HIERARCHICAL IMAGE CLASSIFICATION THRESHOLD ON MANGROVE

OTHMAN BIN MOHD

DOCTOR OF PHILOSOPHY

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Faculty of Information and Communication Technology

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Othman Bin Mohd

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OTHMAN BIN MOHD

A thesis submitted
in fulfillment of the requirements for the degree of Doctor of Philosophy

Faculty of Information and Communication Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

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DECLARATION

I declare that this thesis entitle “Hierarchical Image Classification Threshold On Mangrove” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……

Name : ……

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature :…….…….…….

Supervisor Name :…..……..

Date :...……..……..

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DEDICATION

First and foremost, I would like to thank ALLAH Almighty, for giving me excellence health, ideas and comfort environment so that I can complete this thesis as scheduled.

My greatest thank is to my wife (Raja Haidah Raja Ali), my daughter and sons (Puteri Nur Hazirah, Megat Muhammad Haziq, Megat Muhammad Haikal, Megat Muhammad Hanif and Megat Muhammad Hakim) and my siblings (Mahadir, Rohaya, Dr. Abu Bakar, Mehat, Kamisah, Faridah, Salmah, Omar and Elmi) for their continuous understanding, motivation, encouragement and patience throughout my PhD journey.

I also dedicate this PhD thesis to my many friends who have supported me throughout the process. I will always appreciate all they have done for helping me to complete my thesis and develop my computing skills in image processing.

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ABSTRACT

Mangrove area is an important coastal ecosystem in a tropical region. Managing mangrove is challenging and complex. In order to balance between protection the ecosystem and providing the natural resources that benefits to human being. In addition traditional classification and identification of mangrove tree species require an expert inspector working manually. A demand for accurate and automatic of mangrove species estimation has arose especially for ecological, environmental and economical values. Economically, the knowledge of tree species information is important. In order to meet the mangrove forest planning requirements, the satellite remote sensing with high spatial resolution has been specifically designed for tree species classification to improve accuracy and able to locate preferred tree species. However the main issue in remote sensing is image classification that required to determine an appropriate threshold between species in producing accurate classification map. An image classification on satellite imagery is a complex process and requires consideration of accurate classification system. A pixel in the satellite image may possibly cover more than one object on the ground. A threshold has to be set to classify an overlap of two or more associated spectral properties. Therefore the aim of this study is to determine the optimal threshold value for object classes to ensure the misclassification of image pixels kept as low as possible by analyzing the classification of satellite images at different hierarchical level. Then the optimal threshold will be proposed on satellite image classification for mangrove species with the help of expert inspector from the ground. An evaluation on the accuracy of the proposed threshold value in identifying mangrove shall be made. A hierarchical threshold is expected to significant improvement result on an image classification final map for mangrove species.

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ABSTRAK

Kawasan bakau adalah ekosistem penting bagi pantai di rantau tropika. Penguruan bakau adalah mencabar dan kompleks. Ini adalah kerana ianya melibatkan usaha untuk mengimbangi antara perlindungan ekosistem dan menyediakan sumber-sumber semula jadi yang memberi manfaat kepada manusia. Pengkelasan bakau masih lagi dilaksanakan secara tradisional pada masa ini, dimana proses mengenalpasti spesies pokok bakau masih memerlukan pemeriksa pakar yang melaksanakan kerja mereka secara manual. Permintaan maklumat spesis pokok bakau terutamanya bagi nilai-nilai ekologi, alam sekitar dan ekonomi pada masa ini perlulah dibuat secara automatik dan tepat. Pengetahuan maklumat spesies pokok bakau adalah penting dari segi ekonomi. Untuk itu, bagi memenuhi keperluan perancangan hutan bakau, satelit penderiaan jauh dengan resolusi spatial tinggi telah direka khusus untuk pengelasan spesies pokok untuk meningkatkan ketepatan dan berupaya untuk mengesan spesies pokok pilihan. Walau bagaimanapun, isu utama dalam penderiaan jauh ini adalah untuk mengklasifikasikan imej yang diperlukan untuk menentukan nilai ambang yang sesuai antara spesies dalam menghasilkan peta klasifikasi yang tepat. Pengelasan imej satelit adalah satu proses yang kompleks dan memerlukan pertimbangan sistem klasifikasi tepat. Satu piksel dalam imej satelit boleh mengandungi lebih daripada satu objek di atas tanah. Ambang satu piksel perlu ditetapkan bagi mengklasifikasikan pertindihan dua atau lebih ciri-ciri spektrum berkaitan. Oleh itu, tujuan kajian ini adalah untuk menentukan nilai ambang yang optimum untuk kelas objek bagi memastikan kesalahan dalam mengkelasifikasikan piksel imej disimpan serendah mungkin. Ini dapat dilaksanakan dengan menganalisis klasifikasi imej satelit di peringkat hierarki yang berbeza. Hasil dari analisa yang dibuat, titik ambang yang optimum akan dicadangkan pada pengelasan imej satelit yang melibatkan spesies bakau dengan bantuan pakar pemeriksa di tanah. Ini dilaksanakan bagi memastikan nilai titik ambang yang tepat bagi setiap spesies bakau yang hendak dikenalpasti. Satu nilai titik ambang akan dihasilkan daripada pendekaan hierarki dijangka dapat dihasillan dan berupaya untuk meningkatan ketepatan dan penghasilan peta akhir spesis bakau pada akhir penyelidikan ini dijalankan.

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LIST OF ABBREVIATIONS

DN	-	Digital Number
R	-	Red Band
G	-	Green Band
B	-	Blue Band
FIS	-	Fuzzy Inferences System
Ha	-	hectare
m	-	Meter
FDPSM	-	Forestry Department Peninsular Malaysia

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LIST OF PUBLICATIONS

Mohd, O., Suryanna, N., Sahib, S., Abdollah, M. F., & Selamat, S. R. (2012). Thresholding and Fuzzy Rule-Based Classification Approaches in Handling Mangrove Forest Mixed Pixel Problems Associated with in QuickBird Remote Sensing Image Analysis. *International Journal of Agriculture and Forestry, Scientific & Academic Publishing, 2*(6), 300-306

Suryana, N., Rasip, N. M., & Mohd, O. (2007). *Data Mining and Neural Network Approaches in Handling Mixed Problems Associated Within Hyperspectral Remote Sensing Image Analysis*.

Suryanna, N., & Mohd, O. (2007). *The Quantifiction and The Representation Quality Parameters for Inductive Environmental Model in Geographical Information System* Paper presented at the 2nd Regional Conference on Ecological Modelling (ECOMOD).

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