



**UNIVERSITI PUTRA MALAYSIA**

**IMPROVED WAVELET DENOISING OF HYPERSPECTRAL REFLECTANCE  
USING LEVEL-INDEPENDENT WAVELET THRESHOLDING**

**MOHD. ROZNI BIN MD. YUSOF**

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**By**

**MOHD. ROZNI BIN MD. YUSOF**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfilment of the Requirement for the Degree of Doctor of Philosophy**

**December 2011**

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**Chair: Associate Professor Helmi Zulhaidi bin Md Shafri, PhD**

**Faculty: Engineering.**

A method for preconditioning vegetation reflectance spectra prior to applying wavelet denoising methods is presented. Various methods for denoising signals exhibiting Poisson noise characteristics using wavelet thresholding have been proposed; however, these methods focus on the actual count of photons or electrons or some number directly proportional to them. These methods may be less useful for denoising vegetation reflectance spectra, since reflectance is defined as a ratio of the reflected radiance and the incident irradiance, taking the value between 0 and 1. It is proposed here to precondition the reflectance signal by multiplying it by a constant that reflects the number of photons detected, prior to applying the Anscombe Transform and wavelet thresholding, in order to make wavelet denoising methods more suitable for reflectance spectra. This constant is to be calculated from the noise variance of the square root of the signal and is a nominal

value of the signal radiance. The signal, having been denoised, is subjected to the inverse Anscombe Transform and divided by this constant to obtain the clean reflectance spectrum. The method has been tested on a simulated vegetation reflectance spectrum created using the PROSPECT leaf model and a Poisson noise model, and later on real world signals of different spectral sampling intervals, and is found to satisfactorily denoise vegetation reflectance spectra. Furthermore, the performance in terms of RMSE in the simulation reaches a plateau as excessive levels of wavelet decomposition are used. The visual evaluation of both the synthetic spectra and real world signals used also indicate that this method does not degrade the signal if excessive levels of wavelet decomposition are used for denoising. As level of decomposition is a very important parameter in wavelet denoising, which can result in oversmoothing if not determined correctly, and it is hard to know the correct optimum value *a priori*, this method simplifies the wavelet denoising process by making the precise number of level of decompositions to use non-critical.

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

**PEMBAIKAN NYAH-HINGARAN TERHADAP PEMBALIKAN  
HYPER SPEKTRAL MENGGUNAKAN PENGAMBANGAN WAVELET BEBAS  
TAHAP**

Oleh

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Suatu kaedah bagi mempra-proses isyarat spektra pembalikan tumbuh-tumbuhan sebelum penggunaan kaedah penyah-hingar wavelet dibentangkan di sini. Beberapa kaedah bagi menyah-hingar isyarat yang mempunyai ciri-ciri hingar Poisson menggunakan kaedah pengambangan wavelet pernah dicadangkan; walaubagaimanapun, kaedah-kaedah tersebut adalah bertumpu kepada isyarat bilangan foton yang sebenar, ataupun isyarat yang berkadar terus dengannya. Kaedah-kaedah ini kurang sesuai bagi menyah-hingar isyarat pembalikan tumbuh-tumbuhan, kerana pembalikan ditakrifkan sebagai nisbah di antara radians pantulan dan irradians pancaran, yang mengambil nilai antara 0 dan 1. Adalah dicadangkan di sini bagi mempra-proses isyarat tersebut dengan mendarabnya dengan suatu nilai konstan yang mencerminkan bilangan foton yang dicerap, sebelum penggunaan Transform Anscombe dan seterusnya pembendulan/pengambangan wavelet. Konstan ini dianggap daripada varians hingar punca kuasa dua isyarat pembalikan

tersebut, dan merupakan nilai anggaran radian isyarat. Setelah penyah-hingaran isyarat tersebut, ia melalui songsangan Transform Anscombe dan dibahagikan dengan konstan di atas untuk mendapatkan spektrum pembalikan tulen. Kaedah ini telah diuji ke atas isyarat pembalikan tiruan yang dijanakan dengan model daun PROSPECT dan model hingar Poisson, dan seterusnya ke atas isyarat alam sebenar yang mempunyai kadar cerapan spektral yang berbeza. Adalah didapati bahawa kaedah ini mampu menyah-hingar isyarat spektrum pembalikan tumbuh-tumbuhan. Tambahan lagi, berbeza dengan kaedah wavelet yang biasa, prestasinya dari segi RMSE mencapai kedataran walaupun peringkat penguraian wavelet yang berlebihan digunakan. Hasil penilaian visual isyarat sintetik dan isyarat dunia nyata juga menunjukkan bahawa kaedah ini tidak mejeaskan isyarat sekalipun peringkat penguraian wavelet yang berlebihan digunakan dalam penyah-hingaran. Oleh kerana bilangan peringkat penguraian adalah suatu parameter penting dalam penyah-hingaran wavelet, di mana penggunaan bilangan yang salah boleh mengakibatkan keterlebihicinan dalam isyarat, dan juga bilangan yang paling sesuai sukar diketahui *a priori*, kaedah ini memudahkan penyah-hingaran wavelet bagi isyarat pembalikan dengan menjadikan pengetahuan nilai tepat parameter ini tidak kritikal.

# APPROVAL SHEET 1

I certify that an Examination Committee has met on ..... to conduct the final examination of Mohd. Rozni bin Md. Yusof on his PhD thesis entitled "Improved Wavelet Denoising of Hyperspectral Reflectance using Level Independent Thresholding" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy.

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## APPROVAL SHEET 2

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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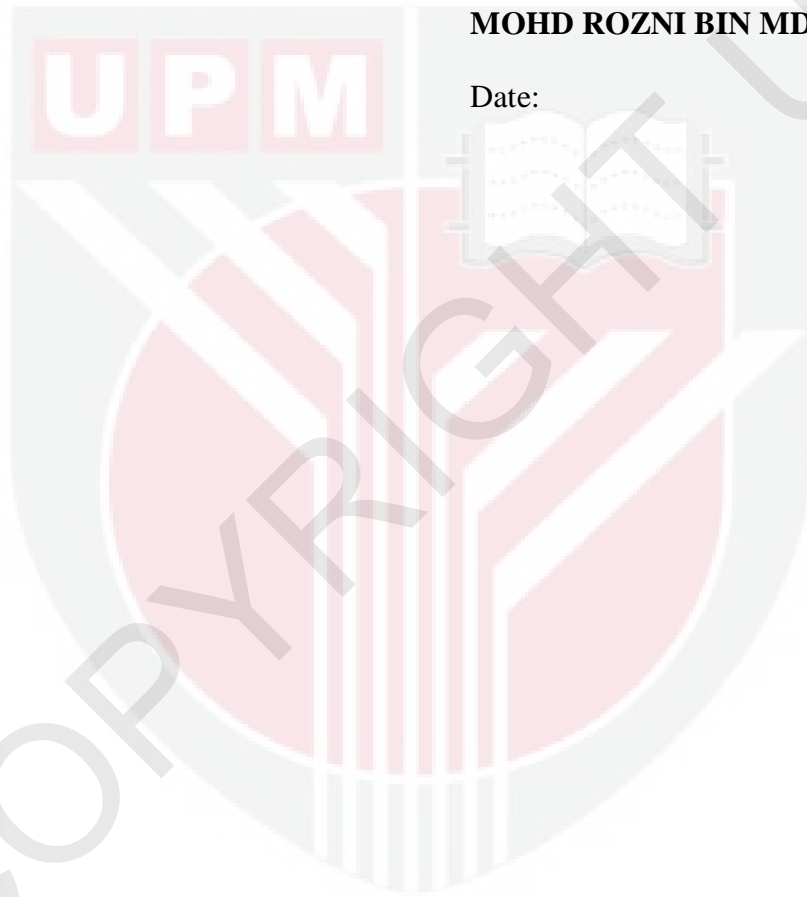
## DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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**MOHD ROZNI BIN MD YUSOF**

Date:



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