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Image Clustering Technique in Oil Palm Fresh Fruit Bunch (FFB) Growth Modeling

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Abstract

Digital images of FFB from anthesis to harvesting stage were acquired and grouped into 25 maturity stages. K-means clustering technique was used to separate the images into three colours clusters that represent three FFB features, Fruitlet, Brown spine and Green spine. The relationship of Hue colour component and FFB maturity stages was established. The FFB was found to grow in three major stages, from week 0 to 5, week 6 to 14 and week 15 to 24. From the relationship a Growth Model was developed and was validated with actual maturity stage. The coefficient of determination, R^2 was 0.95.

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Keywords: Image Processing, Pattern Recognition, Vision System

1. Introduction

Oil Palm (*Elaeis guineensis* Jacq var. Tenera) is one of the most important plantation crops in Malaysia. Oil Palm FFB harvesting and collection form a single largest direct cost in the production of oil palm (Gan et al., 1993; Omereji, 1991). Harvesting Oil Palm FFB at right stage of ripeness is critical to ensuring optimum quality and

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quantity of oil production and thus profitability to the industry (Rajanaidu et al., 1988). In order to maximize the oil extraction rate, the FFB should be harvested at its peak of ripeness (Ariffin, 1984). Currently FFB color and loose fruitlet is the indicator to harvest the FFB. In the standard operating procedure, matured FFB is highly related with number of loose fruits drop under the oil palm tree (Ghani et al., 2004). According to Ghani et al. (2004) if the FFB dropped just one fruitlet, the bunch is at the optimum maturity stage. The loose fruits have a drawback because uncollected loose fruit is one of the factors contributed to the losses in Malaysia oil palm industries. During executing the harvesting operation the harvester will carry a sickle attached to bamboo or aluminum pole for palm tree over 12 m height and chisel for shorter palm. They will move to each tree searching for ripe fruit (including tree without ripe FFB) and used their own experience to guess the maturity stage based on the natural indicators, execute the cutting of the ripe bunch and continue searching for ripe bunch. Time consumed process in searching for matured FFB and tedious harvesting task had force them to lose their judgment, consistency and concentration. Thus the need for FFB maturity determination system and site specific harvesting is crucial. A new kind of monitoring system required to determine maturity stages of oil palm to avoid losses due to loose fruit (Osborne et al., 1992 and Ghani et al., 2004).

Nomenclature

FFB	Fresh Fruit Bunch
FT	Fruitlet
BS	Brown Spine
GS	Green Spine
FMGS	First Major Growth Stages
SMGS	Second Major Growth Stages
TMGS	Third Major Growth Stages

1.1 Project Overview

In every cycle of harvesting operation, farmer does not have any information on how many ripe bunches and which oil palm tree will be harvested. Their task will be easy if they know the exact location of ripe FFB. A reliable FFB maturity stage determination system and its specific location will be very useful towards better oil palm crop management system. Farmer can schedule and execute targeted harvesting effectively if they know the exact location of ripe FFB. Availability of this information enables effective work force management at every harvesting cycle. Worker salary per harvested bunch and total count of bunches can be easily projected before completing the task and yield for every harvesting cycle easily justified after completing the harvesting operation. The need of such information motivates us to develop models that can provide farmers the needed information.

This research was carried out at the Universiti Putra Malaysia oil palm field at the coordinate of 2°58'47.97"N and 101°43'44.77"E. Sixty oil palm trees at the age of five years were selected to be monitored. In this research a fruiting cycle of oil palm FFBs were observed within the period of fruit development starting from the early FFB development until the day of harvesting. Oil palm FFB takes 17 to 24 weeks to ripen from the anthesis stage to maximum oil content synthesis. According to Corley and Tinker (2003) anthesis of normal FFB inflorescence start when the trilobes flower open and after anthesis the trilobes flower change to purplish color. Anthesis in normal inflorescence usually last for 36-48 hours but may extend to a week. Based on this information image acquisition was carried out in three days interval to acquire the images of FFB spanning from the inflorescence stage to harvesting stage.

2. Literature review

Nowadays, the research on ripeness sensing of FFB becomes more and more popular. Advantages of using imaging technology for sensing are that it can be fairly accurate, nondestructive, and yields consistent results. Machine vision is used because it is capable of not only to recognize size, shape, color, and texture of objects, but also provide numerical attributes of the objects or scene being imaged (Yud et al., 2002). Color is considered to be one of the most important external factors of fruit quality, as the appearance of the fruit greatly influences consumers. The relationship between color and level of maturity has been widely studied in agriculture sector. Ariana et al. (2006), Lu (2004), and Xing et al. (2007), developed vision system to access the quality of apple. Feyaerts and van Gool (2001); Piron et al. (2008); Piron et al. (2009) developed vision system for weeds recognition in weeding operation. 3D panoramic image for crop growth status was developed by Kise and Zhang (2008). Estimation of crop age (McMorrow, 2001), paddy rice row detection (Kaizu and Imou, 2008) and vision system for cherry harvesting robot (Tanigaki et al., 2008).

Color of oil palm FFB remains one the important factor which determines the grade and quality of the palm oil. Malaysian Palm Oil Board (MPOB) established four classes of FFB maturity stages by referring to the surface color of the FFB. The classes are unripe, under ripe, optimally ripe and over ripe. The unripe class exhibits purplish black color. Meanwhile under ripe and optimally ripe classes appear reddish black and reddish orange in color respectively. The overripe class exhibits almost entire FFB reddish orange coloration. Color of matured FFB was not a constant feature and varies between individual palms and between geographic areas (Arokiasamy, 1968). To have an accurate estimation of FFB ripeness based on RGB color index required more than 100 samples per class, and the percentage of accuracy was around 90 percent (Abdullah et al., 2001). Wan Ishak et al. (2000) and Alfatni et al. (2008), used RGB color camera to capture the image of harvested FFB. The intensity values of R (Red), G (Green) and B (Blue) were analyzed to differentiate the FFB into categories namely unripe, under ripe, ripe, over ripe, empty and rotten. Abdullah et al. (2001) used computer vision model in order to inspect and grade the oil palm fresh fruit bunches. Balasundram et al. (2006) used camera vision to investigate the relationship between oil content in oil palm fruit and its surface color distribution. In recent years, hyperspectral imaging was introduced in the ripeness estimation of oil palm FFB. Junkwon et al. (2009) developed a system to estimate the weight and ripeness of FFB using color and hyper spectral imaging.

FFB maturity determination developed by Wan Ishak et al. (2000), Abdullah et al. (2001), Balasundram et al. (2006), Alfatni et al. (2008) and Junkwon et al. (2009) focus on four maturity classes of harvested bunches which were unripe, underripe , ripe and overripe. Their research was conducted under controlled environment and involved a complex procedure to acquire the images of FFB. Their application mainly for grading of FFB at mill level. The developed methods and models of FFB maturity determination need to be simplified. As stated by Osborne et al. (1992) a new kind of maturity determination is required that is simple and affordable. The new develop system must cover more FFB maturity classes, and can be applied at field or mill level without involving complex procedure and equipment.

Most researchers select the surface color of the FFB as the feature to establish the relationship. The surface of the FFB comprises many colors, which most researcher account that as single feature by taken the mean value of the colors. Therefore the colors of the surface must be separate into groups of color that can distinguish the FFB feature such as fruitlet, green spine, blunt spine, trilobes flower and many more. Each of these feature have a significant effect towards the FFB maturity. The statistical analysis can be used to determine the significant of these features in determining the maturity stages especially the analysis of variance (ANOVA). Further the Duncan test can be used to compare the mean in order to select the best group of mean value to establish the relationship of color and ripeness. The equation can then be determined from the result. Commonly the linear regression and multiple linear regressions were used to represent the relationship.

3. Materials and methods

Panasonic DMC-TZ10 camera with embedded global positioning system (GPS) receiver was used to acquire the FFB images. Each oil palm trees, female inflorescences at anthesis and FFBs under study were tagged and given an individual identity for data recording and retrieval purposes. The images of FFB were acquired in autofocus mode, independent of specific weather condition, time of acquisition, and distance from the object of interest and camera or FFB orientation. This approach was considered to ease the image acquisition process where it can be carry out by unskilled worker at any time during day light.

3.1 FFB images grouping based on maturity stages

A complete FFB development from anthesis to harvesting was named as 'Full Set FFB'. The images contain a physical appearance of FFB from early development until the days of harvesting. Determination of Full Set FFB maturity stages was manually measured from the recorded data during monitoring process. The date of image acquisition of opened trilobes flower where anthesis stage begins was recorded as the date of maturity stage in week 0 to indicate the beginning of the FFB development. The last image in the Full Set FFB images will be the image of FFB before harvesting takes place. It can be on the same day of harvest or within three days before harvesting (three days interval image acquisition). The Full Set FFB was grouped into 25 groups based on the 25 level of maturity stages. Each group was named as W0 until W24 to indicate level of maturity in week. More than hundred samples of images for each level of maturity stages were acquired to be process.

3.2 Digital image processing

Three physical appearance of the oil palm FFB were considered as feature to determine the maturity stages namely Fruitlet, Green sharp spines (The bract of oil palm female flower) and Brownish blunt spines (the end of flower spikelet). Fig. 1 shows the difference of physical appearance of oil palm FFB 10E in three different maturity stages. The green arrow pointed to Fruitlet, the blue arrow pointed to the Green spine and the red arrow pointed to the Blunt spine. These three features will changed either in colour, size or length as the oil palm FFB grow to matured stage. Based on the visual appearance the easiest feature to evaluate is the colour. The images were processed to extract the colour information to investigate the maturity stages. The colours in the images were separated using image clustering technique.

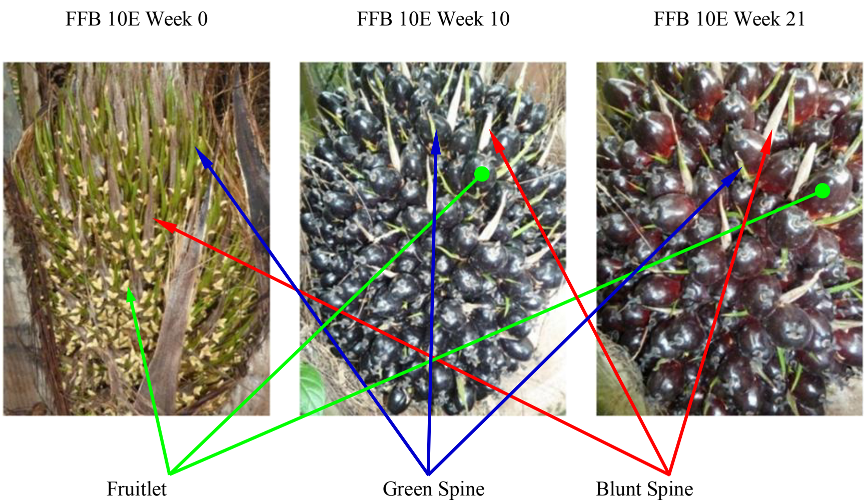

Fig. 1. Physical appearance of oil palm FFB fruitlet, sharp spine and Blunt spine.

3.3 Image clustering

The images were clustered using K-means clustering technique to separate the maturity features into a measureable form. This process was performed to separate the colours in order to remove the unwanted objects and measure the exact colour space value of selected feature that represents maturity features rather than analyse the color space of the whole FFB. The FFB images were in Red, Green and Blue (RGB) colour space. In this process the RGB colour images were converted into HSV (Hue, Saturation and Value) colour space. The Hue colour component of the images were then underwent the image clustering process. Fig. 2 shows the example of the clustered images. It shows the images of three main features namely Fruitlet (FT), Green Spine (GS) and Brown Spine (BS). In order to establish the relationship of Hue colour component value and maturity stages, each group of maturity stages were gone through the Statistical analysis.

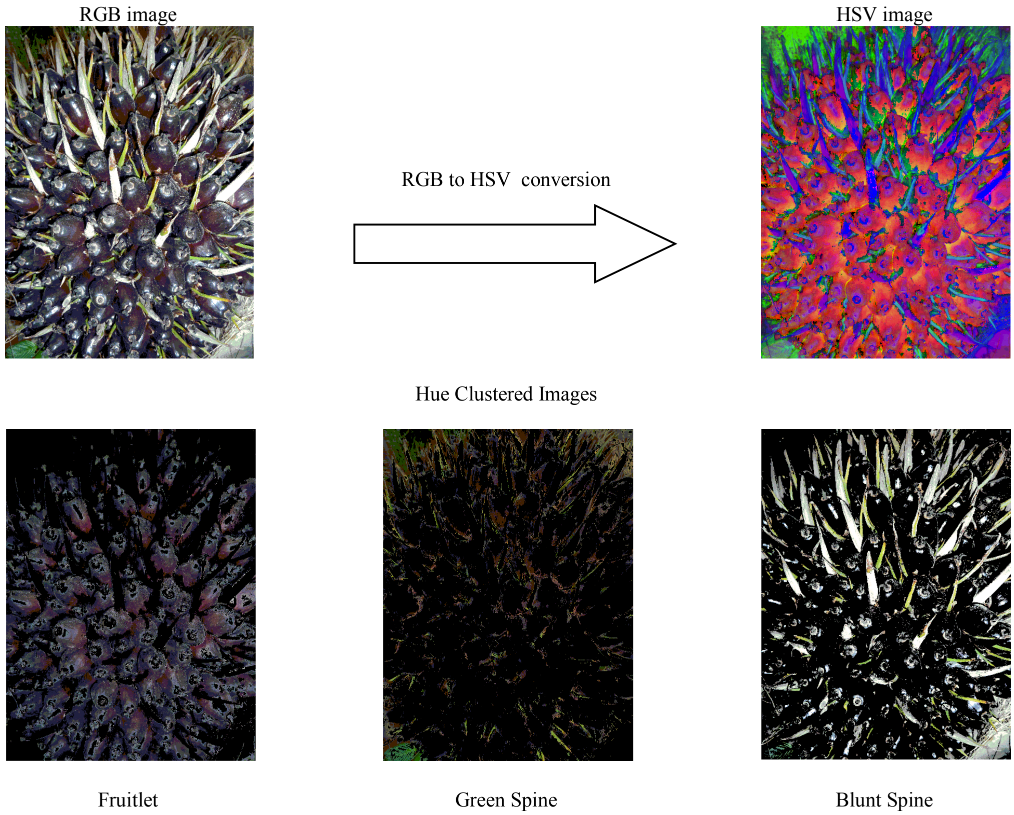

Fig. 2. Clustered images of FFB in Hue colour component.

4. Results and discussion

The mean Hue value was plotted versus the maturity stages. Fig. 3 shows the plotted mean hue for images of Green Spine (GS), Fruitlet (FT) and Blunt Spine (BS). The plotted graph showed that the relationships were not linear for all three clusters. The plotted graph for the mean Hue of FT, GS and BS can be divided into three sections. The first section was from week 0 to 5 named as First Major Growth Stages (FMGS), second section was from week 6 to 14 named as the Second Major Growth Stages (SMGS) and the third section from week 15 to 24 named as Third Major Growth Stages (TMGS).

Through images observation, it was found out that the FMGS was the period of the beginning of the anthesis stage in week 0 where the trilobes flower emerged and changes the color from red to black to the formation of the fruitlet in week 5. SMGS was the period of the fruitlet development from tiny black color to purplish black. During this period (week 6 to 14), it was very difficult to differentiate the maturity stages since all fruitlet appear black in color the only different was the fruitlet sizes. TMGS (week 15 to 24) was where the beginning of the fruitlet color changes from purplish black to yellowish red. This is the period of the synthesis of oil in the fruitlet mesocarp, as the oil accumulate the color of the fruitlet also changes.

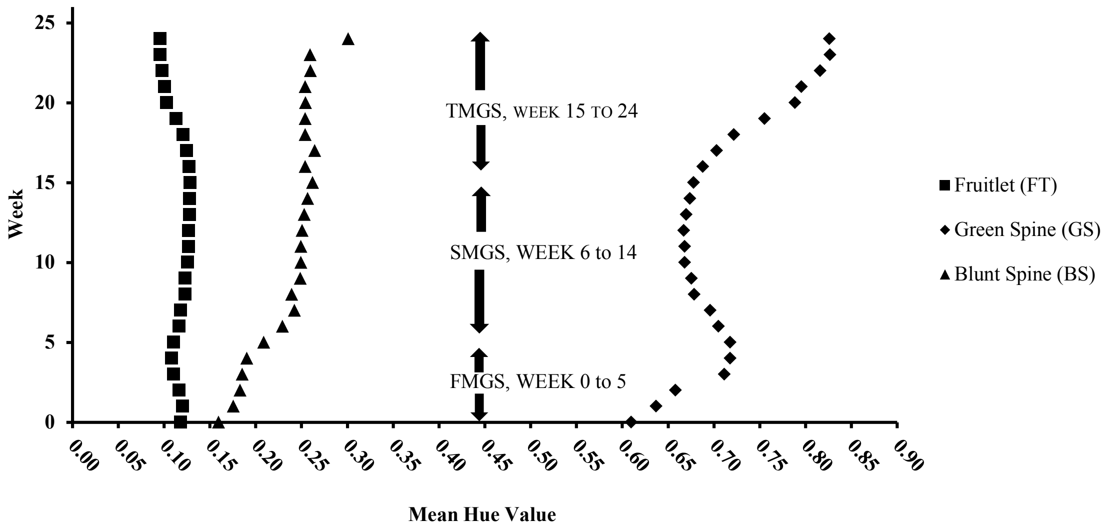

Fig. 3. Graph of the relationship of Hue value and maturity stages.

4.1 FFB growth model by using Hue color space

Table 1 tabulated the obtained Multiple Linear Regression Model (MLR) equation for the FFB Growth Model based on the mean Hue value from each FFB maturity features namely GS, FT and BS

Table 1. The obtained Hue colour component equation for FFB Growth Model.

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 15 to 22)	y = 7.94 – 2.28(GS) + 0.32(BS) + 13.95(FT)

4.2 Data Validation

In the validation process a sets of oil palm FFB were chosen. The accuracies of the validation data were measured in two aspects, the difference between the predicted value and the actual value and the measure of coefficient of determination, R^2 of the predicted value as compared to the actual value. Fig. 4 shows the sample of the graph of Predicted Maturity Stage and Actual Maturity Stage of oil Palm FFB from tree P9. Six FFB from oil palm P9 was chosen namely FFB 9H, 9I, 9J, 9K, 9L and 9M. Random samples of FFB images were drawn from each FFB samples. Extracted Hue value from the images samples were feed to the models. As a result, Hue based models has a coefficient of determination, R^2 = 0.92 in determining the maturity stages of FFB taken from oil palm tree P9.

Predicted maturity stage value from this model can be used to determine how many days left before harvester can execute the harvesting operation, and enabled site specific harvesting since the image data embedded with GPS location. Efficient yield recording since maturity stages and harvesting time is known. Consequently this finding will help increase oil palm production.

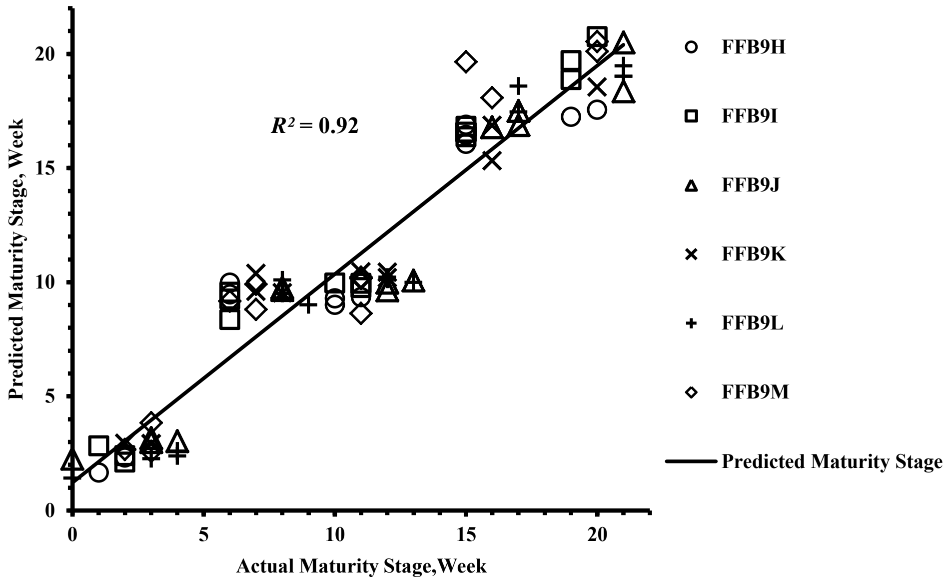

Fig. 4. Plot of actual maturity stage vs predicted maturity stage of FFB samples from oil palm tree P9.

5. Conclusions

The developed models to predict the growth stages of FFB utilize the information of the processed FFB digital images. The models can promote towards better plantation management and can revolutionize the oil palm industries. In term of introducing the site specific oil palm harvesting that will save more time in roaming and searching the ripe FFB. Possible daily harvesting schedule since maturity level and specific location were known. Eliminate grading operation at mill level since maturity stages were confirmed at field level. These advantages will increases oil palm production productivity for the whole plantation in Malaysia. Findings from this research will lead to the path of realization of the robotic harvesting system. Since the developed models solve the detection of FFB maturity level, location of matured FFB and initial information of the exact location of FFB.

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