UNIVERSITI PUTRA MALAYSIA

NEAR-INFRARED TECHNIQUE FOR OIL PALM FRUIT GRADING SYSTEM

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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

November 2013

DEDICATION

To My Mother

To My Father, My Brothers, My Sisters, My Wife Zinib, My Children Mohamed, Ala, AndAnass For Their Moral Support And Encouragement.

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

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Chairman : Associate Professor Abdul Rashid Bin Mohamed Shariff, PhD
Faculty : Engineering

The Malaysian palm oil industry is considered to be highly regulated.A major problem faced by oil palm producers is the accurate grading of fresh oil palm fruits according to their ripeness levels before processing.Classification of oil palm fresh fruit bunch (FFB) maturity is a critical factor that dictates the quality of produced palm oil.The human eye, for example, has historically judged quality via appearances.External features and properties such as color, texture, shape, and size are good indicators for parameters like ripeness.Hence, grading system technologies offer a solution to these problems. The grading systems in general utilized improved engineering designs with image processing techniques to ensure the quality of the product.In this research, a hyperspectral oil palm grading system was built and an image processing techniques algorithm was developed based on the spectral reflectance of the external features of oil palm fresh fruit bunches (FFB). Color changes resulting from biochemical reactions in fruit texture can be related to fruit maturity . In addition, the oil palm fruit pigments such as carotenoids and chlorophylls and their ratios affect the color of the oil palm fruit. Underripe fruits have a higher proportion of chlorophyll that gradually decreases upon maturity. Similarly, carotenoids increases as the oil palm fruits mature. These color and biochemical changes can be observed utilizing the spectral reflectance of the fruit. Using the FFB spectral reflectance this research was used to modify and adapt the hyperspectral scanner to enhance its suitability for the maturity detection of oil palm FFBs at the near-infrared (NIR) range (400 nm to 1000 nm).This objective was achieved by improving the illumination system of the hyperspectral scanner. The strategic positioning of the halogen and applied security design (ASD) lamps helps provide a shadow for free illumination. Image processing approaches, such as image acquisition, image pre-processing, and image feature extraction, as well as image classification were developed to automate the ripeness grading for oil palm fruit bunches. The mathematical model was developed to determine the real value of the

reflection of specific wavelengths for the three categories of oil palm FFBs through regression analysis. The results are then confirmed by a trained human grader. The application software was developed in a MATLAB 7.0 environment, and was used to classify the oil palm FFBs. The data collected by this system are subjected to the artificial neural networks (ANN), kernel nearest neighbor (KNN), support vector machine (SVM) techniques, and a number of statistical analyses such as the CHAID method and one-way ANOVA for oil palm FFB classification. The developed system showed high classification results on accuracy of the maturity detection for the three types of oil palm fruits (nigrescens, virescens, and oleifera) with rates of 95%, 99%, and 98 %, respectively, using the ANN-MLP classifier; rates of 96%, 99%, and 98 %, respectively, using the KNN classifier; and rates of 76%, 96%, and 94%, respectively, using SVM. Based on the results of testing hyperspectral with the scientific results of bands of overripe, underripe, and ripe we fabricated the multiband sensor. This multibandactive sensor has the ability to detect the maturity of oil palm fruit at 735, 750, 780, and 940 nm). The multiband sensor was field tested and can categorize the oil palm FFB into three classes: overripe, ripe, and underripe. The system helps increase the accuracy of the oil palm FFB grading system, which will be useful for the oil palm industry, oil palm engineers, mill operators, plantation managers, small holders, and the research community.

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

PENDEKATAN TEKNIK INFRA MERAH UNTUK SISTEM PENGGREDAN BUAH KELAPA SAWIT

Oleh

OSAMA MOHAMED BEN SAEED

November 2013

Pengerusi : Professor Madya Abdul Rashid bin Mohamed Shariff, PhD
Fakulti : Kejuruteraan

Industri minyak sawit Malaysia dikawal selia dengan rapi. Satu masalah utama yang dihadapi oleh pengeluar kelapa sawit adalah penggredan tepat buah kelapa sawit segar mengikut tahap kematangan buah tersebut sebelum pemprosesan. Klasifikasi kematangan buah tandan segar kelapa sawit (BTS) adalah kritikal dalam menentukan kualiti minyak sawit yang dihasilkan. Secara konvensional penggredan dibuat mengunakan penglihatan mata manusia. Ciri luaran seperti warna, tekstur, bentuk dan saiz adalah petunjuk yang baik untuk parameter seperti kematangan. Oleh itu, teknologi sistem penggredan menawarkan penyelesaian kepada masalah-masalah ini. Sistem penggredan secara umum menggunakan reka bentuk kejuruteraan yang lebih baik dengan teknik pemprosesan imej untuk penentuan kualiti produk. Dalam kajian ini, sistem penggredan kelapa sawit Hiperspektra dibina dan algoritma teknik pemprosesan imej telah dibangunkan berdasarkan pantulan spektrum ciri-ciri luaran tandan buah segar kelapa sawit. Perubahan warna yang terhasil daripada tindak balas biokimia dalam tekstur buah-buahan dikaitkan dengan kematangan buah-buahan. Di samping itu, pigmen buah kelapa sawit seperti karotenoid dan klorofil dan nisbah mereka memberi kesan kepada warna buah kelapa sawit. Buah kurang masak mempunyai kadar klorofil yang lebih tinggi, yang berkurangan beransur-ansur apabila matang. Begitu juga, karotenoid bertambah apabila buah kelapa sawit matang. Perubahan warna dan biokimia ini boleh diperhatikan menggunakan pantulan spektrum buah. Menggunakan pantulan spektrum dari BTS, kajian ini digunakan untuk mengubahsuai pengimbas Hiperspektra untuk meningkatkan kesesuaiannya untuk mengesan kematangan BTS kelapa sawit dengan menggunakan gelombang berhampiran inframerah (400 nm - 1000 nm). Pengubahsuian telah dibuat dengan memperbaiki sistem pencahayaan pengimbas Hiperspektra. Penempatan strategik lampu halogen dan reka bentuk keselamatan telah dibuat. Kedudukan lampu membantu mengelakkan bayang-bayang. Pendekatan pemprosesan imej seperti perolehan imej, imej pra-pemprosesan, dan pengekstrakan ciri imej, serta klasifikasi imej telah dibangunkan untuk mengautomasikan penggredan kematangan bagi tandan buah kelapa sawit. Model matematik telah dibangunkan untuk menentukan nilai sebenar yang mencerminkan gelombang tertentu bagi tiga kategori BTS kelapa

sawit melalui analisis regresi. Keputusan kemudiannya disahkan oleh pegawai penggred yang terlatih. Perisian aplikasi telah dibangunkan menggunakan persekitaran MATLAB versi 7.0, dan telah digunakan untuk menghuraikan ciri-ciri BTS kelapa sawit. Data yang dikumpul oleh sistem ini telah diolah di dalam rangkaian neural tiruan (ANN), kernel jiran terdekat (KNN), mesin vektor sokongan teknik (SVM), dan beberapa analisis statistik seperti kaedah CHAID dan ANOVA sehala untuk klasifikasi BTS kelapa sawit. Sistem yang telah diuji ini menunjukkan hasil pengelasan tinggi pada ketepatan pengesanan matang bagi tiga jenis buah kelapa sawit (nigrescens, virescens, dan oleifera) dengan kejituan 95%, 99%, dan 98 % masing-masing , dengan menggunakan pengelasan ANN - MLP; kadar 96%, 99%, dan 98 % masing-masing , dengan menggunakan pengelas KNN; dan kadar sebanyak 76% , 96 %, dan 94%, masing-masing, dengan menggunakan pengelasan SVM. Berdasarkan keputusan ujian Hiperspektra yang saintifik, kumpulan-kumpulan BTS terlalu masak, kurang masak, dan masak telah dapat dikenalpasti. Sebuah penderia aktif pelbagai jalur direkacipta menggunakan prinsip kajian ini. Penderia ini mempunyai keupayaan untuk mengesan kematangan buah kelapa sawit di tahap gelombang (735, 750, 780, dan 940 nm). Sensor pelbagai jalur ini telah diuji dilapangan dan boleh mengkategorikan BTS kelapa sawit kepada tiga kelas: terlalu masak, masak, dan kurang masak. Sistem ini dapat membantu meningkatkan ketepatan sistem penggredan BTS kelapa sawit, yang akan berguna untuk industri kelapa sawit, jurutera pertanian, operator kilang , pengurus ladang, pekebun kecil, dan komuniti penyelidikan.

AKNOWLEDGEMENTS

All praise and thanks are due to the Name of Allah, Most Gracious and Most Merciful. May peace and blessings be upon His Messenger. I would also like to express the most sincere appreciation to those who made this work possible: advisory members, friends, and family.

I would like to thank Assoc. Prof. Dr. Abdul Rashid Mohamed Shariff for providing me the opportunity to complete my PhD studies under his valuable guidance, for the useful advice and discussions, for his constant encouragement and guidance, and for co-authoring and reviewing a number of my publications, where his practical experience and technical knowledge made this research and those publications more interesting and relevant. In addition, I would also wish to extend special thanks to the supervisory committee members: Assoc. Prof. Dr. A. R. Mahmud, Assoc. Prof Dr. H. Z. Mohd. I owe my deepest gratitude to Dr. M. D. B. Amiruddin from Malaysian Palm Oil Board (MPOB) for his very helpful advice and guidance. I am grateful for their willingness to serve on my supervisory committee as well as for their constant encouragement, helpful advice, and many fruitful discussions.

Engineering Academy Tajoura, Libya is gratefully acknowledged for providing financial support. The support of the academy, and its management under the leadership of its Abdul Rashid Mohamed Shariff helped me meet my financial obligations while staying in Malaysia.

Thanks and acknowledgements are meaningless if not extended to my parents who deserve my deepest appreciation. I am grateful for the countless sacrifices they made to ensure that I could pursue my dreams and for always being there for me. Real and deepest thanks to them. May Allah bless and protect them and may they live a long and healthy life. All praises and words of thanks will not be enough.

Last but not least, very special thanks to my wife, daughter, sons, my family in Libya for their support, love, and encouragement, which comprise the foundation of my success.

I certify that a Thesis Examination Committee has met on 28 November 2013 to conduct the final examination of Meftah Salem M. Alfatni on his PhD thesis entitled "Near-Infarared Technique for Oil Palm Fruit Grading System " in accordance with the Unversities and University Colleges Act 1971 andthe 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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Date: 19 May 2014

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as partial 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 by graduate student

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This is to confirm that:

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