UNIVERSITI PUTRA MALAYSIA

IMPROVED METHOD FOR NOISE REMOVAL FROM HYPERSPECTRAL VEGETATION SPECTRUM USING SECOND GENERATION WAVELETS

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By

LADAN EBADI

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

July 2014

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DEDICATION

I dedicate this dissertation to my parents

my dear father

Mr. Ali Akbar Ebadi

and my beloved mother

Mrs. Mahin Fayyaz

for their generous love and support

Abstract of thesis presented to the Senate of Universiti Putra Malaysia
in fulfilment of the requirement for the Degree of Doctor of Philosophy

IMPROVED METHOD FOR NOISE REMOVAL FROM HYPERSPECTRAL VEGETATION SPECTRUM USING SECOND GENERATION WAVELETS

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July 2014

Chairman : Assoc. Prof. Helmi Zulhaidi bin Mohd Shafri, PhD

Faculty : Engineering

Many of vegetation studies make use of the vegetation reflectance spectra acquired by hyperspectral remote sensing technique. However, the hyperspectral vegetation spectra are highly noisy and the presence of noise affects the results of the spectral discrimination between vegetation species. Moreover, in hyperspectral studies it is common to perform analysis based on derivatives of the spectrum. This method is very sensitive to noise; therefore, noise removal is essential before performing derivative analysis. Also, to relate the cover reflectance to image reflectance in hyperspectral remote sensing imagery, noise-free field spectra are essential. Compared to traditional smoothing methods, wavelet transform shows promising results in denoising area. This thesis applied different types of wavelet transforms including discrete wavelet transform (DWT), lifting wavelet transform (LWT) which is the basis of the second generation wavelets, stationary wavelet transform (SWT), and the proposed method that is based on a combination of LWT and SWT methods that is called stationary lifting wavelet transform (SLWT). The objective of this research is to propose an accurate and stable method based on SLWT for noise removal from hyperspectral vegetation spectrum. The proposed method takes into account the characteristics of the vegetation reflectance spectrum and its results are compared with other three wavelet methods that are DWT, LWT, and SWT. These wavelet techniques were examined on a synthetic vegetation spectrum which is created by PROSPECT leaf model (a model of leaf optical properties spectra) and on several real-world vegetation spectra. To assess the effects of denoising several indicators including root mean square error (RMSE), signal-to-noise ratio (SNR), correlation coefficient and visual evaluation methods were employed. The experimental results showed that compared to other wavelet methods, the proposed method produced highly accurate statistical results. The best denoising results were acquired by applying Haar mother wavelet by making 13% improvement for SNR and by giving an RMSE as low as 0.0002 and correlation coefficient value of almost

one. The visual evaluation showed that the proposed method preserves the absorption features and inflection points, as well as the wavelength positioning of local minima and maxima. Furthermore, the following novel results are concluded from this thesis: the proposed method is level-independent and narrow downs the choice of mother wavelet to a few low-order mother wavelets; as a result, it highly lowers the complexity of the denoising process. Unlike other wavelet-based methods, the proposed method gives reliable and predictable statistical results therefore is a stable method for noise removal from hyperspectral vegetation spectrum.

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

KAEDAH PENINGKATAN UNTUK MENYINGKIRKAN KESAN HINGAR DARI SPEKTRUM TUMBUH-TUMBUHAN HIPERSPEKTRA DENGAN MENGGUNAKAN WAVELET GENERASI KEDUA

Oleh

LADAN EBADI

Julai 2014

Pengerusi : Assoc. Prof. Helmi Zulhaidi bin Mohd Shafri, PhD

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Terdapat banyak kajian tumbuh-tumbuhan yang menggunakan pantulan spektrum tumbuhan yang diperolehi dari teknik penderiaan jauh Hiperspektra. Walau bagaimanapun, terdapat kesan hingar yang banyak di dalam spektrum tumbuh-tumbuhan yang diperoleh dari Hiperspektra dan kehadiran hingar ini memberi kesan kepada keputusan diskriminasi spektrum antara spesies tumbuh-tumbuhan. Selain itu, dalam kajian Hiperspektra ia adalah perkara biasa untuk melaksanakan analisis spectrum berdasarkan spektrum derivatif. Kaedah ini adalah sangat sensitif kepada kesan hingar dalam spektrum; oleh sebab itu, penyingkiran kesan hingar ini adalah penting sebelum melaksanakan analisis derivatif. Tambahan pula, untuk mengaitkan antara pantulan dari permukaan dengan pantulan imej dari imej penderiaan jauh Hiperspektra, spektrum yang bebas kesan hingar adalah penting. Berbanding dengan kaedah pelicinan tradisional, ubahan wavelet menunjukkan keputusan yang meyakinkan di kawasan kesan hingar dibuang. Tesis ini menggunakan jenis ubahan wavelet yang berbeza merangkumi ubahan wavelet diskret (DWT), ubahan wavelet mengangkat (LWT) yang merupakan asas kepada wavelet generasi kedua, ubahan wavelet pegun (SWT), dan juga cadangan teknik yang berasaskan dari gabungan kaedah LWT dan SWT yang dikenali sebagai ubahan mengangkat pegun wavelet (SLWT). Objektif kajian ini adalah untuk mencadangkan teknik yang tepat dan stabil berdasarkan SLWT untuk menyingkirkan hingar dari spektrum tumbuhan hiperspektra. Teknik yang dicadangkan mengambil kira karakter pantulan dari tumbuhan dan keputusannya dibandingkan dengan tiga teknik wavelet yang lain iaitu DWT, LWT dan SWT. Teknik-teknik wavelet ini telah dikaji pada spektrum tumbuhan tiruan yang dicipta oleh model daun PROSPECT (model daun dari bahan optikal spektrum) dan beberapa spectrum dari tumbuhan yang sebenar. Untuk menilai kesan pengurangan hingar, beberapa petunjuk termasuk ralat purata punca kuasa dua (RMSE), nisbah isyarat-hingar (SNR), pekali korelasi dan kaedah penilaian visual telah digunakan. Keputusan eksperimen menunjukkan bahawa

berbanding dengan kaedah wavelet lain, keputusan dari penggunaan teknik yang dicadangkan menghasilkan keputusan statistik yang amat tepat. Keputusan pengurangan hingar terbaik telah diperolehi dengan menggunakan wavelet ibu Haar dengan peningkatan sebanyak 13% untuk SNR dan memberikan RMSE serendah 0.0002 dan nilai korelasi pekali hampir kepada satu. Penilaian visual menunjukkan bahawa dengan mengunakan kaedah yang dicadangkan, ciri-ciri seperti penyerapan dan titik lengkok balas, dan juga kedudukan panjang gelombang daripada minima tempatan dan maksima dapat dikekalkan. Tambahan pula, keputusan baru yang dapat disimpulkan daripada tesis ini: Kaedah yang dicadangkan adalah tahap-bebas dan memfokuskan pilihan wavelet ibu kepada beberapa pilihan wavelet ibu yang lebih rendah; hasilnya, ia telah mengurangkan kerumitan proses penyingkiran kesan hingar. Tidak seperti kaedah berasaskan wavelet yang lain, dengan mengunakan kaedah yang dicadangkan, ia memberikan keputusan statistik yang boleh dipercayai dan boleh diramal. Oleh itu, ianya boleh diguna pakai sebagai kaedah yang stabil untuk penyingkiran hingar ke atas spektrum tumbuhan dari Hiperspektra.

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Finally, I wish to thank all of the friends and acquaintances, that their friendships, love, care and kindness have touched my life over the past few years.

I certify that a Thesis Examination Committee has met on 7 July 2014 to conduct the final examination of Ladan Ebadi on her thesis entitled "Improved Method for Noise Removal from Hyperspectral Vegetation Spectrum using Second Generation Wavelets" 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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This thesis submitted to the Senate of Universiti Putra Malaysia 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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