A NOVEL TECHNOLOGY APPLICATION IN AGRICULTURE RESEARCH

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Abstract: This study introduced the application of novel technology namely camera vision system for detection and classified the maturity stage of oil palm fresh fruit bunches (FFB). Normally FFB are classified into six categories; black, hard, ripe and overripe. However, for initial study, three types of FFB were used; ripe, unripe and overripe. A camera vision system developed in this research is made up of two critical components. The first component is the hardware component that functions as an image acquisition for the system. The second component is the software part which analyzes the image captured by the hardware component. The system made prediction of FFB’s maturity by processing the image captured. The main hardware system in this study is a digital camera to capture the image of the sample oil palm fruits and a light meter to detect intensity of the light. Sample pictures were taken in an oil palm plantation at Malaysia Palm Oil Board (MPOB) Bangi Lama Selangor, Malaysia. Oil palm FFB maturity prediction in this research was done by determining the Hue values of oil palm at different stages of maturity. The prediction was also made on the relationship between Hue and oil content in the fruit.

Key words: Camera vision technology, Non-destructive method, Oil palm fresh fruit bunches Maturity prediction.

INTRODUCTION

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 color of the fruit on the tree is highly dependent on cool temperatures at night, not always present under tropical and subtropical growth conditions. The Color Index may not be used consistently to indicate maturity in these regions. However, although a green fruit may or may not be physiologically mature, a fruit colored on the tree is always mature. So the risk of selecting immature fruit by their color is very improbable, if they are not artificially degreened. Applications of machine vision technology improve industry's productivity, thereby reducing costs and making agricultural operations and processing safer for farmers and processing-line workers. It also helps to provide better quality and safe foods to consumers. It holds great potential and benefits for the agricultural industry because of its simplicity, low cost, rapid inspection rate, and broad range of applications.

LITERATURE REVIEW

The technique of using non-destructive method such as vision to determine the oil palm ripeness,
Wan Ishak et al., (2000) used camera vision to categorize ripeness of oil palm FFB. 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. Idris et al., (2003) use colorimeter and found a strong correlation between mesocarp oil content and color values of internal mesocarp surface. He mentioned that a strong correlation was found between mesocarp oil content and color values with $R^2 = 0.82$ (in second order polynomial regression analysis). A ripe fruit contains a maximum amount of oil in the mesocarp indicated by a plateau on the graph. Color value at this point was taken to differentiate between ripe and under ripe fruits. Advantages of using imaging technology for sensing are that it can be fairly accurate, nondestructive, and yields consistent results. Razali et al., (2009) used camera digital camera to recognize the oil palm fruit maturity. They did the analysis of the FFB images which captured in both conditions of outdoor direct sunlighting and natural environment in real oil palm plantation. The captured FFB images were uploaded into analysis software to determine the digital value of $R$, $G$ and $B$ color component.

**METHODOLOGY**

The first monitoring period for oil palm fruit and lighting intensity was made started on the 11 December 2008 until 31 December 2008. The second monitoring period was held from 10 August 2009 until 06 October 2009. All experiments were conducted within 8 to 9 weeks monitoring period. The FFB images captured were only after the fruit was completely growth with the fruit color skin changed at from black to reddish color. This is based on the study by Kaida and Zulkifly, (1992) that mentioned; at the stage of young fruits ripeness (within 7 to 11 weeks after flower was open - anthesis), the color of fruits skin is black and only change to reddish black from that duration. They mentioned the fruits within 15 to 17 weeks after anthesis, had color surface of black plus reddish black while the oil percentage was less than 5%, at 18 to 19 weeks after anthesis, the fruits color was reddish orange with 40 to 48% oil content, at 20 to 22 weeks, the fruit color surface was reddish orange plus orange and at 22 to 23 weeks after anthesis, the fruit color was mostly orange with more than 50% oil content. The measurement of the oil content was based on percentage of oil with fresh Mesocarp ratio. It is the wet base measurement.

**Experimental set-up for Image Capturing**

The fruits were selected from 3 categories of palm tree at aged of 5, 16 and 20 years old and 3 tress were choose on each categories. The five years old tree was chosen because the initial production of FFB, while twenty years old tree represents the optimum output of FFB while the 25 and 30 years old trees are considered optimum aged for replanting (Azman and Mohd. Noor, 2002). Sixteen years old palm tree are regarded as the middle aged of oil palm production. All the tress used in the experiments were selected from variety of Tenera (Dura X Pasifera): *Elaeis Guineensis* and monitoring duration at from the FFB at ripe maturity stage until overripe maturity stages. Forty nine experiments were carried in this work and the research plot conducted was at the UKM-MPOB Research Station in Bangi Lama, Selangor, Malaysia situated about 30 km South of Kuala-Lumpur. Figure 1 shows the map of the research site.

The work was carried out to determine the relationship of optical properties of matured FFB with light intensity which measured at outdoor intensity on directly exposed to the sunlight. The monitored area on FFB skin was fixed and only captured during day light. The experiment continued with different maturity stages of FFB were exposed to direct sunlight and natural lighting intensity in the actual plantation at Muar, Johor and Felda Kemahang 1, Tanah Merah, Kelantan, Malaysia.
RESULT AND DISCUSSION

This study present and discuss about the relationship of optical properties of the oil palm fruit with the oil content of mesocarp oil palm fruit at different stage of maturity.

Figure 2 shows the relationship between the value of matured FFB and the sunlight intensity. The pixel value of the image would be directly influenced by slight changes of daylight intensity. Because of the high correlation between the lighting intensity with the optical properties of $R, G$ and $B$ in outdoor condition, therefore it was difficult to identify the exact optical value for matured FFB.

Correlation for RGB Color Components

The optical properties of RGB component of matured FFB were captured and analysed based on outdoor lighting condition taken at various time. Table 2 shows the Linear Regression model and the regression squared of correlation for RGB Color Components of Matured FFB in outdoor Condition.

From the experiment which record, the daylight intensity was at its maximum at around 11:00 am with FC value of 6740 and pixel value of 255 for red, 227 for green, and 232 for blue colour components. This was due to the clear sunlight in the morning that brought about maximum intensity values recorded.
The minimum values were recorded at 15:00 pm with FC value of 690 and pixel value of 149 for red, 76 for green, 43 for blue. The cloud covers on the sky that came around 15:00 pm caused lower reading of the intensity of light.

For the red colour component, the pixel value before 12:00pm was always constant at 255. The pixel values varied linearly after 12:00pm. The minimum pixel value for red component was 138 is recorded at 15:00 pm with intensity reading of 690. The calculated linear regression equation as follows:

\[ y \text{ (pixel value)} = 0.020x(FC) + 149.1 \]
\[ R^2 = 0.865 \]

For the green colour component, the maximum pixel value was 227 recorded at 11:00am with intensity reading of 6740 while the minimum pixel value was 76 recorded at 15:00 pm with intensity reading of 690. The calculated linear regression equation is as follows:

\[ y \text{ (pixel value)} = 0.023x(FC) + 79.11 \]
\[ R^2 = 0.944 \]

For the blue colour component, the maximum pixel value was 232 recorded at 11:00am with intensity reading of 6740 while the minimum pixel value was 43 recorded at 15:00pm with intensity reading of 690. The calculated linear regression equation as follows:

\[ y \text{ (pixel value)} = 0.026x(FC) + 49.19 \]
\[ R^2 = 0.964 \]
Table 1: The linear regression model and regression squared of correlation for RGB color components of matured FFB in outdoor condition

<table>
<thead>
<tr>
<th>Color Component</th>
<th>Linear Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>$y$ (pixel value) = 0.020 $x$ (FC) + 149.1</td>
<td>0.865</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td>$y$ (pixel value) = 0.023 $x$ (FC) + 79.11</td>
<td>0.944</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue</td>
<td>$y$ (pixel value) = 0.026 $x$ (FC) + 49.19</td>
<td>0.964</td>
</tr>
</tbody>
</table>

From the result, the R, G and B color components had highest pixel value at 11:00am, with the highest intensity of 6740 FC while lowest at 15:00pm with intensity of 690 FC. This showed that the pixel value of the image would be directly influenced by slight changes of daylight intensity. Because of the high correlation between the lighting intensity with the optical properties of R, G and B in outdoor condition, therefore it was difficult to identify the exact optical properties of digital value for matured FFB. Similar results were obtained in many other researches which mentioned that the change in intensity would change all the components of R, G and B accordingly and this is due to high correlation between each component with the intensity (Littmann and Ritter, 1997; Pietikainen, 1996; Cheng et al., 2001). There is a widespread belief that some models are more "natural" than others. For example, the standard reference work on computer graphics by Foley et al. (1990) claims that: The RGB color models are hardware oriented. This advantage caused the RGB to be the most commonly used model for the television system and pictures acquired by digital images after modulating the intensity of the three primary colors (red, green, and blue) on each pixel of digital image (Comaniciu and Meer, 1997). By using this principle, Wan Ishak et al., (2006); Wan Ishak, (2008); Wan Ishak and Khairudin, (2008) had developed and tested the color vision system for weed detection and spraying. Any change in the intensity reading on the field was updated into the software automatically, and the Graphical User Interface (GUI) software was trained to recognize the RGB of the target weed which matched up with the current.

Colorsace of RGB and Hue Conversion

The HSL (Hue, Saturation and Luminance) color system has the ability to represent color for human perception, because human vision can distinguish different hues easily, whereas the perception of different intensity or saturation does not imply the recognition of different colors (Cheng et al., 2001). Besides, application of 1-D hue space is computationally less expensive than in the 3-D RGB space. For this study, the developed graphical user interface software was used to convert the RGB of matured FFB image into Hue value. Figure 3 shows the graph of Hue correlation with the intensity in outdoor condition.
The formula for converting RGB to Hue digital value for matured FFB in outdoor condition is as follows (Gonzalez and Wintz, 1987);

\[
\begin{align*}
    \text{if } B \geq G; \\
    H^0 &= 360^\circ - \cos^{-1}\left[-0.5[(R-G) + (R-B)]\right] / [(R-G)^2 + (R-B)(G-B)]0.5 \times 255 / 360 \\
    \text{if } B < G; \\
    H^0 &= \cos^{-1}\left[-0.5(R-G) + (R-B)\right] / [(R-G)^2 + (R-B)(G-B)]0.5 \times 255 / 360
\end{align*}
\]

From the graph, the correlation of \( R^2 \) is low. The digital value of matured FFB which was monitored in outdoor environment was almost constant throughout, when the Hue optical properties was used. The variances of lighting intensity did not effect the Hue value, which were also stated by David (1990), Gevers and Smeulders (1999) in their research. This is due to the fact the Hue colorspace system separates the color information of an image from its intensity information. The Hue value of matured FFB was below than 70 and similar average was also found by Abdullah et al. (2001 and 2002) tested on controlled condition.

Low or high saturation was left unassigned to any regions in many color segmentation algorithms which mean that if the intensity of the color lies close to white or black, hue and saturation play little role in distinguishing colors (Cheng et al., 2001). For any application of vision machine, even for the best recognition machine; human being, light is responsible for sighting ability. This also proof by the righteous book, as stated in Al-Quran in Surah Al-Baqarah verse 17 more less meaning that the lighting is most factor for viewing purpose.

Besides imaging objects in the visible color region which is between 400 – 700 nanometer (nm), some machine vision systems are also able to inspect objects in light invisible to humans, such
as ultraviolet (200 to 400nm), near-infrared (700nm to 2500nm) and infrared (2500 to 5000nm). The information received from objects in invisible light regions can be very useful in determining preharvest plant maturity, disease, or stress states. It is very useful in determining plant and vegetable variety, maturity, ripeness, and quality. It is also useful in detecting postharvest quality and safety, such as defects, composition, functional properties, diseases and contamination of plants, grains and nuts, vegetables and fruits, and animal products (Yud et al., 2002). Machine vision can also be performed using X-ray imaging and nuclear magnetic resonant imaging (MRI). X-ray and MRI are widely used in medical applications. Even though they have potential for detecting diseases and defects in agricultural products and food (Chen et al., 1989; Schatzki et al., 1997; Marks et al., 1998), their applications in the agricultural sector are limited because of the high cost of equipment and low operational speed.

**ANOVA Result for FFB Color Value Exposed to Direct Sunlight and Natural Environment**

The data obtained during the processing of images was analyzed using statistical data analysis software. The ANOVA single factor analysis was executed using SAS 9.1. Tables 1, 2, 3 and 4 show the ANOVA result analysis for the colors values of different maturity stages (namely unripe, ripe and overripe) with two lighting intensities (namely direct sun lighting and natural environment).

**Table 1: AVOVA analysis for Hue**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml</td>
<td>1</td>
<td>33836.2340</td>
<td>33836.2340</td>
<td>4.61</td>
<td>0.0344</td>
</tr>
<tr>
<td>fm</td>
<td>2</td>
<td>518963.8271</td>
<td>259481.9136</td>
<td>35.35</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>ml*fm</td>
<td>2</td>
<td>40898.5342</td>
<td>20449.2671</td>
<td>2.79</td>
<td>0.0668</td>
</tr>
</tbody>
</table>

1ml represent lighting intensities
fm represent maturity stages

**Table 2: AVOVA analysis for Red**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml</td>
<td>1</td>
<td>54991.9886</td>
<td>54991.9886</td>
<td>60.40</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>fm</td>
<td>2</td>
<td>121463.0276</td>
<td>60731.5138</td>
<td>66.71</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>ml*fm</td>
<td>2</td>
<td>100265.6837</td>
<td>50132.8419</td>
<td>55.07</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

1ml represent lighting intensities
fm represent maturity stages

**Table 3: AVOVA analysis for Green**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml</td>
<td>1</td>
<td>52672.76244</td>
<td>52672.76244</td>
<td>22.98</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>fm</td>
<td>2</td>
<td>17750.53921</td>
<td>8875.26961</td>
<td>3.87</td>
<td>0.0243</td>
</tr>
<tr>
<td>ml*fm</td>
<td>2</td>
<td>22706.89881</td>
<td>11353.44940</td>
<td>4.95</td>
<td>0.0090</td>
</tr>
</tbody>
</table>

1ml represent lighting intensities
fm represent maturity stages
Table 4: AVOVA analysis for Blue

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>Mean Square</th>
<th>F Value</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>ml</td>
<td>1</td>
<td>30247.10325</td>
<td>30247.10325</td>
<td>10.97</td>
<td>0.0013</td>
</tr>
<tr>
<td>fm</td>
<td>2</td>
<td>34.35769</td>
<td>17.17885</td>
<td>0.01</td>
<td>0.9938</td>
</tr>
<tr>
<td>ml*fm</td>
<td>2</td>
<td>10068.05951</td>
<td>5034.02976</td>
<td>1.83</td>
<td>0.1667</td>
</tr>
</tbody>
</table>

*ml represents lighting intensities*  
*fm represent maturity stages*

The significant level of 1% was chosen for this calculation, which is traditionally used by researchers (Jeremy and Mark, 2001). From table 3, the Hue color values was not significant at different lighting condition with value of Pr > F showed more than 0.01. Compare to the color values of R, G and B, the Pr > F showed less than 0.01 which means that the R, G and B were highly significant with the effect on different lighting intensity level that shown in tables 4, 5 and 6, respectively. The conclusion from this analysis was that only the Hue color value can be used to determine the FFB color on variance lighting condition while the color value of R, G and B cannot be use due to effect of the intensity changing. That was agreements with other researches which mentioned that the change in intensity would change all the digital value of R, G and B accordingly and this is due to high correlation between each component with the intensity (Littmann and Ritter, 1997; Pietikainen, 1996; Cheng et al., 2001).

The Hue and Red color values had significant effect to distinguish the maturity level (fm) of FFB with Pr > F are showed less than 0.01 as shown in Table 3 and 4 respectively. This was agreement which produced by Abdullah et al., (2002), Wan Ishak et al., (2000); Rashid et al., (2004) and Choong et al., (2006), which stated that the digital value of FFB image was having significant relationship with FFB maturity. The Green and Blue color values were not significant effect to differentiate the FFB maturity level as shown in Table 5 and 6 which indicated the value of Pr > F showed 0.0243 and 0.9938 respectively.

The Hue and Blue color values were not interaction with different lighting condition and the maturity level which indicated Pr > F for ml*fm showed 0.0668 and 0.1667 respectively. From the ANOVA analysis, the Hue is the best color values to distinguish different maturity levels of FFB under direct sun lighting and natural environment conditions in oil palm plantation. Differences in lighting intensity did not affect the Hue color value of the object color which also stated by David (1990), Gevers and Smeulders (1999), because this color system separates the color information of an image from its intensity information.

Means Table

Table 5 show the Mean table for the Hue color value to indicate the percentage of the range among different maturity level of FFB.

<table>
<thead>
<tr>
<th>ml</th>
<th>fm</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
<td>170.70</td>
<td>4.03</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>10</td>
<td>244.90</td>
<td>6.87</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>10</td>
<td>6.30</td>
<td>4.32</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>23</td>
<td>100.17</td>
<td>112.88</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>23</td>
<td>172.43</td>
<td>115.79</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>23</td>
<td>28.61</td>
<td>69.62</td>
</tr>
</tbody>
</table>
From the Table 7, the means of the Hue value for unripe FFB showed between 100 to 170.7, for the ripe FFB showed between 172.434 to 244.90 and overripe FFB showed between 6.3 to 28.61. The result was similar to Abdullah et al (2001) which indicated the Hue value for overripe maturity level was at lower values of 50. The percentage of the unripe to ripe FFB was at 30% to 42% while for ripe to overripe FFB was at 83% to 97%.

CONCLUSION

The Hue color value was greatly significant in identifying the optical properties of each of the categories of FFB namely ripe, unripe and underripe. This result showed that the digital value has significant relationship with FFB maturity. Hue has the highest digital color value, to show a good mechanism for distinguishing maturity stage of oil palm fruits. The Pr > F for Hue on natural environment testing was no interaction with the lighting from the direct sunlight. The phenomenon was different for the natural environment which was covered with tree canopies. So, taking this into account, with the appropriate setting of shutterspeed of the camera, appropriate white balance setting and Hue for determining the digital value of an FFB image, the maturity prediction based on the mesocarp oil content can run on real-time basis in oil palm plantation.

The Hue value was the best color digital component to differentiate the maturity level of FFB in real time oil palm plantation. The experiment conducted in an oil palm plantation and direct sun lighting had showed good result on significance of digital value with maturity level. The extreme intensity of light happened during imaging of FFB under direct sunlight was sheltered by oil palm leaf canopy when experiment on natural environment of oil palm plantation. Protecting the tree from light is the main role played by an oil palm canopy and it is a fundamental requirement for crop growth, which was achieved up to 90% at maximum.

REFERENCES

Ripeness, MPOB Information Series (pp. 195).


Rashid S, Nor AA, Radzali M, Shattri M, Rohaya H, Roop G (2004) Correlation Between Oil Content and DN Values, Department of Biological and Agriculture, Universiti Putra Malaysia, GISdevelopment.net.


