UNIVERSITI PUTRA MALAYSIA

EVALUATIONS OF OIL PALM FRESH FRUIT BUNCHES MATURITY DEGREE USING MULTIBAND SPECTROMETER

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FK 2017 66

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By

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Thesis Submitted to the School of Graduate Studies. Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

May 2017

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Abstract of thesis presented to the Senate of University of Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

EVALUATIONS OF OIL PALM FRESH FRUIT BUNCHES MATURITY DEGREE USING MULTIBAND SPECTROMETER

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May 2017

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Faculty : Engineering

The demand for high accuracy in grading system of the ripeness and maturity level of the Oil Palm Fresh Fruits Bunch (FFB) is one of the important impending factor facing the oil milling industry globally. This limitation directly affects the Oil Palm Extraction Rate (OER), the quantity, and quality of products produced annually, thereby reducing the profitability margin of the milling industry. However, numerous studies targeted at investigating several improved techniques of grading, and classification of the current oil palm maturity classification in order to enhance the oil palm yield in terms of quality, and quantity annually have been carried out. In view of the needed improvement in OER, there is need to test a novel data mining, and knowledge discovery approach within collected spectrometer data from the oil palm FFB, using WEKA software for classification, and prediction of the oil palm FFB ripeness, to enhance the current manual human grader system. In this research, several machine learning algorithms housed in WEKA data mining tool were proposed for the building of a classifier models, as compared with other earlier manual, and statistical analytical method which require high computational knowledge in coding, time consumption, and prion to human or computational error. This novel approach is tested on the 106-labelled sampled of oil palm FFB of four ripeness categories of unripe, under ripe, ripe, and over ripe by human grader, with reference to the stipulated standard of the Oil Palm Grading Manual (OPGM) of Malaysia. The reflectance data of different wavelength bands incidence from 8 LED modules upon the oil palm FFB, were extracted by 4 different sensors of a spectrometer in laboratory experiment, for onward detailed analysis with machine learning algorithms in WEKA data mining tool. The result illustrated that just one sensor features (sensor 4) are significantly enough to build a good, accurate classifier model that can predict, and classify the oil palm FFB ripeness, rather than the proposed 4 bands sensors with 32 feature attributes. Hence, reducing cost for other sensors, improving the analysis time for the classifier model building, and enhancing the productivity of the system at large. Furthermore, the Lazy-IBK algorithm have been validated to produce the best classifier model, with the machine learning algorithm performance of 65.26%, recall of 65.3%, and 65.4% F-measured as compared to other evaluated machine learning

classifier algorithms proposed within the WEKA data mining algorithm. The ROC curve area indicated an average weighted value of 77.4% for the area under the curve as indicated, which is a measure applied for the accuracy of the applied algorithm. In conclusion, the simple machine learning algorithm model evaluation is developed to classify the oil palm maturity degrees, in order to validate the human grader assessments to enhance the productivity of the oil milling industries.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MENILAI KEMATANGAN BUAH SAWIT SEGAR DENGAN MENGGUNAKAN PELBAGAI JALUR PENGESAN SPEKTROMETER

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Tuntutan tinggi di atas ketepatan sistem pengredan aras keranuman dan kematangan Buah Sawit Segar (FFB) adalah salah satu faktor pasti yang dihadapi oleh Industri Pengilangan Minyak di seluruh dunia. Kekangan ini menjejaskan secara langsung Kadar Pengestrakan Sawit (OER), kuantiti dan kualiti produk yang dihasilkan setiap tahun, dan seterusnya mengurangkan garis keuntungan industri pengilangan. Namun demikian, banyak kajian yang menyasarkan pengkajian ke atas beberapa teknik pengredan dan klasifikasi kematangan sawit yang diperbaiki untuk meningkatkan lagi hasil sawit dari sudut kualiti dan kuantitinya saban tahun. Tambahan lagi, oleh kerana kurangnya panduan jelas tentang algoritma atau teknik mana yang paling sesuai dengan klasifikasi keranuman sawit segar untuk menggantikan pengred manusia manual semasa. Dalam kajian ini, beberapa algoritma pembelajaran mesin dalam alat perlombongan data dicadangkan dalam membina model pengklasifikasi, yang diuji ke atas 106 sampel berlabel FFB sawit mengikut empat kategori keranuman- tidak ranum, kurang ranum, ranum dan terlebih ranum oleh pengred manusia, dengan merujuk kepada piawaian terancang Manual Pengredan Sawit (OPGM) Malaysia. Data pantulan insiden band jarak gelombang yag berbeza-beza dari modul-modul 8 LED ke atas FFB sawit, diestrak oleh 4 pengesan spektrometer berlainan dalam satu eksperimen makmal terbuka, untuk analisis terperinci dengan algoritma pembelajaran mesin dalam alat perlombongan data WEKA. Keputusan menunjukkan bahawa satu ciri pengesan (pengesan 4) memadai untuk membina satu model pengklasifikasi yang baik dan tepat serta boleh meramal, dan mengkelaskan keranuman FFB sawit, daripada 4 pengesan yang dicadangkan dengan 32 ciri. Oleh itu, dengan mengurangkan kos untuk pengesan lain, memperbaiki masa analisis untuk membangunkan model pengklasifikasi dan meningkatkan lagi produktiviti sistem secara keseluruhannya. Tambahan lagi, algoritma Lazy-IBK telah disahkan untuk menghasilkan model pengklasifikasi terbaik, dengan prestasi algoritma 65.26%, perolehan kembali 65.3%, dan 65.4% sukatan F berbanding dengan algoritma cadangan iaitu algoritma pengklasifikasi pembelajaran mesin yang dinilai. Kawasan lengkuk ROC menampilkan nilai berat purata 77.4% untuk kawasan di bawah lengkuk deperti yang ditunjukkan, iaitu satu pengukuran yang diaplikasi untuk ketepatan dan

generalisasi algoritma yang digunakan. Kesimpulannya, satu penilaian model algoritma pembelajaran mesin mudah dibangunkan untuk mengklasifikasi keranuman sawit dengan tepat, untuk mengesahkan penilaian penggred manusia untuk menambahbaiki OER, mengoptima prestasi dan meningkatkan produktiviti industri pengilangan minyak.

ACKNOWLEDGEMENTS

My sincere appreciation to my supervisor, Associate Professor Gs Sr. Dr. Abdul Rashid bin Mohammed Shariff, PhD, CEng, the chairman of my supervisory committee, for giving me this opportunity to embark on this project and guiding me throughout this excitingly challenging task. I would like to also thank other members of my supervisory committee: Associate Professor Rimfiel b. Janius, Associate Professor Zulkifly Abbas, Dr Ghafour Amouzad Mahdiraji for their supports and advices during the period of my study. I appreciate their knowledge, collaborations and recommendations in making this project a dream come true.

I am also grateful to the Geographical Information System Research Centre (GISRC), FELDA Agricultural Services Sdn. Bhd. and Department of Biological and Agricultural Engineering, Faculty of Engineering University of Putra Malaysia, for their contribution in facilitating smoothly for the completion of this project alongside with other co-researchers in the Centre. Last but not least, my deepest appreciations to my family, friends, especially my lovely parents who supported me in many terms. I could not have done this research work without their patients and supports.

I certify that a Thesis Examination Committee has met on 29 May 2017 to conduct the final examination of Adilijiang Tuerxun on his thesis entitled "Evaluation of Oil Palm Fresh Fruit Bunches Maturity Degree Using Multiband Spectrometer" 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 Master of Science.

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LIST OF ABBREVIATIONS

ANN	artificial neural network
ARFF	attribute related file format
CSV	comma separated value
FFB	fresh fruit bunches
GANN	genetic algorithm neural network
GDI	graphic device interface
HSI	hue saturation and intensity
LED	light emitting diode
MAE	mean absolute error
MPOB	Malaysian palm oil board
NIR	near infra-red
NOL	neutral oil
NIR	near-infra red
OER	oil extraction rate
OPRiD	oil palm ripeness detector
RGB	red, green and blue
RMSE	root mean squared error
RSM	response surface methodology
ROC	receiver operating characteristic
SVM	support vector machine
UPM	Universiti Putra Malaysia
MPOC	Malaysian Palm Oil Council
WEKA	Waikato Software
UVS1	ultra violet from sensor 1
BlueS1	blue from sensor 1
GreenS1	green from sensor 1
AmberS1	amber from sensor 1
RedS1	red from sensor 1
DRedS1	deep red from sensor 1
FRedS1	far red from sensor 1
IRedS1	infra-red from sensor 1

UVS2	ultra violet from sensor 2
BlueS2	blue from sensor 2
GreenS2	green from sensor 2
AmberS2	amber from sensor 2
RedS2	red from sensor 2
DRedS2	deep red from sensor 2
FRedS2	far red from sensor 2
IRedS2	infra-red from sensor 2
UVS3	ultra violet from sensor 3
BlueS3	blue from sensor 3
GreenS3	green from sensor 3
AmberS3	amber from sensor 3
RedS3	red from sensor 3
DRedS3	deep red from sensor 3
FRedS3	far red from sensor 3
IRedS3	infra-red from sensor 3
UVS4	ultra violet from sensor 4
BlueS4	blue from sensor 4
GreenS4	green from sensor 4
AmberS4	amber from sensor 4
RedS4	red from sensor 4
DRedS4	deep red from sensor 4
FRedS4	far red from sensor 4
IRedS4	infra-red from sensor 4

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Oil palm fruit is mostly grown in the tropical parts of South Eastern Asia, South Africa and South America as a major export product. This provides a major source of vital food for several millions of people and an essentially import diet for human healthy living (World Oil, 2016). Medically, the oil has good resistance to oxidation and enhances exposure to high temperatures, thereby enhancing it uses as a frying agent. The palm oil structure encourages its addition to other frying oils in large proportions, and also has good economic values as may be needed as an export product (Jamil, Mohamed, & Abdullah, 2009). Moreover, the oil palm industry in Malaysia is highly regulated, and one major problem faced by industry is in the accurate grading system of the fresh oil palm fruits based on its ripeness, which helps in the determination of the quality and quantity of the palm oil that could be extracted from the Fresh Fruit Bunches (FFB). The quest for increase in the Oil Extraction Rate (OER) in Malaysia have been an important research areas, which is necessitated as a result of limited land resources availability, since oil palm is one of the major agricultural export product that covers approximately over 5 million hectares of land within the country (Ismail et al., 2009). The maturity rate of the oil palm FFB determines the quality and quantity of OER that could be achieved annually, thereby contributing to per capital GDP of the country economy growth annually. Furthermore, a ripe oil palm FFB produces a high and qualitative OER, while an under ripe FFB will produced less OER, while overripe FFB has lesser oil quality as the case maybe.

The FFB maturity and ripeness dictates the product marketability and increase in the demand of the product based on its good quality, result from correct ripeness prediction. The FFB ripeness is generally categorised into four basic classes as: ripe, under ripe, unripe and overripe (Abdullah et al., 2001). There are several ranges of colour exhibited by the fruits from yellow at the base, reddish orange, dark purple to at the black at the apex and red. Most tender FFB contain 50 to 100 red-violet ripe fruits per bunch, since the ratio FFB pigment like the carotenoids and chlorophylls determines the colour of the FFB. Hence, fruits with higher proportion of chlorophyll, gradually decreases as the FFB matures, while a high content of carotenoids increase as oil palm fruits mature(Jamil et al., 2009). Therefore, the FFB colours changes that is due to these mentioned factors from biochemical reactions can relates to the fruit maturity.

This thesis presents a data mining approach for accurate classification of the oil palm FFB into under-ripe, ripe, and over-ripe categories, in order to address the above stated problems and limitations. This research was done at an oil palm plantation in peninsular Malaysia.

1.2 Problem Statement

The oil palm sector faces many problems, one major challenges being the accurate grading system of the oil palm FFB based on maturity. The accurate prediction of the oil palm FFB maturity helps in the determination of the oil palm extraction rate (OER) from the FFB. (Yeow et al., 2010). The quest for increase in the OER has also called for a more robust and reliable means of FFB maturity grading in Malaysia, which has triggered several researches in this area, and also motivated this research work for the application of an intelligent data mining, and knowledge discovery approach based on available spectrometer data without human intervention for the oil palm FFB ripeness prediction with lesser time, and rigor. Furthermore, the accuracy of the human grader as currently adopted in the Malaysia oil palm industries cannot be ascertained during grading, labeling and harvesting of the oil palm FFB. It is also considered to be time consuming, strenuous and also subjected to human error of judgments which may also compromised the final grading result (Hudzari, 2012) (Hazir et al., 2012).

This thesis presents a data mining and knowledge discovery approach for the extraction of hidden useful knowledge from the spectrometer extracted data, for accurate classification of oil palm FFB maturity in a laboratory experimental setup, for the building of a classifier model that can accurately predict the oil palm FFB maturity levels. This validates the performance of the conventional human grader assessments system of the maturity determination of the oil palm FFB into unripe, under-ripe, ripe and over-ripe categories. This research was done at an oil palm plantation in peninsular Malaysia.

1.3 Research Objectives

In order to achieve an effective performance evaluation and applicability of spectrometry data for the accurate maturity level determination of the oil palm FFB ripeness classification, so as to addresses the above stated problems, the following objectives are set out to be achieved:

1. To determine the most significant spectrum bands from the built model for the oil palm FFB ripeness classification model building.
2. To determine the best classier model for effective generalization of the built model for future prediction of the oil palm FFB maturity level.
3. To validate the performance evaluation of the built mode against conventional human grader assessment in the oil palm industries.

1.4 Scope of Research

In this research work, the scope is limited to these areas based on the gap discovered from the reviewed literatures:

i. Only matured freshly harvested 106 samples of nigrescens oil palm FFB were used for this research work.
ii. The harvesting skills of the human grader is not considered in this study
iii. The data extraction from the OPRiD spectrometer sensor application for the reflectance reading of the 8 band LED module light.
iv. Only visible light, infra-red and ultra violet in the wavelength range of 10 – 1000000 nm are considered as dictated by the equipment used.
v. 106 oil palms FFB samples with four maturity classes of unripe (31), under-ripe (25), ripe (24) and over-ripe (26) were considered in this research work, as compared to the conventional six known classes.
vi. The distance between the spectrometer and the samples to the measured are fixed and not adjustable as seen in some other models of spectrometer.
vii. The research experiment was conducted in the laboratory on already labeled oil palm FFB harvested and labeled by human grader manually.

1.5 Research Contribution

This research work achieves the following contributions to knowledge in this field of study:

i. Building of an intelligent model that could generalized in the classification of the oil palm FFB as compared to the conventional manual grading system.
ii. Determination of an accurate spectrometer band frequency, appropriate for the effective classification of the oil palm FFB ripeness, thereby saving time and energy applied in the application of all extracted wavelength band from the spectrometer sensors.
iii. Determination an improved OER classifier model that will improve the productivity of the oil palm industries in term of cost optimization and profit maximization.

1.6 Thesis Layout

Chapter 1 (Introduction), entails the background of study to this research work, necessary insight on the oil palm extraction rate improvements, problems statement, research hypothesis and objectives to be achieve.

Chapter 2 (Literature Review) discusses reviews on the previous proposed techniques as applied in both classical and modern oil palm FFB grading system as proposed in the literatures. Other applied nature inspired optimization algorithm application was also considered in solving the stated problems. However, recent proposed AI approaches in

recent researches in this area were studied and compared with the earlier conventional known methods to determine its merits and weakness.

Chapter 3 (Methodology and Procedures) discusses the elaborate steps in achieving the set research objectives that is hypothesized. The equipment experimental setup in the laboratory for features extractions from the oil palm FFB, alongside with relevant data extraction and recording for onward application in data mining tool of WEKA software. The entire sequence of procedures in achieving the set objectives was fully explained in this chapter.

Chapter 4 (Results and Discussions) presents all obtained results and discussions on the outcome of all findings, validations and testing. Results comparison is also detailed.

Chapter 5 (Conclusion) the derive conclusion on the research work, discussion on the research contributions and recommend with some potential future researches improvement.

1.7 Summary

This chapter introduces the basic concepts and guidelines of this research work with illustrations on basic known fact based on the pending challenges faced in oil palm industries, with respect to accurate maturity grading of oil palm FFB ripeness determination and its impacts on the OER. A proposed data mining and knowledge discovery approach is proposed to address the pending identified research gap problems, through building of an intelligent classifier model that could generalized and enhanced accurate classification of the oil palm FFB ripeness. The next chapter will illustrate several literatures reviewed on recent research works in this area, while the merits and challenges of earlier applied method will also be mention accordingly. The research gap will be discovered to enhance the newly proposed techniques and its merit with future research area for improvement also mention.

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