UNIVERSITI PUTRA MALAYSIA

OIL PALM FRUIT BUNCHES MATURITY PREDICTION USING STANDARD DEVIATION OF COLOURS

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By

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June 2015

Chairman : Professor Wan Ishak Wan Ismail, PhD, PEng
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Determination of correct maturity stage of the oil palm fruit bunches is crucial in maximizing oil extraction rate (OER) of the fresh fruit bunch (FFB). A right determination of the maturity stage will lead to the right time of fruit bunch harvesting day which is only ripe fruit bunch will be harvested. Traditional inspections of oil palm fruits to determine its degree of maturity was inaccurate and varies among different inspectors. While current practices of oil palm maturity stage determination such thru observation of number of loose fruits felled on the ground was destructive and time consuming. In this research, non-destructive and real time image capturing was applied and digital value of hue was used as a color space for image analysis. The research is conducted to monitor the color deviation of the oil palm bunch during the ripening process. The procedure in this study is started with real time image acquisition using Keyence camera which will give real time reading of HSB (Hue, Saturation and Brightness) digital number. Nine different fruit bunch from 5 years old of the oil palm trees selected for this study and the variety of oil palm is *Tenera*: *Elaeis Guineensis*. The hue digital value obtained from the Keyence camera real time reading will then analyzed and correlated with mesocarp oil content and number of loose fruits to develop a model for oil palm fruit bunch maturity stage. During image capturing, light intensity surrounding the fruit bunch was monitored using Extech Lightmeter. Regression analysis of linear model shows that the color deviation derived from hue standard deviation was significant in estimating the days to harvest the fruit bunch. The equation model obtained was $y = 0.109x + 0.89$ and $R^2 = 0.726$ with y, x and R^2 respectively represent hue standard deviation i.e. color deviation, estimated days to harvest and regression squared. It was physically observed that color distribution on surface of ripe fruit bunch is more uniform while color distribution for under ripe is less uniform. Delayed days to harvest affected the fruit bunch to become overripe. Overripe means the number of loose fruits and content of mesocarp's free fatty acid (FFA) would increase. In determination of oil content, it was found that there is a different pattern rate of oil accumulation in different part of the fruit bunch. Overall relationship of the average oil content with days to harvest shows a high correlation with equation model $y = 0.779x + 69.79$ and $R^2 = 0.774$ with y, x and R^2 respectively represent percentage of mesocarp oil content, estimated days to harvest and regression squared. From the model developed will hopefully helpful in predicting the optimum day to harvest the oil palm fruit bunch.

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

RAMALAN KEMATANGAN BUAH KELAPA SAWIT MENGGUNAKAN SISIHAN PIAWAI WARNA

Oleh

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Penentuan kematangan tandan buah kelapa sawit yang betul adalah penting dalam memaksimumkan kadar ekstrak minyak (KEM) bagi tandan buah segar (TBS). Penentuan kematangan yang betul akan membawa kepada hari pemetikan tandan buah yang betul dimana hanya tandan buah yang masak akan dipetik. Pemerhatian secara tradisional buah kelapa sawit untuk menentukan kematangan buah adalah kurang tepat dan berbeza dikalangan pemerhati. Sementara amalan penentuan tahap kematangan buah kelapa sawit yang terkini seperti pemerhatian bilangan buah lerai yang jatuh di atas tanah adalah merosakkan dan memakan masa. Dalam kajian ini, pengambilan gambar yang tidak merosakkan dan pada masa sebenar diaplikasikan dan nilai digital warna digunakan sebagai ruang warna untuk analisis imej. Kajian yang dilakukan adalah untuk memerhati sisihan warna tandan buah sawit ketika dalam proses kemasakan. Prosedur dalam kajian ini bermula dengan pengambilan imej secara masa sebenar menggunakan kamera Keyence dimana akan memberi bacaan nombor digital HSB *(Hue, Saturation and Brightness)* secara langsung. Sembilan tandan buah daripada pokok yang berusia 5 tahun dipilih untuk kajian ini dan jenis kelapa sawit adalah *Tenera*: *Elaeis Guineensis.* Nilai digital warna yang diperolehi dari bacaan terus kamera Keyence akan dianalisis dan akan dihubungkaitkan dengan kandungan minyak dalam mesokap dan bilangan buah lerai untuk menghasilkan model untuk tahap kamatangan tandan buah kelapa sawit. Ketika sesi pengambilan imej, keamatan cahaya pada tanda buah dipantau menggunakan Extech Lightmeter. Analisis regresi model linear menunjukkan bahawa keseragaman warna yang diterbitkan dari sisihan piawai warna adalah signifikan dalam menganggarkan hari bagi memetik tandan buah. Persamaan model yang diperolehi adalah $y = 0.109x + 0.89$ dan $R^2 = 0.726$ dengan y, x dan R^2 masing-masing mewakili sisihan piawai warna iaitu keseragaman warna, anggaran hari untuk memetik dan kuasa dua regresi. Secara fizikalnya adalah diperhatikan bahawa taburan warna pada permukaan tandan buah yang masak adalah lebih seragam, manakala bagi yang kurang masak taburan warnanya adalah kurang seragam. Kelewatan dalam memetik buah akan menyebabkan buah menjadi terlebih masak. Terlebih masak disini adalah bermaksud bilangan buah lerai dan kandungan asid lemak bebas akan meningkat. Dalam menentukan kandungan minyak, telah didapati bahawa terdapat pola kadar pengumpulan minyak yang berbeza pada bahagian yang berbeza pada tandan buah. Hubungan keseluruhan purata kandungan minyak dengan hari untuk memetik menunjukkan korelasi yang tinggi dengan persamaan model $y = 0.779x + 69.79$ dan $R^2 = 0.774$ dengan y, x dan R^2 masing-masing mewakili peratusan kandungan minyak, hari untuk memetik dan kuasa dua regresi. Daripada

model yang telah dihasilkan diharapkan dapat membantu dalam meramal hari yang optimum bagi memetik tandan buah kelapa sawit.

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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 Master of Science. The members of the supervisory committee are as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CCD	Charge Couple Device
DN	Digital Number
DTH	Days to Harvest
FC	Foot Candle
FELDA	Federal Land Development Authority
FFA	Free Fatty Acid
FFB	Fresh Fruit Bunch
HSB	Hue, Saturation, Brightness
HIS	Hue, Saturation, Intensity
HSL	Hue, Saturation, Luminance
KEM	Kadar Ekstrak Minyak
LF	Loose Fruits
MPOB	Malaysia Palm Oil Board
MRS	Minimum Ripeness Standard
OER	Oil Extraction Rate
RGB	Red, Green, Blue
R^2	Regression Squared
RGB	Red, Green, Blue
STD	Standard Deviation
TBS	Tandan Buah Segar
UPM	Universiti Putra Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background

As a developed nation, Malaysia is one of those countries which rely heavily on agriculture sector as its main source of income. But nowadays, Malaysia is no longer relying solely on agriculture as the contributor for its income. This is mainly due to its economic diversification that took place for the last 30 odd years. In the past few decades, Malaysia was aggressively expanding its economic activities by engaging in other sectors like oil and gas, heavy industry, automotive, electronics, information technology and tourism. However, only recently the government has put the focus back to agricultural sector as one of the most important sector that would help Malaysia achieving its 2020 visions. Agriculture plays an important role in rural population in Malaysia. Most of the rural populations are engaged in agricultural work with oil palm plantation dominating Malaysia total area of planted commodity crop. The total oil palm planted area, both in West and East Malaysia, in 2011 was 5.00 million hectares. This was a 3.0% increment against 4.85 million hectares recorded in 2010. This was due to increase in planted area in Sarawak which saw an increase of 11.0% or 102,169 hectares. Sabah has the largest oil palm planted area with 1.43 million hectares or 28.6% of total oil palm planted area, followed by Sarawak with 20.4% of total oil palm planted area.

Palm oil is the most widely traded oil in the world. The palm oil is widely used for the production of bio-diesel, cosmetics, food product, pharmaceutical and etc. In 2011, its exports reached almost 39.04 million metric tons of which 46% of world's total production came from Malaysia followed by Indonesia as the world second largest palm oil exporter. However, Indonesia is still the largest producer of palm oil in the world. Similar trend in export of palm kernel oil was recorded in the same year, with the volume reaching 1.17 metric tons.

With the encouragement from the world market demand, Malaysia has allocated a huge amount in research and development on oil palm industry. The establishment of MPOB (Malaysia Palm Oil Board) a special body that responsible in R&D and any matter regarding national palm oil industry is further evidence of the seriousness of the government in this area. UPM (Universiti Putra Malaysia, formerly known as Agricultural University of Malaysia) is another organization that is highly committed on palm oil R&D.

With strong government backing, many states of the art technologies have been introduced in recent years. The introduction of technology is inevitable in order for Malaysia to compete and meet the demand of this robust global market. As a result, many types of machines were invented such as CANTAS by MPOB, oil palm loose fruit picker, robot arm for harvesting purpose, machine vision for bunch ripeness determination and etc.

Color is one of the most visible indicators used to determine the maturity of agricultural fruits, and is applicable also to oil palm fruit bunches. In order to automate the harvesting operation of oil palm fruit, an artificial vision system which replaces the human eye for recognizing mature fruit bunches is needed. Color is considered a

fundamental physical property of agriculture products. Application of vision system in agricultural produces is difficult and challenging. This is due to the uncertainty in shape, color and other physical properties of agricultural fruits.

Currently, the maturities of fruit bunches are determined by its color, number of loose fruits felled on the ground and percentage of oil content. If fruit bunches are harvested too early or unripe, it may not reach optimum oil content when processed. If they are harvested too late, the fresh fruit bunches (FFB) become overripe, thus produced oil with high acidity of Free Fatty Acid (FFA) during mill extraction process and resulted in low quality of oil (Azis et al., 1984; Kaida et al., 1996; Wan Ishak et al., 2000). Therefore, a parameter which can be used to determine the level of maturity of fruit bunches with respect to the optimum oil content is needed. Machine vision technology had been used to inspect and grade FFB of an ordinary *Elaeisguineensis* in categorizing FFB ripeness. The optical properties of an oil palm FFB with it maturity status as ripe, unripe or overripe will be determined through its oil content measurement (Razali et al., 2009). Ishak W.I.W and Hudzari R.M (2010) developed color simulation forecasting model for oil palm fruit bunch ripeness in real time environment. Therefore, this thesis presents the simulation of fruit bunches maturity by adding another color characteristic of ripening process of fruit bunch which is the color uniformity of the whole surface of the fruit bunch. The experiment was conducted on fruit bunch in real time growth condition at oil palm plantation. The fruitlets of oil palm were plucked on the same day as the images of fruit bunches were being captured using Keyence Camera Vision. The fruitlets samples were then brought to the laboratory for oil content analysis.

1.2 Problems Statement

Determination of ripe fruit is important to ensure only ripe or fully ripe fruit bunches are harvested. These ripe bunches are sent to the oil mill for processing. Any unripe fruits supplied to the oil palm mill will affect the quality and quantity of oil extraction. There are many researches that have been conducted in search of possible techniques to gauge the maturity of the fruit bunch. Azis (1973) introduced floatation technique, Turner and Gilibanks (1974) relate the maturity of the fruit with number of detached fruits from the bunch, while Kaida and Zulkifly (1992) found that there is a relationship with microwave frequency with moisture content of the fruits. However, all of the techniques mentioned are destructive and time consuming.

One destructive technique which requires the workers to injure the fruit bunch using harvesting chisel to ensure the ripeness of the fruit bunch is due to their inability to see clearly the color of fruit bunch which is high on the tree. Another harvesting technique that has been practice in the palm oil plantation is the fruit bunches bunch will be harvested when the workers see around 5 to 10 loose fruits felled on the ground. The problem with this technique is the worker might not able to see or count the number of loose fruits felled on the ground. This technique is prone to error in judgments and inconsistencies. The worker also did not bother to collect all the loose fruits felled on the ground.

Color is the most common criteria used to measure the ripeness of all type of fruit including oil palm fruit bunch. Therefore, an accurate human inspection is crucial to determine the ripeness of the fruit. Unfortunately, each workers doing harvesting may

have their own inspection decision vary from each other. This will result in inconsistent maturity or ripeness of the fruit bunch harvested.

Most of the previous researches done on vision system were applied on controlled lighting environment. M.H Razali et al., (2011) developed an outdoor image based model for estimation of fruit ripeness. The model relates surface color of the fruit bunch with oil content. However, the color of the fruit bunch surface might vary slightly from one tree to another or even from one bunch to another. This is possibly due to change of environmental condition. For example, if we compare two different ripe bunches; the color of the fruit bunch surface of the two might differ slightly. From our observation, fruit bunch that was directly exposed to sunlight will have brighter reddish orange color than fruit bunch that grow under the shade. Therefore, the purpose of this research is to study another characteristic of the fruit bunch to refine the maturity identity of the fruit bunch in outdoor condition. In this study, a color measurement tool available in Keyence camera was applied on the color appearance of the whole exposed fruit bunch skin surface. It was reported that the ripening of the fruit bunch are not uniform which usually begins from the apical section, and gradually spreading toward equatorial and basal sections of the bunch (Kaida and Zulkifly, 1992). This characteristic of the fruit bunch maturing surely will result in different pattern of color distribution appeared during ripening process. The different pattern of color distribution was expected to have a close relationship with stage of fruit bunch maturity.

1.3 Objectives of the Study

The main aim of this study is to develop a model for optimum day of harvesting the fruit bunch based on the color uniformity and mesocarp oil content correlation. The specific objectives of the study are as follows:

1. To develop the procedure for outdoors imaging technique of machine vision for oil palm fruit maturity inspection.
2. To determine the hue value of each three (apical, middle, and basal) part of the fruit bunch surface and analyze it pattern of color uniformity.
3. To determine the oil content of the oil palm fruits at different stage of maturity from three different part of the fruit bunch.

1.4 Scope of the Study

This study focused on the determination of color deviation of the fruit bunches. The images were captured by using Keyence Camera CV-3001. The type of oil palm fruits being studied in this research is of nigrescens type and from the *tenera* variety (hybrid between the *dura* and *pisifera)* which is mostly planted in Malaysian oil palm plantations. All experiments were carried out for 5 years old tree only. During session of image capturing, one fruitlet from each part was plucked for oil content analysis. The oil content of the mesocarp is percentage of oil to dried mesocarp. The monitoring period of each bunches was start from approximately two weeks before ripe till ripe.

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