CAFEi2016-151

Comparison study on oil palm fresh fruit bunch (FFB) maturity stages determination based on color recognition model and position of FFB in leaf spiral

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Abstract

Optimum quality of oil production can be obtained by managing the harvesting operation of oil palm fresh fruit bunches (FFB) at the right stage of ripeness. High content of free fatty acid (over-ripe bunches) will increase the refinery cost. Therefore it is crucial to determine the harvesting date of FFB. This study explores the possibility of determine the maturity stage based on the location of FFB in the leaf spiral. Since matured oil palm produced two leaves per month, each leaf axil potentially produced inflorescences. Pollination of FFB will take place at leaf number 17 up to 20 and mature bunch will be at leaf number 30 to 33. Based on this information, a relationship of FFB position will be at spiral and maturity stages can be established. This paper presents the comparison analysis of color recognition model and position in leaf spiral in determining the maturity stages of FFB.

Keywords: maturity stages, site specific harvesting, leaves spiral, harvesting model.

INTRODUCTION

Oil palm fresh fruit bunch (FFB) harvesting operation cause the largest cost in the production of oil palm (Omereji, 1991; Gan et al., 1993; Kassim et al., 2014). Accurate yield estimation will be very useful to plan labor and machinery equipment, monetary budget, oil palm mill capacity and various oil palm management aspects.

Harvesting oil palm fresh fruit bunches (FFB) at the right stage of ripeness is critical to ensure optimum quality and quantity of oil production thus profitable to the industry (Rajanaidu et al., 1988). FFB maturity stage and oil palm tree location are very important to manage workers, machines and other agricultural resources to increase productivity. This information are also useful for yield forecasting and crop management (Kassim, et al., 2012). Overripe FFB contain high free fatty acid (FFA) which will decrease the oil quality and increase the refinery cost (Idris Omar et al., 2009). Oil synthesis will stop a few days before the fruitlet fall from the bunch. At this point, the oil content in mesokrap is at optimum level (Turner and Gillbank, 1982; Idris Omar, et al., 2009).

In manual harvesting of oil palm, color is the most important indicator for farmers to determine the maturity of the oil palm FFB (Razali et al., 2009). The current method to determine ripeness of FFB is by observing the color. Usually experts uses experiences to determine the maturity. The color of unripe FFB is dark purple while the ripe FFB is reddish color.

Oil palm tree produces 3 new leaves per month for below 7 years age and produces 2 leaves per month for above 7 years old (Corley, 2009). Naturally, the leaves arranged in spiral. There were found 8 spiral and each spiral has 5 leaves. According to Corley (2009), pollination stage will take place on the flower at leaf number 17 up to 20 and mature bunch will be subtended in between leaf number 30 to 33. Based on the number of leaf produce per month and the position of FFB on leaf spiral, the age of the FFB can be estimated hence the date of

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harvest can also be estimated.

The existing color recognition model was developed by Kassim, (2014) for oil palm tree below 7 years old. In this research the model will be tested for oil palm tree which is above 7 years old. The data of images will be processed by the "color recognition model" to analyze the color space value in each group of maturity stages.

MATERIALS AND METHODS

This research was carried out at Ladang 15 oil palm plantation at Universiti Putra Malaysia (UPM). The age of the oil palm tree was 9 years old when the research was done. There were six rows and twenty seven trees selected for this research. Each oil palm trees and FFBs were tagged and given unique identity for data recording. In this research, the actual date of harvesting by farmers was compare with the estimated date of harvesting based on FFB position in leaf spiral and color recognition model.

FFB Maturity determination in relation with leaf position

Oil palm tree can be classified as left-handed or right-handed spiral. Both spiral have the same arrangement except the spiral rotation was inverted. As shown Figure 1, both tree have 8 spiral, 5 leaves in each spiral and a total of 40 leaves. But in real oil palm tree it can be more or less. Left-handed spiral as shown on Figure 1(a) has a leaves twisting to the left towards the center of the oil palm tree. The position of the leaf was ascending by plus 8 from the center to the last leaf of oil palm tree. According to Corley, oil palm tree age above 7 years old produce two leaves per month. Each leaf have an equal potential of producing flower in their leaf axils and the duration of FFB to be matured and ready to harvest is 6 month after pollination process at leaf number 17 up to leaf 20. Normally the position of matured FFB was subtended between leaf number 30 to 33. Based on this information, a relationship of FFB position in the leaf spiral and FFB maturity stages can be established.

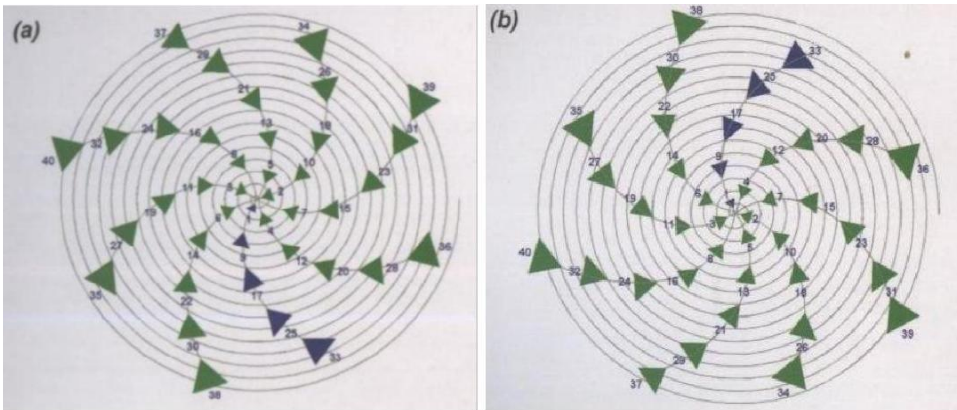

Figure 1. Graphical Representation of Oil Palm Leaf Spiral. (a) Left-handed spiral (b) Right-handed spiral (Fairhurst, 1998).

Derivation of Harvesting Model Formula

Growth models were developed by Kassim, (2014) to determine the FFB maturity stages and the information was used to estimate FFB harvesting date. The formula utilized the information of maturity stage in week value determined by using growth model, duration of FFB development (6 month), rate of leaf production (2 leaves per month), and the information of the date of data acquired. Equation 1 was derived to calculate age of the FFB.

$$W = 4\left[\frac{FFBPLS - FFBALS}{RLP}\right] \quad (1)$$

W = Predicted age FFB (week)
FFBPLS = FFB position in leaf spiral (x^{th} leaf)
FFBALS = FFB at anthesis in leaf spiral (20^{th} leaf)
RLP = Rate of leaf production (2 leaves per month)

In order to solve Equation 1 and determine the predicted age of FFB in weeks (W), number of leaf produces per month must be determined first. In this case, rate of two leaves produced per month is identified through the age of the oil palm tree which is above than 7 years. FFB anthesis in leaf spiral (FFBALS) should be decided. In this research we are using 20th leaf as FFB starts to anthesis and 33 rd as leaf holding matured FFB. FFB position in leaf spiral has to be calculated manually from the oil palm tree based on the spiral representation shows on Figure 1. Information of predicted age of FFB in weeks is used to calculate the date of harvest in Equation 2.

$$DOH = DODA + [DOFBB - (W \times 7)] \quad (2)$$

DOH = Date of Harvest (DD/MM/YYYY)
DODA = Date of Data Acquired (DD/MM/YYYY) DOFBB = Days of
FFB Development (6 month = 180 days) W = Predicted age of FFB
(week)
(W x 7) = Predicted age of FFB (days)

Days of FFB development (DOFBB) need to be identified first in order to solve Equation DOFBB was taken as 180 days (6 month). Date of data acquired (DODA) was the date of the FFB position in leaf spiral identified and FFB image was captured.

Color recognition model software

The images of FFB were acquired in autofocus mode independent of specific weather condition, time of acquisition and distance from object of interest. This approach can be done by any unskilled worker at any time during day light. FFB bunch must be visible at least 80% of the total image size. The image was captured when it is still on the tree in order to estimate the date of harvesting. Figure 2 shows the flow chart of the process to extract the digital images data.

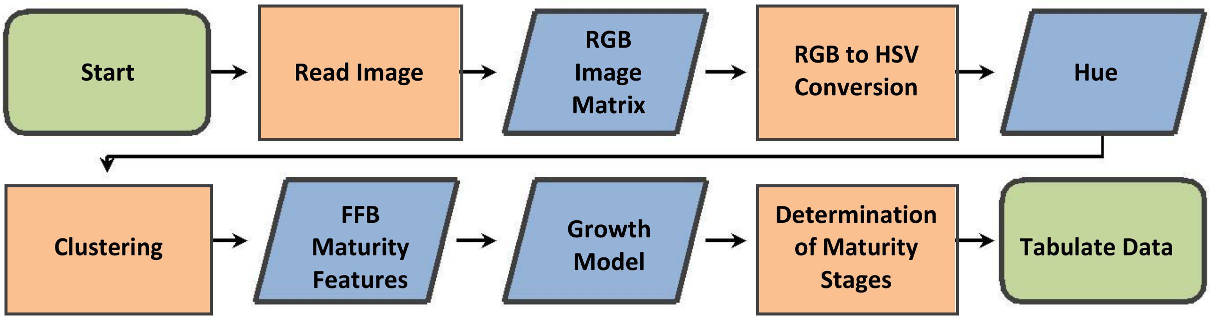

Figure 2. Flow chart of the Color Recognition Model Software.

Table 1. Color Model based on different major maturity group stages (Kassim et al., 2014).

Growth Stages	Multiple Linear Regression Model (MLR)
FMGS (Week 0 to 5)	y = 2.52 - 14.28(GS) + 3.09(BS) + 1.54(FT)
SMGS (Week 6 to 14)	y = 12.7 + 6.84(GS) + 6.23(BS) – 7.80(FT)
TMGS (Week 1 5 to 22)	y = 7.94 – 2.28(GS) + 0.32(BS) + 13.95(FT)

In order to automate the process of determining the FFB growth stages and maturity prediction, a GUI was developed by using MATLAB application. The process begins where the software read the image data loaded by the user. The software performs the color space conversion from RGB (red, green and blue) color space into HSV (hue, saturation and value) color space followed by the color clustering process. The extracted FFB features was be arranged in a table and the FFB maturity stages were determined based on the growth model. According to Kassim et al. (2014), FFB can be classify in three major stages. The first stage was from week 0 to 5 known as First Major Growth Stages (FMSG), second stage was from week 6 to 14 known as Second Major Growth Stages (SMGS) and third stage from week 15 to 24 known as Third Major Growth Stages (TMGS). FMGS was the beginning period of anthesis where trilobes flower emerged and changes the color from red to black until the formation of fruitlet. SMGS was the period of the fruitlet development from black color to purplish black. TMGS was where the beginning of the fruitlet color changes from purplish black to yellowish red. On each maturity stages, the data needs to be run separately as classified using different color model as in Table 1. The software automatically tabulate the data after completed the image processing task. The data information contain estimated FFB age in week and estimated date of harvest.

RESULTS AND DISCUSSION

Table 2 shows sample processed data at the end of the research. There were 27 oil palm trees monitored throughout this research.

Table 2. Sample of processed data.

Tree-FFB	Date of Data acquired	Position of FFB in leaf spiral	Estimated Harvesting Date by using		Actual Harvesting Date by farmers
			Position of FFB in Leaf Spiral	Color Recognition Model	
P20-C	14-Oct-15	29	7-Dec-15	17-Dec-15	30-Dec-15
P20-D	14-Oct-15	26	18-Jan-16	31-Jan-16	29-Jan-16
P20-E	14-Oct-15	28	21-Dec-15	20-Dec-15	30-Dec-15

Overall data comparison

The existing color recognition model was compared with the result based on FFB position. Both methods were tested on unharvest bunch and date of harvest estimation was compared with the actual harvesting date. Total of 102 oil palm FFB were monitored in this research. Date of oil palm FFB being harvest by harvester was recorded as the actual harvesting date. Since that harvesting cycle in interval of 2 weeks' time, therefore we consider ± 2 weeks as acceptable result. The accuracy of both method were shown in Figure 3.

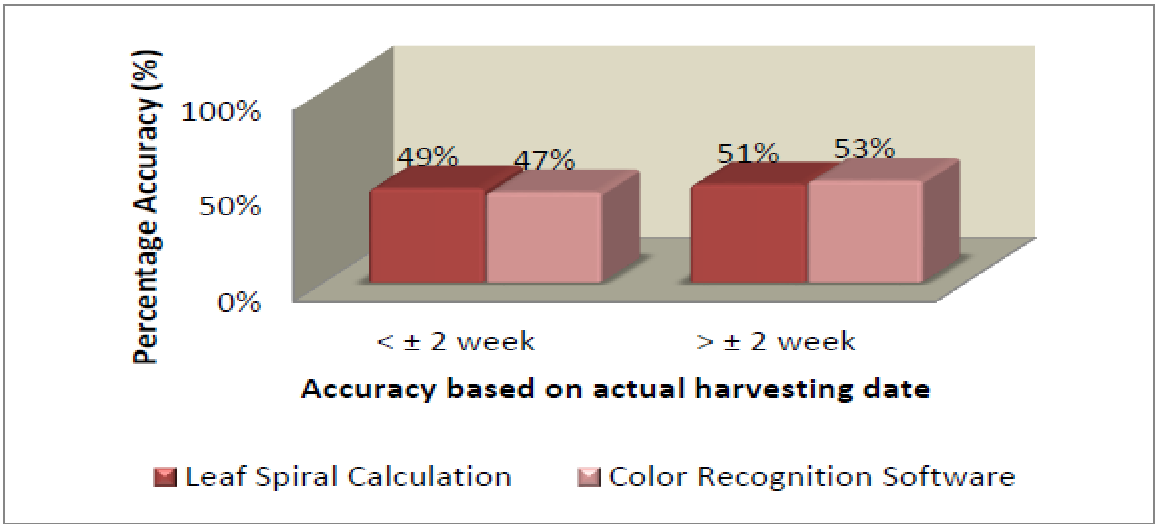

Figure 3. Accuracy percentage comparison between calculation leaf spiral and color recognition model software method.

Harvesting date estimation using leaf spiral calculation shows 49% accuracy result whereas 47% accuracy by using color recognition model. Remaining 51% estimation using spiral calculation shows inaccurate result whereas 53% inaccurate result for color recognition model software. There is no significant difference in accuracy between leaf spiral estimation and color recognition model software estimation. Based on percentage of accuracy, harvesting date estimation using leaf spiral calculation gives slightly better result compared to color recognition model software method.

Maturity group stages comparison

Identification of major maturity group stages was important for oil palm FFB harvesting date estimation for color recognition model. Based on Table 1, Multiple Linear Regression Model (MLR) equation for each major maturity group stages was different based on the mean Hue value from each maturity features. Figure 4 shows the comparison of accuracy between the three maturity stages compared with the actual harvesting.

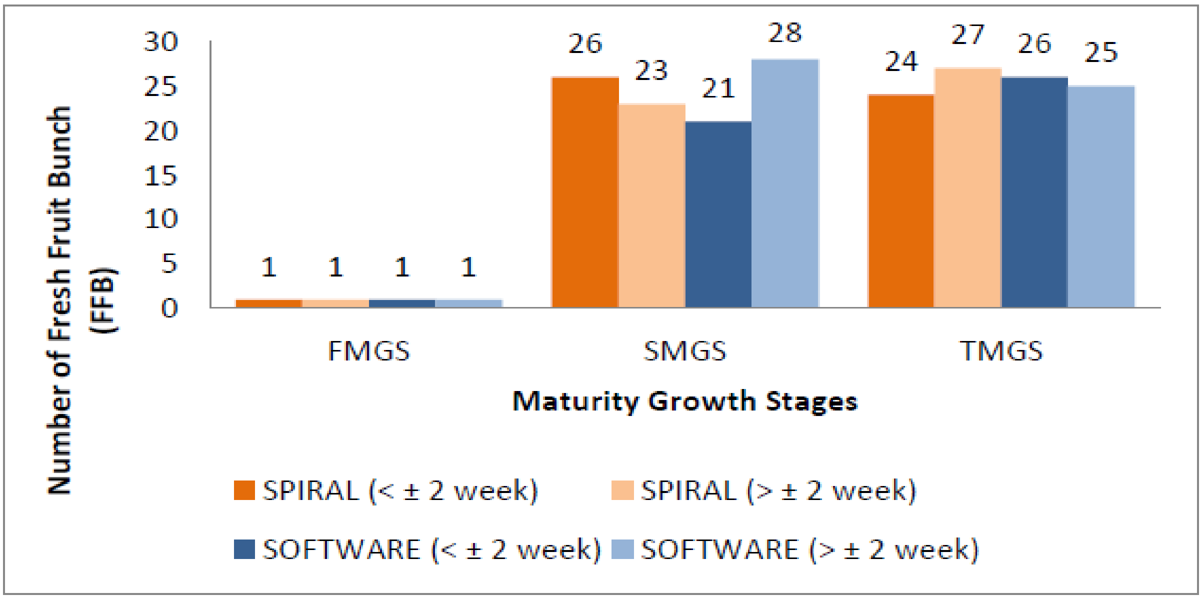

Figure 4. Comparison accuracy between major maturity group stages.

There were only two available FFB between FMGS group (week 0 to 5) during this research. The result shows only one bunch accurate on estimation harvesting date using both method leaf spiral calculation and color recognition model software. There were 49 FFB observed on SMGS (week 6 to 14). The result shows that estimation harvesting date using leaf spiral calculation method has a better accuracy with 26 bunch accurate compare to color recognition model software accuracy was 21 bunch accurate. For TMGS (week 15 to 24), there were 51 FFB observed in this research. The result shows that estimation harvesting date using color recognition model software method has better accuracy with 26 bunch accurate whereas using leaf spiral calculation method was 24 bunch accurate.

CONCLUSIONS

The following conclusions can be drawn from the study:

- In this research, the comparison between two methods of oil palm FFB harvesting date estimation was studied. The two method was using leaf spiral calculation and color recognition model software.
- Both method shows quite similar result and has been proven applicable in filed practice. However, harvesting date estimation using leaf spiral calculation shows slight better result and the method was easy to conduct compare to color recognition model.
- Estimation using leaf spiral calculation method can be used by all group of maturity from week 0 until the ripe bunch. This method was not dependent on the color of the FFB but only on the leaf number production per month. Vice versa, for color recognition model software method color of FFB was the most important features that effect the accuracy of the software.
- Therefore a better data collection method for color recognition model software method should be propose in order to use this method on plantation scale.

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