutan bandar adalah satu aktiviti yang penting di kawasan perbandaran yang memerlukan maklumat mengenai status untuk menentukan strategik terbaik. Walaupun terdapat beberapa kaedah tradisional yang menyatakan kesukaran untuk mengenal pasti spesies pokok di kawasan bandar yang lebih besar, terdapat permintaan terhadap teknik yang cepat dan sensitif, yang dijangka akan memudahkan peningkatan pemantauan melibatkan teknologi penderiaan jauh dan teknik analisis imej untuk inventori hutan bandar, pengesanan spesies pokok bandar dan pengurusan ekologi. Matlamat utama kajian ini adalah untuk membina peraturan generik daripada imej satelit Worldview-2 yang menggabungkan informasi spektrum, ruang, warna dan tekstur yang diekstrak daripada data latihan yang disediakan untuk mengesan spesies pokok. Selepas proses segmentasi, langkah yang paling penting ialah pemilihan sifat yang digunakan untuk mengurangkan dimensi dan mendiskriminasi sifat-sifat khusus yang berbeza. Kaedah penilaian sifat penilai yang diaplikasi dalam kajian ini adalah CfsSubsetEval. Keputusan pemilihan sifat khusus menunjukkan bahawa 26 sifat telah dipilih daripada 56 sifat yang terdapat pada imej WorldView-2. Dalam kajian ini, sebahagian besar daripada hasil yang memuaskan dicapai daripada model generik. Ini secara langsung membuktikan bahawa teknik ini boleh dilakukan dengan mudah pada imej WorldView-2 yang berbeza dari kawasan yang berbeza dan mampu memberi ketepatan yang tinggi melalui penggunaan algoritma untuk mengesan spesies pokok *Mersua Ferrea, Samanea Saman* dan *Casuarina Sumatrana* tanpa menggunakan apa-apa data latihan. Kajian ini juga meneroka penggunaan dan orbandingan klasifikasi berdasarkan objek, dan dua teknik klasifikasi berasaskan piksel yang biasa digunakan iaitu "maximum likelihood" dan "support vector machine" berdasarkan imej satelit WorldView-2 untuk menilai potensi pengesanan pokok bandar melalui teknik klasifikasi berbeza. Kaedah klasifikasi menggunakan "maximum likelihood" dan "support vector machine" menghasilkan keputusan ketepatan klasifikasi yang paling rendah disebabkan algoritma ini hanya mengekstrak maklumat spektrum sahaja dari setiap piksel dan seterusnya gagal untuk menggunakan maklumat ruang, warna dan tekstur.

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I certify that a Thesis Examination Committee has met on 27 May 2016 to conduct the final examination of Razieh Shojanoori on her thesis entitled "Object-Based Imagery Analysis for Automatic Urban Tree Species Detection using High Resolution Satellite Image" 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 Doctor of Philosophy.

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LIST OF ABBREVIATIONS

AF	Attribute Filters
AGFLVQ	Adaptive Gaussian Fuzzy Learning Vector Quantization
ANN	Artificial neural network
CHM	Canopy height model
C.Sumatrana	*Casuarina Sumatrana*
DBH	Diameter at breast height
DEM	Digital elevation model
DSM	Digital surface model
DT	Decision tree
FLAASH	Fast line-of-sight atmospheric analysis of spectral hypercubes
GFLVQ	Gaussian fuzzy learning vector quantization
GIS	Geographic information system
GLCM	Grey level co-occurrence matrices
HSR	High spatial resolution
KL	Kuala Lumpur
Landsat ETM+	Landsat enhanced thematic mapper plus
Landsat TM	Landsat thematic mapper
MCH	Mean canopy height
MD	Minimum distance
M.Ferrea	*Mesua Ferrea*
MODIS	Moderate resolution imaging spectroradiometer
MIVIS	Multispectral infrared visible imaging spectrometer
MLC/MLH/ML	Maximum likelihood classification
MS	Multispectral
NDVI	Normalized difference vegetation index
NIR	Near infrared
NLP	National landscape policy
OB	Object-based
OBIA	Object-based images analysis
Pan	Panchromatic
PCC	Percent canopy cover
QUAC	Quick atmospheric correction
RBF	Radial basis function
ROI	Region of interest
RS	Remote sensing
SVM	Support vector machine
SAR	Synthetic aperture radar
SID	Spectral information divergence
SAM	Spectral angle mapper
S.Saman	*Samanea Saman*
UPM	Universiti Putra Malaysia
VHR	Very high resolution
WV-2	WorldView-2

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays the world's population in urban areas is more than rural areas. The latest statistics of world's population has demonstrated that 54 precents of the world's population lives in urban areas, and this population is going to be 66 precents by 2050 (The United Nations, 2014). Urban area is commonly defined as spaces with artificial surfaces and dense population, and the vegetation that covers an urban area is considered an urban forest. Urban forests may include any type of vegetation in a metropolitan area; types of vegetation include trees, shrubs, and woody plants on the roadside or plants on a larger scale, such as a forest park.

Urban forests not only result in social and economic advantages, such as recreational spaces and tourism attraction, but also provide several benefits to the ecosystem. The most important effect of urban forests in the ecosystem include the following: protection of biodiversity, avoidance of soil erosion, carbon storage, nutrient cycling, improvement of air and water quality, slowing wind and reducing water volume caused by storms, moderate local climate, energy waste minimization by creating shades to buildings, and decreasing heat in an island (Akamphon & Akamphonb, 2014; Conine et al., 2004; Gobster & Westphal, 2004; Huang et al., 2007; Ma & Ju, 2011; Shahidan et al., 2010; Xiao & McPherson, 2005).

As urban forests are vital in ecology, their management, which is called urban forestry, must include strategic and appropriate urban design and planning (Huang et al., 2007; Iovan et al., 2008; Kong & Nakagoshi, 2005). Nevertheless, rapid urbanization, which poses a threat to the safety of an ecosystem (Hepinstall-Cymerman et al., 2013), has compelled scholars to focus on urban green spaces. Human society seems to have realized that living without nature is difficult and unsafe (Kong & Nakagoshi, 2005; Li et al., 2010).

With progressing urbanization, managing urban forests has become a significant concern. The growth of residential and commercial areas can negatively affect vegetation and ecology. Hence, one of the issues in urban forestry is determining the state and quantity of urban vegetation and buildings and controlling their growth and deterioration (Gillespie et al., 2012; Iovan et al., 2008; Kong & Nakagoshi, 2005). Sufficient knowledge on urban forests, such as tree location, size, and species, is essential for effective urban forestry (Ardila et al., 2012).

For instance accurate and reliable information on different tree species is crucial to urban vegetation studies. This information assists urban planners and researchers in urban planning and disaster management (Gong et al., 2013; Hao et al., 2011; Iovan et al., 2008).

Urban spaces are complex areas; hence, accessibility to all trees by field survey is extremely difficult and time-consuming. In this method, the entire city or some parts of an area are randomly selected for sampling (Nowak et al., 2008). At present, remote sensing can overcome these limitations. It can be used to obtain highly accurate information by monitoring and managing urban areas and vegetation(Ardila et al., 2012).

Given the spectral similarity between different tree species, hyperspectral data can discriminate urban tree species appropriately because of characteristics such as narrow-band, multi-channel, and inclusion of continuous spectrum information. However, these data have several drawbacks, including limited coverage, high volume, and high cost(Shafri et al., 2012). Studies conducted with high-resolution satellite imageries, such as IKONOS and QuickBird, also extract tree species effectively (Hájek, 2006; Ke & Quackenbush, 2007; Mora et al., 2010; Puissant et al., 2014; Sugumaran et al., 2003; Voss & Sugumaran, 2008).

Nonetheless, tree detection and information extraction from urban areas are difficult when traditional pixel-based image classification methods are used. This classification lowers classification accuracy due to the high-grade spectral variability within land cover classes that are affected by sun angle, gaps in tree canopies, and shadows (Johnson & Xie, 2013; Yu et al., 2006).

To overcome the aforementioned limitations, object-based image analysis (OBIA) approaches can be utilized to improve classification accuracy (Li et al., 2010; Lobo, 1997; Puissant et al., 2014; Shouse, 2013). Several studies have been conducted to detect tree species; however, the lack of rule sets for conducting this detection process in urban areas remains a major setback.

In tropical areas such as Malaysia, common urban management issues involve controlling the wind, cooling the environment, and increasing energy savings. Thus, the present study attempts to develop new generic rule sets to extract the tree species, which are among the most popular species of urban trees and can increase energy efficiency and limit the damage to properties by windbreak. Moreover, WorldView-2 (WV-2) imagery is used because of the potential of new bands with high spatial resolution to detect vegetation (Immitzer et al., 2012; Latif et al., 2012; Marshall et al., 2012; Nouri et al., 2014; Pu & Landry, 2012; Rapinel et al., 2014).

1.2 Problem Statement

In tropical countries such as Malaysia, the urban development leads to deforestation and disappearing of urban trees. The estimated global deforestation rate is about 7.3 milion hectares annually. If the current rate of deforestation continues, up to 28,000 species are expected to become vanish by next quarter, and it will take less than 100 years to destroy all the forests on the earth.

Rapid urbanization, which poses a threat to forests and the safety of an ecosystem (Hepinstall-Cymerman et al., 2013), has compelled scholars to focus on urban green spaces. With progressing urbanization, managing urban forests has become a significant concern. Insufficient knowledge on urban forests, such as tree location, size, and species, will be destroyed the urban forestry.

Since urban spaces are complex areas; accessibility to all trees by field survey is extremely difficult and time-consuming. Although remote sensing technique is the best method to overcome the time and coverage limitations, some data such as hyperspectral data has the important limitations such as cost, time and coverage. Hence the purpose of this research is to develop a new generic rule set to detect urban tree species based on the remote sensing economical data using statistical approach.

1.3 Scope of the Study

This study focuses on detection of three tropical urban tree species. For this purpose the characteristics of the trees are limited to the colour, texture, spatial and spectral information, so the ages of the trees will not be considered in the analysis. Moreover the minimum size of the trees will be 1.5 m^2.

The study will not cover the counting of trees and will only focus on the detection of tree species. Lastly the study area is limited to the urban area, and the locations are situated in Malaysia.

1.4 Research Objectives

The general objective of this thesis is to develop a new generic rule set to detect urban tree species from Very High Resolution Satellite (VHR) imagery such as WorldView-2. The specific objectives of this study include:

- To evaluate the performance of pixel-based and object-based image analysis (OBIA) methods for detection and discrimination of urban tree species.
- To develop a new generic rule set to discriminate urban tree species based on an OBIA by utilizing spectral, spatial, color and texture information.
- To validate the transferability of the new generic rule sets in other study areas.

1.5 Structure of thesis

The thesis is made up of five chapters, each corresponding to the objectives and contributing towards an advance understanding of the remotely sensed precursors. This first chapter introduces the thematic context of the study, the research problem, the motivation to pursue the research, and the research objectives.

The second chapter reviews literature related to the proposed topic. Aside the literature of the importance of urban forest, the previous efforts on approaches and techniques for urban tree species detection and discrimination by remote sensing are explained (including different imagery and classification techniques).

The third chapter explains an improved framework for urban tree species detection. In first part of this chapter the image pre-processing on WV-2 imagery is considered; secondly the pixel-based classification (Maximum Likelihood and Support Vector Machine) and object-based (OB) classification are explained. Finally the procedure to develop a new generic model to discriminate urban tree species is discussed.

In the fourth chapter of this thesis, the analysis results, which are done on the remotely sensed imagery, are collected. The first part is the spectral-based classification results, and the main part of this chapter is the result of the new generic model which is based on OB classification.

Finally, chapter five focuses on the summary, conclusions, contribution of this study and recommendations for future research.

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