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# Oil Palm Fruit Bunch Grading System Using Red, Green and Blue Digital Number

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**Abstract:** This research deals with the ripeness grading of oil palm fruit bunches. The current practice in the oil palm mills is to grade the oil palm bunches manually using human graders. This method is subjective and subject to disputes. In this research, we developed an automated grading system for oil palm bunches using the RGB color model. This grading system was developed to distinguish between the three different categories of oil palm fruit bunches. The maturity or color ripening index was based on different color intensity. Our grading system employs a computer and camera to analyze and interpret images equivalent to the human eye and brain. The colors namely Red, Green and Blue (RGB) of the palm oil fruit bunch were investigated using this grading system. The computer program developed and used the mean color intensity to differentiate between the different color and ripeness of the fruits such as oil palm FFB. The program results showed that the ripeness of fruit bunch could be differentiated between different categories of fruit bunches based on RGB intensity.

**Key words:** Grading system, ripeness, color, oil palm, fruit bunch, digital number

## INTRODUCTION

Color provides valuable information in estimating the maturity and examining the freshness of fruits and vegetables. Color is one of the most significant criteria related to fruit identification and fruit quality and is a good indicator for ripeness. The color of an object is determined by wavelength of light reflected from its surface. In biological materials the light varies widely as a function of wavelength. These spectral variations provide a unique key to machine vision and image analysis.

Red, Green and Blue are the primary colour components. They are additive, when adding colored lights and subtractive when adding paint pigments. Although the process followed by human brain in perceiving color is a psychological phenomenon that is not yet fully understood, the physical nature of color can be expressed on a formal basis supported by experimental and theoretical results.

In agricultural applications, especially for fruits, we cannot estimate fruit quality just by its shape or pattern. That is because a fruit may have a different shape and pattern but the same level of quality. To solve this problem, the grading system should be able to analyze the color of the fruit and then obtain its quality based on the density of color by using the RGB model. Many grading systems have been developed and practically used for fruits and vegetables. It is possible to substitute human labor and increased the precision by using machine vision.

Most of the traditional methods that have been used to assess fruit ripeness are destructive and thus cannot be so readily applied. Some of these methods rely on the measurement of fruit firmness, which is correlated to ripeness, by using a penetrometer based on shape, feature and colors. Other strategies include measuring levels of chemical species and parameters that are correlated to ripeness such as pH, or spectral image analysis.

Shape is one of the important visual quality parameters of fruits and vegetables. Currently human sorters are employed to sort fruit based on shape. Shape is a feature, easily comprehended by human but difficult to quantify or define by computer. Image processing offers solution for sorting of fruits based on their shape. Many researches explored to establish relationship between object shape and its boundary values in Fourier spectrum. Rao *et al.* (1999a) developed an on-line apple grading system, he also present some new approaches using correlation techniques, graphical analysis of radius and area signature, directional change of contour and boundary Fourier coefficient to extract the shape. Devrim and Bernard (2004) provided comparisons of several feature selection algorithms and classifiers. Their results prove that floating forward selection is the best within heuristic methods and support vector machines

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are better than nearest neighbor classifier in discriminating stem-ends/calyxes from defects.

Computer vision based automatic quality sorting of apple fruits is a hard but necessary task for increasing the speed of sorting as well as eliminating the human error in the process. In this field Unay and Gosselin (2004) classified jonagold apples of varying size and types to pre-determined categories as correctly and as quick as possible. Yang *et al.* (2000) developed an (ANN) Artificial Neural Network to classify images taken from the field and detect the presence of weeds.

The recent development and application of image analysis and computer machine vision in sorting of agricultural materials and products in the food industries was represented by Raji and Alamutu (2005). Basic concepts and technologies associated with computer vision, a tool used in image analysis and automated sorting is highlighted. Edreschi *et al.* (2004) showed that an approach to classify potato chips using pattern recognition from color digital images consists of 5 steps: (1) image acquisition (2) preprocessing (3) segmentation (4) feature extraction and (5) classification. The color in tomato is the most important external characteristic to assess ripeness and post harvest life and is a major factor in the consumer's purchase decision (López Camelo and Gómez, 2004).

Color is a good indicator of the ripeness of fruits and digital image processing is a process where the color data from a sample can be retrieved without making physical experiment on the sample. In other words, the data can be obtained by looking at the image or picture of the product with the help of software that converts the image into Digital Number (DN). Saad *et al.* (2003) determined the color band from image analysis that best correlate against the oil content. Rashid *et al.* (2002) investigated the correlation between oil content in the oil palm fruit against the color of the oil palm fruit. Images from samples of oil palm fruits were acquired using a camera with proper lighting and angle. Image processing and analysis of the samples was carried out. Physical measurements of the amount of oil content in the fruit were carried out by chemical analysis. This study revealed that there is a high positive correlation between the color of the oil palm fruit and the amount of oil in the fruit. This study helps in increasing the efficiency of quality harvesting and grading of oil palm Fresh Fruit Bunches (FFB).

Coronas of apple tree leaves and fruits in order to monitor and compare their state under different conditions were studied by Aleksander and Igor (2002). The results of their study show that coronas of leaves and fruits give useful information about the health status of plants.

Grading of large number of fruits creates a problem related to large variations among the population of fruits. This problem is addressed by using the tools provided by the statistical methods. Rao *et al.* (1999a) developed an on-line apple grading system based on some of the most important external parameters including the fruit's surface color. The specially developed C++ system software package collects the scene for further processing and analysis using RGB mode, color analysis of fruits based on histogram and statistical data based on histogram analysis (Percentage of color components, Mean of color components and correlation factor). Wan Ishak *et al.* (2000) investigated the use of a machine vision system to identify the oil palm fruit bunch by color and trigger a signal to enable the robot to pick the bunch. This project employed a vision system to differentiate and analyze the colors between the oil palm fruit bunches and between the colors of the oil palm bunch with the other objects available in the oil palm plantation.

The current research at the oil palm mills is to grade the oil palm bunches manually using human graders. This method is subjective and frequently disputes arise from this manual grading. Thus the major objective of this research is to develop an automated oil palm fruit bunches grading system using RGB.

## MATERIALS AND METHODS

This study was conducted in 2006 and 2007 at the Bangi Oil Palm Experimental Station. This study was conducted by the research team from University Putra Malaysia (UPM), in collaboration with the Malaysian Palm Oil Board (MPOB) and Malaysian Center for Remote Sensing (MACRES). This study is confined to the whole bunch of an oil palm fruit. The samples of this study are based on three categories of ripeness of fruits which are ripe, under ripe and over ripe. The images covered the whole sides of the fruit by using 2 cameras to get 2 different images simultaneously. This study did not involve the analysis of texture and the shape of the oil palm bunch. Figure 1 shows the integration of software and hardware and Fig. 2 shows the grading system setup.

The instrumentation for the grading system can be divided into hardware and software. The hardware (Fig. 1) consists of 2 cameras. These cameras are connected with computer by cables. The cameras were used to capture images of the whole bunch. The software consists of MATLAB version 7 running on windows XP OS. The MATLAB software was used to perform analysis on the colors of the images.

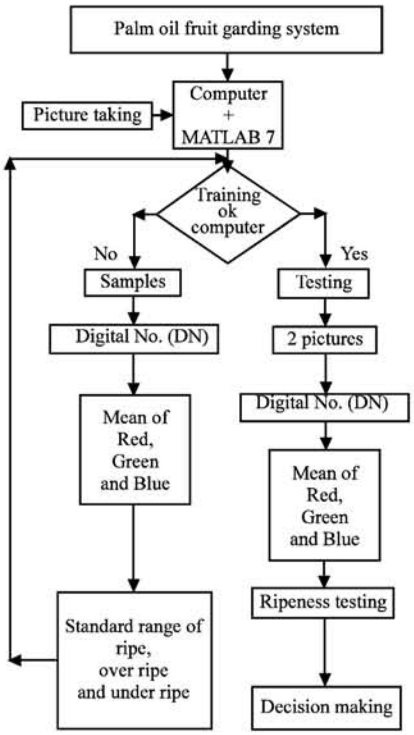


Fig. 1: Integration of software and hardware

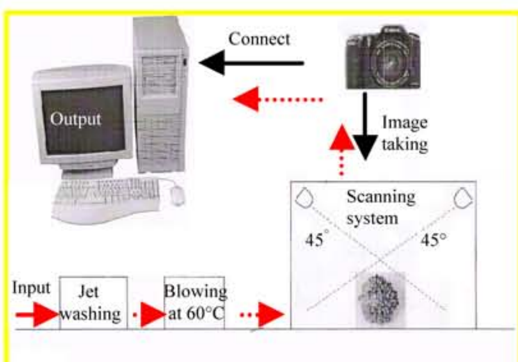


Fig. 2: Fruit grading system setup

**Data collection:** Image data of oil palm bunches are collected from a plantation. Two pictures for each maturity category (ripe, under ripe and over ripe) were taken simultaneously from opposite sides for each oil palm bunch. These images are stored in the hard disk of a high speed PC. Sample the original data for each bunch is shown in Fig. 3.

**Noise removal:** Color density is analyzed to determine the ripeness of each bunch. However, the background color

Fig. 3: The original image for each bunch

Fig. 4: The data without background for each bunch

of the images may mislead the RGB color density of each bunch. For this reason, we need to work on the bunch without its background color. This is done by removing the background color. Figure 4 shows the images after the background has been changed to white color.

The images are now ready to be analyzed. The DN value of each bunch can be obtained and ripeness of the bunch can be known.

**Training Stage:** In this project the computer program was written using MATLAB 7 to analyze the RGB data of the images. First of all, the program reads the data from the specific file and changes it to a DN matrix. The computer program used the mean color intensity to differentiate between the different colors or ripeness of the fruits by using this formula.

$$\text{Mean of red} = \text{r/No. of pixels}$$

$$\text{Mean of green} = \text{g/No. of pixels}$$

$$\text{Mean of blue} = \text{b/No. of pixels}$$

Where:
r = Red pixel
g = Green pixel
b = Blue pixel

This step was individually performed on each image of the oil palm bunch. The mean for the whole bunch is obtained by calculating the mean for both images. This procedure is repeated with all the samples which we used them as training samples for our program. The color of oil palm FFB was classified as ripe, over ripe and under ripe. These samples are shown in the Fig. 5-7, respectively.

We need to obtain the range value (minimum and maximum mean) of RGB density for each category (ripe, over ripe and under ripe). This range value is used as the reference and standard value of ripeness for our test program.

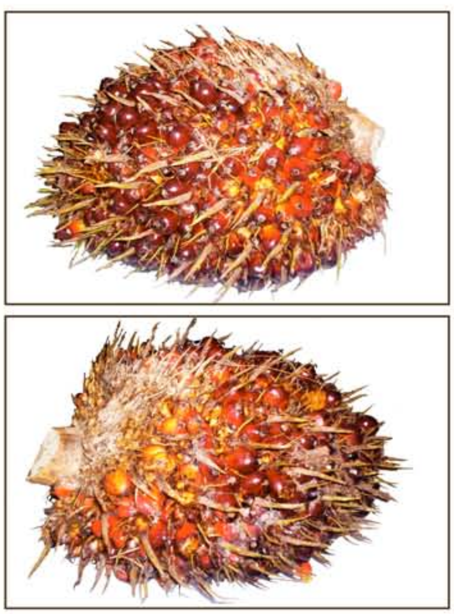

Fig. 5: The two images for ripe bunch

Fig. 6: The two images for under ripe bunch

Fig. 7: The two images for over ripe bunch

**Testing stage:** In this step the computer program calculates the mean color intensity for RGB which is related to picture 1 and picture 2 individually. After that calculating of the mean color intensity of RGB for the whole bunch is performed and the mean of picture 1 and 2 computed.

Next, the computer program test for the ripeness of the bunch based on the standard mean of the ripeness according to the training program. This is done by using IF statement. Finally, the ripeness is obtained and the result displayed.

## RESULTS AND DISCUSSIONS

**Training program:** The computer program calculated the mean color intensity to differentiate between the different colors or ripeness of the fruits. This method is done on 30 pictures for 15 samples. This represents 5 samples for each category (ripe, under ripe and overripe). The mean RGB for each category of the oil palm fruit bunch sample maturity is shown in Table 1-3.

After obtaining the RGB intensity of the samples for each category we compared them with each other in order to calculate the range of RGB intensity of the oil palm fruit bunches for each category as shown in the Table 4. These ranges are placed in the testing program as reference of the ripeness for testing of bunch.

**Testing program:** This part explains two stages which are the program's result and the program's interface.

**The program's results:** The computer program used the mean color intensity to differentiate between each ripeness category. Test program is executed in order to show steps of the life cycle for the data inside the program.

First of all, the program reads the data and changes it into DN and work with it as matrix of DN. In order to eliminate the effects of the white color background of the pictures, the program will trace the matrix of DN and use its function to convert the white color (255) to black color (0). Because the RGB of white color equal to 255 with high effect, but the RGB of black color equal to 0 with no effect. The results of program will show the original image with white background and converted the white background into black background as shown in the Fig. 8, respectively.

The program checks image 1 and image 2, pixel by pixel by using FOR LOOP function in order to calculate the mean of color components (RGB) for each image. The mean of RGB for each picture has already been obtained through the procedure that has been described. The mean of RGB for the whole bunch is obtained by calculating the mean value for the two pictures which are shown in the Table 5. The mean of RGB color will appear for each color (band) of the bunch with its histogram refer to Fig. 9-11.

After we obtained the mean of RGB for each color, the program will show us comparison between the means RGB of the colors for whole bunch as shown in the Fig. 12.

The mean values are calculated; the ripeness of the bunch is tested by comparing between the results of the Table 5 and the results of standard samples in Table 4. The final results are in Fig. 13.

Table 1: Mean RGB intensity of the sample for ripe category

| | Mean of RGB | | |
|---|---|---|---|
| Samples | Red | Green | Blue |
| 1 | 88 | 38 | 50 |
| 2 | 93 | 43 | 56 |
| 3 | 87 | 25 | 41 |
| 4 | 97 | 50 | 61 |
| 5 | 75 | 51 | 56 |

Table 2: Mean RGB intensity of the sample for under ripe category

| | Mean of RGB | | |
|---|---|---|---|
| Samples | Red | Green | Blue |
| 1 | 60 | 33 | 39 |
| 2 | 60 | 33 | 39 |
| 3 | 55 | 30 | 36 |
| 4 | 60 | 35 | 40 |
| 5 | 60 | 28 | 33 |

Table 3: Mean RGB intensity of the sample for over ripe category

| | Mean of RGB | | |
|---|---|---|---|
| Samples | Red | Green | Blue |
| 1 | 47 | 35 | 33 |
| 2 | 58 | 35 | 44 |
| 3 | 67 | 43 | 52 |
| 4 | 53 | 40 | 46 |
| 5 | 50 | 42 | 45 |

Table 4: The range of RGB intensity of the sample of categories.

| | RGB intensity range | | | | | |
|---|---|---|---|---|---|---|
| | Red | | Green | | Blue | |
| Category | Min | Max | Min | Max | Min | Max |
| Ripe | 75 | 97 | 25 | 51 | 41 | 61 |
| Under ripe | 55 | 60 | 28 | 35 | 33 | 40 |
| Over ripe | 47 | 67 | 35 | 42 | 33 | 52 |

Table 5: The mean of RGB intensity of the tested bunch

| | Mean of RGB | | |
|---|---|---|---|
| Tested image | Red | Green | Blue |
| Picture 1 | 88 | 36 | 50 |
| Picture 2 | 87 | 39 | 51 |
| Whole bunch | 88 | 38 | 50 |

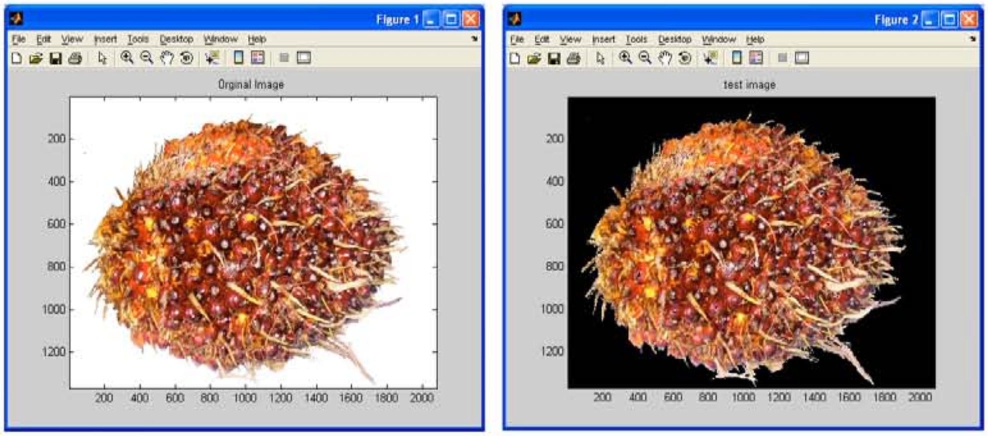


Fig. 8: The original image and converted image with black background

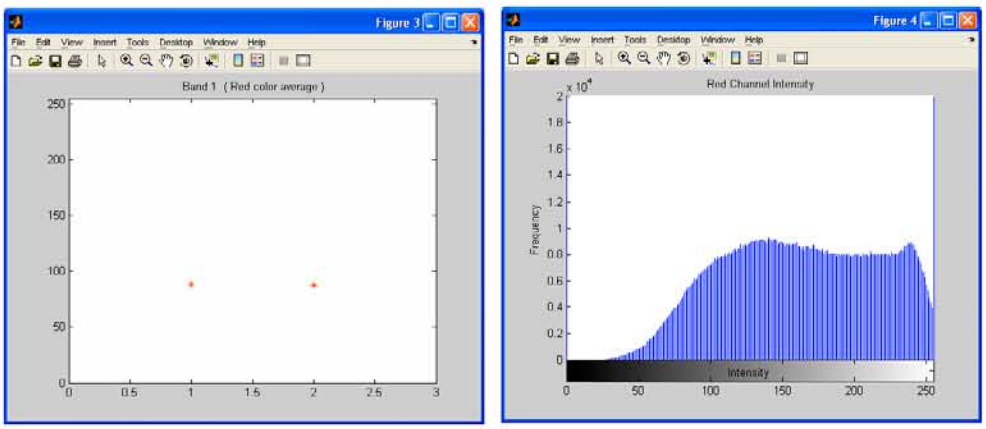


Fig. 9: Band 1 (Red color mean) with its histogram

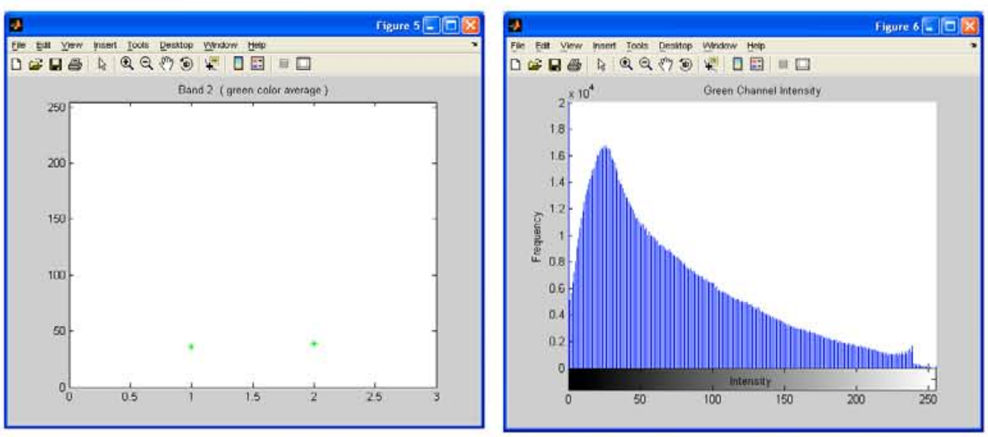


Fig. 10: Band 2 (Green color mean) with its histogram

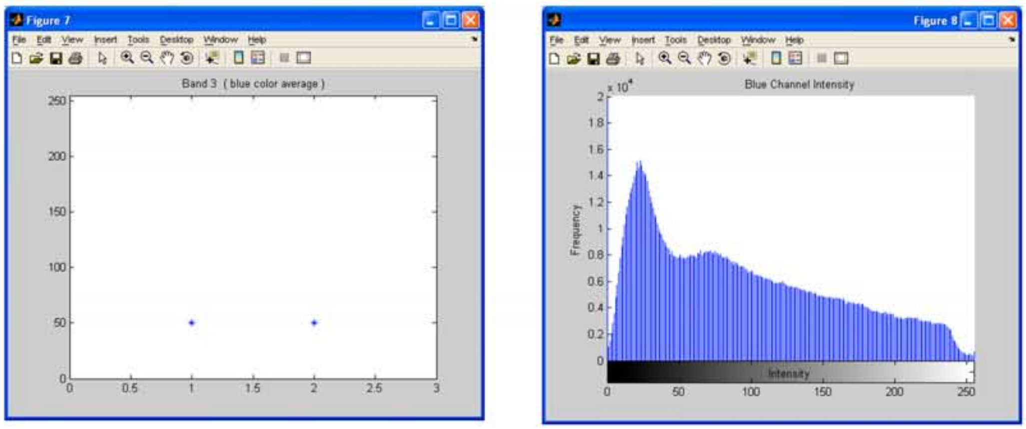


Fig. 11: Band 3 (Blue color mean) with its histogram

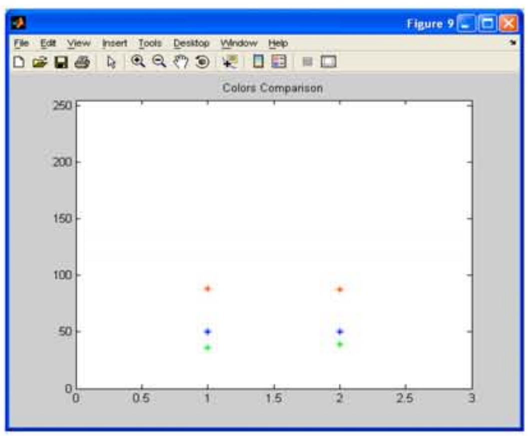


Fig. 12: Comparisons between the means RGB of the colors for whole bunch

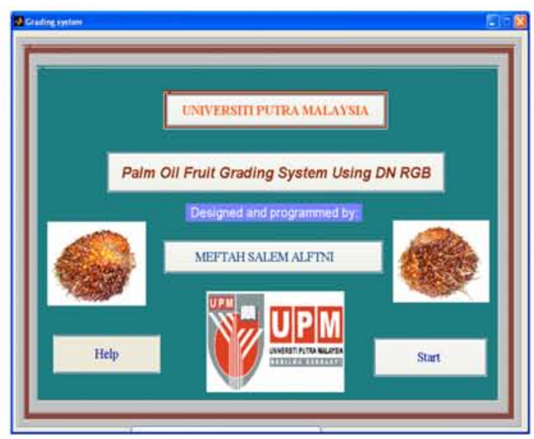


Fig. 14: The main form of the interface

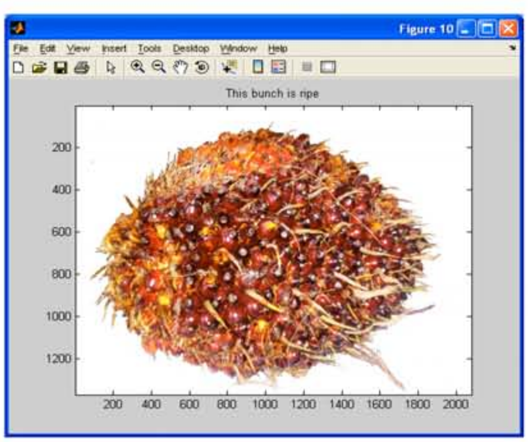


Fig. 13: Result of the ripeness for the bunch

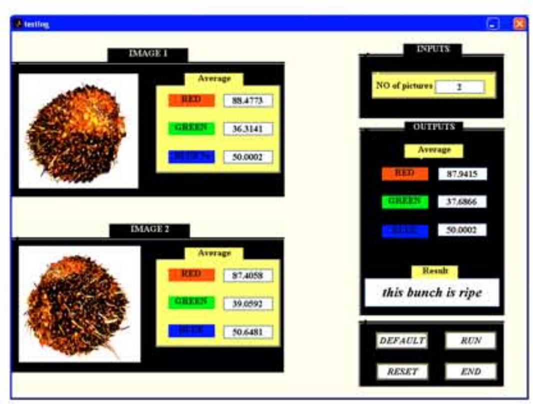


Fig. 15: The steps and results of the grading system with their methodology

Finally, the computer program will test the ripeness of our bunch depending on the standard mean of the ripeness.

From present experience in this research, the accuracy of the results obtained depends on the accuracy of the data source and the number of training samples.

The grading system that we have developed in this research is able to detect and differentiate between the different categories of ripeness of the oil palm fruit bunches. Thus, the major objective of present research has been achieved.

The basic premises of this research involved the principle of reflection of light. As ripeness is indicated by color of the fruit, our ability to capture the value of the reflected light (DN) and to classify it against the degree of ripeness led us to develop the appropriate relationship. This relationship between the reflected light and ripeness is well correlated and thus forms the scientific basis for our automated grading system. The results obtained from this research are also generalized and applied to different oil palm bunches different plantation from around the world. As light is an important of this research, it is important to monitor and maintain similar light throughout the experiment. As light intensity may vary, it will be practical to have a controlled environment for the oil palm fruit being imaged.

This study builds upon earlier base created by several researches. The earlier study aim of Saad *et al.* (2003) used the digital image processing as a process where the data from a sample is retrieved without making physical experiment on the sample.

Thus, data can be obtained by looking at the Image or picture of the product with the help of software that converts the image into Digital Number (DN). However, Saad *et al.* (2003) worked on individual fruits and not the whole bunch.

Rashid *et al.* (2002) investigated the correlation between oil content in the oil palm fruit against the color of the individual fruit of oil palm fruit. Physical measurements of the amount of oil content in the fruit were carried out by chemical analysis. Their finding are of help in increasing the efficiency of quality harvesting and grading of oil palm Fresh Fruit Bunches (FFB) and forms an important base for our research.

The on-line apple grading system based on some of the most important external parameters including the fruit's surface color.

The details including the experimental results and techniques of implementation of color grading are presented in by Rao *et al.* (1999b). They used HIS [Hue, Saturation and Intensity] color model often used for image processing.

Earlier study by Ismail *et al.* (2000) investigated the use of a machine vision system to identify the object (i.e. oil palm fruit bunch) by color and send the signal to enable the robot to pick the object. The C++ programming language was used to write program to differentiate the colors and signals to the robot arm. Present system was developed based on MATLAB.

**The user interface's results:** The program has already been developed and the results of the fruit's ripeness have already been obtained. In order to manage them and make them easily understood by the users, we have created the user interface.

The interface is designed using forms depending on our requirement in the program. One of the forms will contain the main menu which contains information and some buttons such as help button which consists of guidance instruction to our system and start button of our program. The main form of the interface is shown in Fig. 14.

After we execute the user interface of the grading system. Pressing the start button will open the second form which will be our way to run the test program.

The second form of the system is shown in the Fig. 15. It contains the actual steps and results along with the methodology. The second form will appear with different boxes which are image 1 box, image 2 box, inputs box, outputs box and the box of buttons (default, run, reset and end).

To run our program press default button. Program automatically enters the number of bunch's pictures as 2 which is the default number in our system. The number of picture will appear in the input box immediately. Image 1 and image 2 boxes will show the pictures of tested bunch individually with its mean for RGB.

The ripeness of bunch is tested and its RGB mean will appear in the outputs box. Finally, we can use the reset button to clear all the results in order to prepare for new testing or use the end button.

The contribution of present system compared to the other system is the first system in the world which was able to classify the ripeness for whole bunch of oil palm fruits and also this system is able to implement the applications of real time systems especially for online grading system.

## CONCLUSIONS

This project was conducted to determine and differentiate between the colors properties of oil palm fruit bunch. The grading system was able to detect and differentiate the ripeness of oil palm FFB between the different categories of oil palm FFB. The computer program using MATLAB 7 software was written to analyze the RGB data of the images. The computer program used the mean color intensity to differentiate between the different color and ripeness of the fruits such as oil palm FFB. The color of oil palm FFB was classified as ripe, under ripe and over ripe. The range of RGB intensity of the oil palm fruit bunches came out as result of training program to be as a reference of the ripeness in the test program.

The test program in this prototype system is successfully able to differentiate between the three ripeness categories of the oil palm fruit bunches.

The unique feature of this research is that we have identified a positive correlation between the colors of the oil palm fruit bunch against its ripeness. This has led us to develop an automated grading system.

In future, the grading system can be connected to the internet to make it available for users to test the ripeness of their fruit online. This will allow the farmers to determine the grades of their fruit before selling them at the mill.

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