IMPROVED STATISTICAL RECOGNITION ALGORITHMS FOR OIL PALM RIPENESS IDENTIFICATION

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To my beloved mother, husband, kids and family members

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ABSTRACT

Awareness for high quality crude oil is crucial in oil palm production. Proper grading process is important to ensure only the ripe fruits are taken into consideration for the maximum level of oil content. Currently, researchers focus mainly on providing an automatic grading system using various techniques such as producing digital numbers, oil palm colorimeter, photogrammetric grading, fuzzy or neuro-fuzzy technique and so on. Even though some of them have more than 85% accuracy, it is only valid in controlled environment. However, when they are applied in real situation with uncontrolled environment, the accuracy can drop to less than 50%. So far, there is limited study on suitable colour model conducted on oil palm ripeness identification. Most researchers use RGB colour model to determine an oil palm ripeness. This research looks into the suitability and performance of HSV colour model in classifying an oil palm ripeness. Distance Measurement and Linear Discriminant Analysis are chosen as methods to classify an oil palm ripeness in this study. Histogram is used as a feature vector for feature extraction method while colour as a feature to be analysed. Images of oil palm were captured by an expert in the form of JPEG images. Preprocessing is then performed to remove noise and background from the images. Subsequently, images are transformed into histogram and mean value are extracted. Selected Distance Measurement such as Euclidean Distance, Nearest Neighbour, Furthest Neighbour and Mean Distance are then used for feature matching process. An Oil Palm Ripeness Identification algorithm is proposed, wherein an elimination technique is also introduced in the process. In addition, a Multiple Features Technique is also proposed to find the best feature which brings a very good recognition rate for selected Distance Measurement. The results show that 98% accuracy have been obtained in comparison with other researchers' work.

ABSTRAK

Kesedaran untuk menghasilkan minyak mentah berkualiti tinggi adalah penting dalam pengeluaran minyak sawit. Proses penggredan yang betul adalah penting untuk memastikan hanya buah masak diambil kira untuk tahap maksimum kandungan minyak. Pada masa ini, penyelidik memberi tumpuan terutamanya dalam menyediakan sistem penggredan automatik menggunakan pelbagai teknik seperti menghasilkan nombor digital kolorimeter, minyak sawit, penggredan fotogrametri, teknik kabur atau kabur neuro dan sebagainya. Walaupun sebahagian daripada mereka mempunyai lebih daripada 85% ketepatan, ia hanya sah dalam persekitaran terkawal. Walau bagaimanapun, apabila ia digunakan dalam situasi sebenar dengan persekitaran yang tidak terkawal, ketepatan boleh jatuh kepada kurang daripada 50%. Setakat ini, kajian yang dijalankan terhadap model warna yang sesuai adalah terhad ke atas pengenalan kematangan kelapa sawit. Kebanyakan penyelidik menggunakan model warna RGB untuk menentukan kematangan kelapa sawit. Kajian ini melihat kepada kesesuaian dan prestasi model warna HSV dalam mengklasifikasikan kematangan kelapa sawit. Jarak Pengukuran dan Analisis pembezalayan Linear dipilih sebagai kaedah untuk mengklasifikasikan kematangan kelapa sawit dalam kajian ini. Histogram digunakan sebagai ciri vektor bagi kaedah pengekstrakan ciri manakala warna adalah ciri yang akan dianalisis. Gambar kelapa sawit telah ditangkap oleh seorang pakar dalam bentuk imej JPEG. Prapemprosesan kemudian dilakukan untuk menghilangkan bunyi dan latar belakang dari imej. Selepas itu,imej diubah ke dalam bentuk histogram dan nilai purata diekstrak. Jarak Pengukuran terpilih seperti Jarak Euclid, Jarak Jiran Terhampir, Jarak Jiran Paling Jauh dan Jarak Purata kemudiannya digunakan untuk pencarian ciri sepadan. Satu algoritma Pengenalan Kematangan Kelapa Sawit dicadangkan dimana teknik penghapusan juga diperkenalkan dalam proses. Di samping itu, Teknik Pelbagai Ciri juga dicadangkan untuk mencari ciri terbaik yang membawa pengiktirafan kadar pengecaman yang amat baik bagi Pengukuran Jarak terpilih. Keputusan menunjukkan bahawa ketepatan 98% telah diperolehi berbanding dengan kerja penyelidik yang lain.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Recent development in oil palm research indicates the need to provide a computer-based grading system (Jaffar *et al.*, 2009; Jamil *et al.*, 2009). Currently, manual grading system at oil palm mills leads to misconduct and disputes. Since colour is one of main indicators of ripeness (MPOB, 1995), it is important to research a right technique to determine the fruit ripeness through colour differentiation. As mentioned by Alfatni *et al.* (2008),colour provides useful information in estimating the maturity and in examining the freshness of fruits and vegetables. Thus, the colour of the oil palm fruits remains one of the important factors that determine the grade and the quality of the palm oil (Rashid *et al.*, 2002; Wan Ishak *et al.,* 2000).

Colour recognition models have been applied widely in industrial sectors, commercial fields as well as for social responsibilities. For instance, these models are used as a reliable parameter in robotics machines for the aid of the blind and the colour-blinded people, diamond colour sorting, quality control in the manufacture of coloured paper (Stoksik *et. al*. (1991) and in characterising thermal paints (Lalanne, 2002).

Human eyes have three types of sensors and the signal of these three sensors determine the colour response of the observer. The response of this system produces the three-dimensional phenomenon in three-dimensional spaces. When a human sees something, the light enters the eye and hits the light detector on the retina. This is similar to how a digital camera works (Peter, 2005). Two main characteristics that are decisive for visual inspection and classification of fruits are colour and shape (Affendi *et al.*, 2010).

This chapter is organised into thirteen parts. First, background of the problem is introduced. Then, problem statement is addressed together with research question, research aims, research objectives, scope, and significance of study, research contributions, and lastly thesis organisation. Details of thesis organisation will be described in Section 1.13.

1.2 Importance of Oil Palm Research

Oil palm is catching bigger attention for contributing in Malaysian economy today. Fy Ng *et al.* (2011) explored the potential of oil palm as a renewable energy for biomass. Therefore, oil palm-based biomass can be expected to play a prominent role in the future when the demand for renewable energy is expected to increase rapidly. Currently, almost 80% of Clean Development Mechanism (CDM) projects in Malaysia are from the oil palm industry, including renewable energy-related projects such as biomass from empty fruit bunches and the generation of biogas by capturing methane from the palm oil mill effluent ponds (The Star, 2010).

In addition, the oil palm industry has also been identified by the Malaysian Government's Economic Transformation Programme (ETP) as one of the major economic pillars that would spearhead the economic growth by 2020. The ETP was launched in October 2010 by the Prime Minister of Malaysia, YAB Dato' Sri Mohd Najib bin Tun Abdul Razak as a comprehensive effort that will be able to transform Malaysia into a high-income nation by 2020 (PEMANDU, 2010). This is also in line with the motto of Felda Palm Industries Sdn. Bhd. (FPISB) at its oil palm mills that states "Towards 100% ripe FFB". This indicates the importance of identifying ripeness of oil palm to provide high quality of oil during sterilisation process.

The Entity Point Projects (ETP) roadmap has identified that the oil palm industry will raise its Gross National Income (GNI) contribution from the current RM52.7 billion to RM178 billion by 2020 and this will be achieved through the implementation of eight core Entry Point Projects (EPP) (PEMANDU, 2010). Moreover, according to MPOB (2009), the use of oil palm is considered as "a road to zero waste".

For many years, the aviation industry has been criticised for its high greenhouse gas (GHG) emissions. The negligible GHG footprint of the oil palm industry has encouraged the industry to consider the use of palm oil biofuel to help reduce emissions in the aviation industry. Malaysian palm oil potentially fits the road map because of its ability to replace a small percentage of the world aviation biofuel demand. The lack of an excess supply from other vegetable oils and a high demand for palm oil for food will cause market forces to price palm oil above petroleum fuel. Non-food oil crops, such as jatropha, can also be grown on degraded land, but they yield only 20 per cent that of oil palm and are more expensive to produce, thus making them a much less attractive solution. Development of aviation biofuel from other vegetable oils will be next to impossible. Oil palm is the only viable solution in the long term (The New Straits Times, 2012).

The Minister of Plantation Industries and Commodities, Tan Sri Bernard Dompok has launched the Oil Palm Smallholders Replanting and NewPlanting Schemes, which is one of the eight Entry Point Projects (EPP) under the Palm Oil National Key Economic Area (NKEA) with the objective to increase the productivity and income of the smallholders. Under the palm oil NKEA, the contribution of palm oil industry to the Gross National Income is expected to increase to RM178 billion, compared to RM52.7 billion in 2009. The palm oil NKEA comprises five EPPs for upstream activities, and three EPPs for downstream activities (Minister, Ministry of Plantation Industries and Commodities, 2011).

Figure 1.1 shows the performance of Malaysian oil palm industry in 2011 based on production, stock, export, import, and price of oil palm.

	NOVEMBER(r)	DECEMBER(p)	DIFFERENCE	
			QUANTITY	(%)
PRODUCTION (Tonnes)				
CRUDE PALM OIL				
Peninsular Malaysia	886,663	770,373	(116,290)	(13.12)
Sabah	496,523	492,259	(4,264)	(0.86)
Sarawak	244,588	232,261	(12,327)	(5.04)
Total	**1,627,774**	**1,494,893**	**(132,881)**	**(8.16)**
PALM KERNEL	403,109	381,942	(21,167)	(5.25)
CRUDE PALM KERNEL OIL	199,639	189,812	(9,827)	(4.92)
PALM KERNEL CAKE	221,838	210,336	(11,502)	(5.18)
STOCK (Tonnes)(s)				
CRUDE PALM OIL				
Peninsular Malaysia	549,836	430,152	(119,684)	(21.77)
Sabah	457,708	444,344	(13,364)	(2.92)
Sarawak	220,865	189,781	(31,084)	(14.07)
Total	**1,228,409**	**1,064,277**	**(164,132)**	**(13.36)**
PROCESSED PALM				

OIL				
Peninsular Malaysia	478,321	561,460	83,139	17.38
Sabah	254,235	311,688	57,453	22.60
Sarawak	109,043	101,799	(7,244)	(6.64)
Total	**841,599**	**974,947**	**133,348**	**15.84**
TOTAL PALM OIL				
Peninsular Malaysia	1,028,157	991,612	(36,545)	(3.55)
Sabah	711,943	756,032	44,089	6.19
Sarawak	329,908	291,580	(38,328)	(11.62)
Total	**2,070,008**	**2,039,224**	**(30,784)**	**(1.49)**
PALM KERNEL	154,073	125,330	(28,743)	(18.66)
CRUDE PALM KERNEL OIL	198,498	197,947	(551)	(0.28)
PROCESSED PALM KERNEL OIL	159,609	176,296	16,687	10.46
TOTAL PALM KERNEL OIL	**358,107**	**374,243**	**16,136**	**4.51**
PALM KERNEL CAKE	336,125	302,318	(33,807)	(10.06)
EXPORT				
PALM OIL	1,664,591	1,589,883	(74,707)	(4.49)
PALM KERNEL OIL	108,063	126,283	18,220	16.86
PALM KERNEL CAKE	277,490	228,647	(48,842)	(17.60)
OLEOCHEMICAL	202,085	208,074	5,989	2.96
BIODIESEL	12,411	405	(12,006)	(96.74)
IMPORT (TONNES)(q)				
CRUDE PALM OIL	87,198	126,778	39,581	45.39
PROCESSED PALM OIL	1,067	19,893	18,826	1,764.14
PALM OIL	88,265	146,672	58,407	66.17
TOTAL PALM KERNEL OIL	53,896	37,182	(16,714)	(31.01)
PRICE (1% OER) (Local Ex-Mill)				
FFB (AVERAGE RM/TONNE)	32.82	33.18	0.36	1.10

Figure 1.1 Performance of Malaysian Palm Oil Industry (Source: MPOB Web Page, 2012)

1.3 Background of the Research Problem

Rapid development of oil palm industry leads to the awareness for high quality crude oil production. The best quality of Fresh Fruit Bunches (FFB) needs to be produced in order to meet the objective of high quality oil content during sterilisation process. To maintain the status of number one oil palm producer in the world, the quality of oil palm needs to be carefully monitored and preserved. In this case, grading process is important to ensure only the ripe fruits are selected for the maximum level of oil content.

As explained by MPOB (1995) in its Oil Palm Fruit Grading Manual, Fresh Fruit Bunch (FFB) is defined as fresh fruit that is sent to mill for processing within 24 hours after harvest. However, in real practice, grading process of oil palm is conducted manually by human grader. Thus, this manual grading process leads to misconduct and human error while inspecting for the right category of fruits for the purpose of oil palm production at the mill. Human graders' mood varies all the time and this will affect the manual grading on site. It is extremely important to note that to identify the degree of ripeness of FFB, it must be at 95% level of confidence as required by the MPOB. Therefore, wrong evaluation on graded fruits will result in wrong report regarding the oil content. However, the most critical part of oil palm grading is the fruit classification. Error in classifying the right category of FFB will cause error in estimating the oil content.

Research conducted by the Federal Land Development Authority (FELDA) at mills show that the estimated oil content for ripe fruit is 60%, while underripe is 40% and unripe is only 20% minus water and dirt. This indicates the importance of the right classification of FFB during grading process to prevent from mistakenly claiming that low quality fruits are the good ones. Problem will occur if the high percentage of Basic Extraction Rate claimed by the appointed graders is proven to be of poor quality during oil production process.

According to MPOB Manual (1995), the grading process can only be performed by the grading staff of the mill that has the capability and experience in the grading of fresh fruit bunches. Unfortunately, the grading processes are conducted manually and the human mistakes might happen. In current grading process, about 50-100 bunches of FFB are selected randomly from each consignment to be graded and represented top, middle and bottom portions of the consignment. The grader might give high result for that particular consignment which has low quality of bunches. What is usually happens is when that bunches are sent to the mill, the actual quality of oil are relatively low compare to the grading result.

This research proposes a grading scheme of Pattern Recognition technique by exploiting Distance Measurement in Multiple Features for oil palm ripeness identification. This technique of Pattern Recognition will use mean value which is extracted from histogram of each images of FFB. However, we will not perform any image processing because of the fact that the weaknesses of image processing in providing the accuracy of data. In addition, pre-processing in image processing like the processes of background subtraction, noise removal and image enhancement are inaccurate for most algorithms (Chellappa and Aggarwal, 2004). This is also supported by Weiss *et al* (2006) and Ross *et al* (2005) who say that image processing will reduce the distortion of images and this will make it less reliable for further process. This problem is then solved by A. Chambolle (2004) who used a numerical method which proved to be a better solution. To eliminate the limitations of using the image processing method, a simulation of grading system is proposed for oil palm ripeness identification.

In oil palm production, grading process is known as an input feeder for later processes in oil palm production. Therefore, it is extremely important to improve the current grading process by simulating the grading system using Pattern Recognition technique. It is observed that Statistical Pattern Recognition can offer better solution for this particular problem. This is supported by findings by Jain *et al.* (2000) due to the availability of Statistical Pattern Recognition in handling large databases and stringent performance requirements (speed, accuracy, and cost).Nureizi and Watada (2009) provided fuzzy evaluation criteria to support the weightage of important features of oil palm grading. By exploiting Distance Measurement in Multiple Features, it is hoped to improve current grading process as mentioned previously.

1.4 Manual Grading Process

Grading process is conducted manually by a licensed grader at oil palm mill. Therefore, Malaysia Palm Oil Board (MPOB) has issued a manual grading of oil palm to promote quality awareness and as a guideline especially for small farm operators throughout the country. This manual describes about sampling procedures and grading methods.

There are six steps to be taken in manual grading process. It starts with lorry consignment that enters the oil palm mill. Then, the lorry needs to park on the weight bridge to be weighted. After that, lorry is instructed to park four meters from loading ramp before unloading the FFB. The FFB is then unloaded from lorry and grading process by MQI (Mill Quality Inspector) begins. Grading result is entered into PDA to determine the Oil Extraction Rate (OER). In the last process, an empty lorry is weighted to get the total weight (tonne) and real graded extraction rate.

1.5 Definition of Ripeness

Ripe oil palm, as mentioned by MPOB (1995), must have the features shown in Figure 1.3.

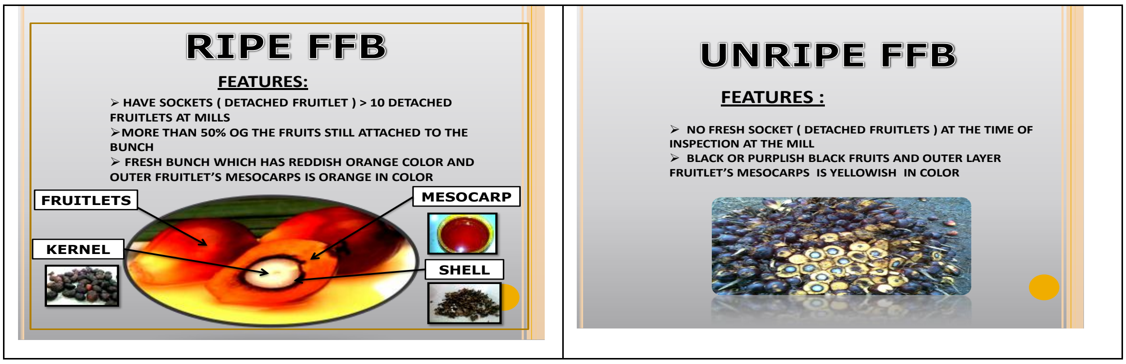

Figure 1.3 Features of Ripe and Unripe FFB (Source: FPISB, 2011)

Referring to Figure 1.3, ripe bunch is a fresh bunch that has reddish orange colour and the outer fruitlet's mesocarp is orange in colour. On the other hand, unripe bunch is defined as a fresh bunch that has black or purplish black fruits and the outer layer fruitlet's mesocarp is yellowish in colour. Unripe bunch must have sockets (detached fruitlet) more than ten when processed at mills. Moreover, more than 50% of the fruits are still attached to the bunch and lastly fruits colour is reddish orange and the outer layer of fruitlet's mesocarp is orange.

Thus for unripe FFB, as mentioned in MPOB Manual (1995), it must have no fresh socket (detached fruitlets) during the inspection time at mill. In addition, the fruits are black or purplish black and the outer layer fruitlet's mesocarp is yellowish in colour.

1.6 Problem Statement

Recently, researchers have worked with several methods to distinguish ripeness categories of oil palm bunch using contact and non-destructive method. Some of the methods are as follows: red, green, and blue digital number (Alfatni *et al.*, 2008), hue, saturation, and intensity imaging technique (Wan Ishak *et al.*, 2000; Tan *et al.*, 2010; Abdullah *et al.*, 2002), oil palm colorimeter (Tan *et al.*, 2004; Idris *et al.*, 2003), photogrammetric grading (Jaafar *et al.*, 2010), image-based modelling (Wan Ishak & Hudzari, 2010), fuzzy regression approach (Nureizi & Watada, 2010), Neuro-fuzzy technique (Jamil *et al.*, 2009), microwave moisture sensors (Khalid *et al.*, 2006), hyperspectral (Phorntipha *et al.*, 2009, Osama *et al.*, 2010), and MRI and Bulk NMR (Sharifudin *et al.*, 2010). These methods give a very good sign to change from manual grading to computerised grading system. Even though some of them have more than 85% accuracy, it is only valid in controlled environment. However, when they are applied in real situation with uncontrolled environment, the accuracy can drop to less than 50% (Jamil *et al.*, 2009).

1.7 Research Questions

The research questions are as follows:

1) How Statistical Pattern Recognition technique is able to classify the oil palm ripeness?
2) What type of colour model is suitable for oil palm ripeness identification?
3) How to exploit the best Distance Measurement for measuring the similarity of oil palm ripeness?
4) How the most dominant feature pair for oil palm ripeness identification is measured?

1.8 Research Aim

This study aims to improve Statistical Pattern Recognition algorithm for oil palm ripeness identification.

1.9 Objectives of the Study

The goal of this study is to propose a new scheme based on histogram to identify oil palm ripeness. In order to achieve the goal, several objectives must be achieved:

i. To determine the most suitable colour model for oil palm ripeness identification.
ii. To obtain the most suitable distance measurement for oil palm ripeness identification.
iii. To propose a new algorithm called OPRI for oil palm fruit ripeness identification.

1.10 Research Scope

There are 16 bunch classifications in MPOB Manual (1995).However, in this research, only ripe and unripe categories were chosen to be tested as the main category of FFB (MPOB, 1995; FPISB, 2011). Dataset for training and testing was obtained from Kilang Sawit Felda Bukit Sagu Kuantan, Pahang, Malaysia. This research intended to assist graders in performing grading processes for oil palm at mills. The only feature taken into consideration was colour, as colour is one of the main ripeness indicators for oil palm as proved by Nureizi & Watada (2010). As stated by Abdullah et al. (2004), colour is mainly used to assess grading as it serves as an instant indicator of good or bad product quality and consumers tend to associate colour with flavour, safety, nutrition, and level of satisfaction.

Oil palm is taken and tested based on “as it is” state without considering lighting environment, background or noise in outdoor environment. This is due to limitations concerning the environmental factors that cannot be controlled such as weather in monsoon season starting from October to January every year especially in East Coast Malaysia. In this study, images of oil palm were captured during daylight using sunlight as natural lighting source, which is considered the best lighting sourcein outdoor environment as mentioned by May & Amaran (2011).

1.11 Significance of Research

The necessities of improving the manual grading process of oil palm at mills are extremely important. This is due to inaccurate report by grader regarding the oil content during sterilisation process. Moreover, by providing a new scheme, this can help graders to reduce human errors while grading, besides allowing the grading process to be easier, smoother, and more transparent. Besides, this research can compare and validate result of the new scheme with expert decision.

1.12 Research Contributions

There are three contributions of this research:

i. Development of a new algorithm called OPRI for oil palm ripeness identification.

ii. Determining the most suitable colour model for oil palm ripeness identification.

iii. Obtaining the best distance measurement for oil palm ripeness application.

1.13 Organisation of the Thesis

This thesis is organised as follows: Chapter 1 describes the introduction of the whole thesis. This includes problem statement, objectives, research aim and scope. Chapter 2 presents the state-of-the-art works introduced by other researchers for oil palm and other fruits ripeness identifications including the techniques used. Chapter 3 explains materials and methods used, while in the following two chapters (Chapter 4 and 5), we respectively introduce the original works for oil palm recognition, including classifiers (Distance Measurement) and Discriminant Analysis(LDA). Finally, we draw conclusions from the proposed works and provide some directions for future studies in Chapter 6.

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