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RIPENESS LEVEL CLASSIFICATION FOR PINEAPPLE USING RGB AND HSI COLOUR MAPS

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ABSTRACT

An image processing technique is used to evaluate the level of ripeness of fresh pineapple. The classification of the fruit will be judged by the colour change on the skin of the pineapple. A sample image is taken using a digital single-lens reflex camera under a controlled environment. An algorithm is developed using MATLAB software to evaluate features based on an image of the pineapple. Features from the image are segmented according to RGB and HSI colour maps. This paper will introduce a technique to distinguish between unripe, ripe and fully ripe fruit. The maturity index varies from Index 1 through Index 7 where Index 1 is an unripe pineapple and Index 7 is a fully ripe pineapple. By using fuzzy logic classification, the result shows that 100 % accuracy for the fully ripe and 85 % for unripe and ripe level can be achieved.

Keywords: *Pineapple, Maturity index, Ripeness, Image processing, Fuzzy logic*

1. INTRODUCTION

Pineapple is one of the major fruits consumed in Malaysia and also globally. For the past 10 years, it has been estimated that more than 150,000 metric tons of fresh pineapple have been produced in Malaysia [1]. The pineapple industry in Malaysia is divided into two market needs either for fresh consumption or for production purposes. For product purposes, the red or green pineapple is used. For fresh consumption, the Sarawak, Josapine and Moris pineapples are used.

The Josapine type has been developed by the Malaysian Agriculture Research and Development Institute (MARDI). This hybrid pineapple is a combination between 'Johor' type which hybrid of 'Singapore Spanish' and 'Smooth Cayenne' and 'Sarawak' or known as 'Smooth Cayenne' [1]. Although the number and facts shows that Malaysia is major producer of pineapple, in terms of preparation, inspection and grading of pineapple this is still done manually by workers and is thus subject to human error.

Pineapples can be classified according to their weight and also the level of maturity. Pineapple can be sorted into three different weight levels which are Small (S), Medium (M) and Large (L). When sorting according to maturity level, seven different levels of maturity namely from Index 1 to Index 7 are measured based on the colour of the skin of the pineapple [2].

The classification of pineapple is done manually by a Federal Agricultural Marketing Authority (FAMA) expert officer and a benchmark has been set to be followed by others in the pineapple industry when identifying the maturity index of pineapples [3]. This manual inspection is done for grading the size of three major grades which are S, M, and L and also to check for uniformity and flaws on the skin to meet the standardized regulation before the pineapple can be processed.

In terms of the consumer view, the external condition of the pineapple is the first criteria to observe when buying fresh pineapple. Consumers will be looking for any defects on the physical of the fruit such as the colour of the skin, the size and also the odour of the pineapple. These three

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criteria will contribute to the good quality and freshness of the pineapple.

However, the classification is often made incorrectly by farmers and consumers due to the human factor [3]. Each human will evaluate the maturity of pineapples differently based on their own understanding of pineapple maturity. Therefore, with the aid of machine vision technology, assessing the maturity of pineapples will become much more accurate and reduce any human error and ensure uniformity throughout the process.

The importance in determining the maturity condition is because when a fruit achieves a higher level of maturity, the chance of the fruit becoming damaged will become higher after it has been harvested [2]. Therefore, determining the maturity level will help the farmer and also the export company to select pineapples based on their maturity to be made in concert with the distance of shipment of the fruit.

Vision technology has attracted the attention of various industries based on its capabilities and diversity of function. Vision systems have been used as inspection systems, for security aspects, in industrial manufacturing, robotic systems and also in optical gauging. A vision system is a preferred choice due to the inherent high consistency and accuracy when involved in image processing [3]. In the agricultural sector, vision systems are a well-known technology and have been used for quality evaluation, volume determination, and classification based on size and maturity level of particular fruits over recent years [5].

The agricultural sector has been introduced to machine vision systems especially for quality inspection of fruits and vegetables [3]. Using image analysis is a most effective instrument in processing features of the fruit skin such as detecting bruises, colour intensity, size and shape [4]. Image processing is one of the ideal instruments to be used in the agricultural sector because it uses non-destructive evaluation rather than the traditional technique that has been used to examine fruit [4], [5].

Therefore, the objective of this research is to standardize and reduce human error in the classification of pineapple maturity. The system will use colour segmentation, Red Green Blue (RGB) and Hue, Saturation and Intensity (HSI) and colour maps to evaluate the texture of the pineapple skin to determine the level of maturity.

2. THEORY

2.1 Pineapple Classification

Pineapple can be classified into seven levels of maturity based on the change of the colour on the skin of the fruit. The skin will start from a pale green and gradually turn a orange or yellowish colour upon ripening [1]. Each level of maturity is given a number and can be distinguished by eye based on the skin of the pineapple having slightly or completely changed to a yellowish colour. Figure 1 shows the index according to colour of pineapple skin for the Josapine type while Table 1 show the ripeness level according to the index of maturity.

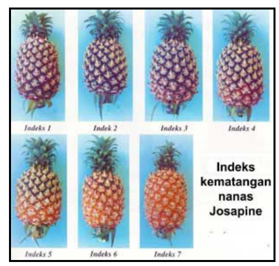

Fig 1: Level of index based on skin colour for Josapine pineapple type

Table 1: Ripeness level according to index maturity

Ripeness	Index of Maturity
Unripe	Index 1, Index 2
Ripe	Index 3, Index 4, Index 5
Fully ripe	Index 6, Index 7

2.2 Red Green Blue Colour Spectrum(RGB)

RGB colour space is combination of Red, Green and Blue spectrum components to produce multiple colour space models. Each RGB colour component represents a value from 0 to 255. Each pixel in an image will have these three colour components to produce one combination of colour [5]. Each pixel in an image also will contain information about the coordinates of the pixel on the image. Figure 2 shows an example of how RGB colours are represented on a pineapple.

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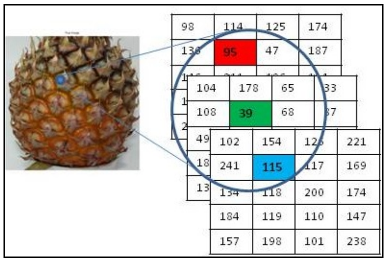
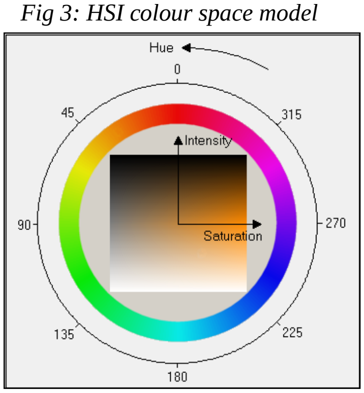


Fig 2: RGB colour space

2.3 Hue, Saturation and Intensity (HSI)

HSI is the combination of the Hue component, Saturation component and Intensity component in a pixel in an image [6]. Hue is a colour space that can be presented in 360° form. For 0° represents red colour, 120° represents green colour and 240° represents blue colour. One of the advantage of this colour space is it is suitable for processing images when the surrounding lighting is not constant [6]. Figure 3 shows how HSI is represented in 360° form. Saturation is defined as how much the colour is polluted with white component. If the amount of white pollution is high, the colour will become much grayer and if the colour is less polluted, the colour will become a much more solid colour. For Intensity, it is defined as the brightness of the colour.

Fig 3: HSI colour space model



Equation 1, 2 and 3 are a mathematical model colour conversion between RGB and HSI[6].

$$I = \frac{R+G+B}{3} \qquad (1)$$

$$H = \begin{cases} \theta, if\ B \le G \\ 360° - \theta, if\ B > G \end{cases} \qquad (2)$$

$$S = 1 - \frac{3}{R+G+B} min(R,G,B) \qquad (3)$$

where I and S are in the range of [0,1], H is in degrees in the range [0°,360°] and θ is:

$$\theta = cos^{-1}\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}} \right\}$$

2.4 Fuzzy Logic Classification

Fuzzy logic classification is a tool to map the pattern from the input and match accordingly based the setup to give an output [10]. Fuzzy logic is used as the classifier as it is well-known for providing a simple definite conclusion based on rough input information [8]. For this paper, the classifier is designed based on the number of specific colour pixels on a test image, namely Red, Green and Saturation in order to determining the final output. Therefore, the fuzzy logic classifier will has three inputs generated from the feature extraction process of the image and also one output which is the ripeness level.

Figure 4 below show the fuzzy logic features using MATLAB software which accepts three input values and gives one output using the Mamdani-style system.

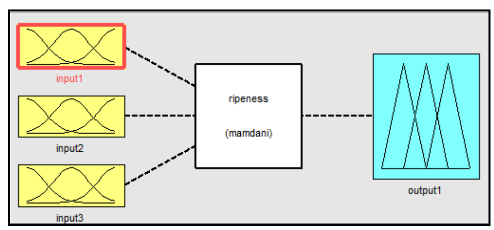


Fig 4: Fuzzy Logic Features

2.5 Image Processing

Image processing is basically to obtain the required information from an image. To obtain the information, several processing techniques need to be carried out such as pre-processing, feature extraction and feature classification [9]. Pre-processing is a technique to eliminate unimportant information by cropping the image into a specific area, resizing the image as a certain amount of pixels and filtering any noise from the image. For feature extraction, the required information will be filtered out to obtain the unique features from the image [11]. These unique features will be used for feature classification.

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3. Materials and Methods

3.1 Overview

The overall system can be divided into three main categories which are pre-processing techniques, feature extraction technique and the classification technique. In pre-processing, it will explain on how the image is being process to ensure all images are in the same category and also the features can be extracted. For feature extraction technique, this can be described as the how the interesting features that are extracted from the image. In classification, it will explain on how the information been classified. Figure 5 shows an overall flow chart of the system.

3.2 Data Collection

Data collection is technique of collecting images of the pineapples Acquiring the image need to be done properly and scientifically to ensure all variable are been controlled so that the data for this project will be valid. The images used in this project were collected with the aid from the Malaysian Pineapple Industry Board (LPNM) which provided pineapples of type Josapine.

A professional photographer is used to capture all the images. Professional services is needed to ensure all properties of the fruit seen in the images are clear and will help to reduce using filtering for processing in a database. The fruit located at a fix coordinate for entire photography session. A high definition camera at a distance of 150cm is place in front of the pineapple. All these important aspect will ensure the process of capturing images for processing will be in a controlled environment.

3.3 Pre-Processing

In the pre-processing section, each image will pass through several level of filtering to remove any unwanted noise or information. This is because, with filtering done to the image, it automatically reduces the size of the image and will improve the process time. Firstly, the surroundings of the image that doesn't have important information will be cropped to reduce the size of the image from the real size.

For example, Figure 6 (a) shows the real image and Figure 6 (b) is the result after cropping. After the background has been cropped, the size of the entire image in this project will be standardized at 600x600 pixels. This is because to ensure all images pass through the system will the same size as shown in Figure 6 (c) below. After all the images are the same size, nest technique will be carried out.

Fig 6 (a) Real Image *Fig 6 (b* *Image*

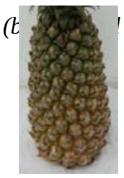

Fig 6 (c) Resized Image

3.4 Feature Extraction

Feature extraction is used to obtain the required information from an image using several techniques. Feature extraction will also help the system to eliminate the background and reduce processing time. The features that are extracted will be in the form of two colour maps which are the RGB spectrum and the HSI spectrum.

For the RGB spectrum, the image will be converted into a red channel and a green channel. From these two channels, the image will have similar properties in terms of pixel values as a grayscale image. Each pixel in the red and green channels will have a value in the range of 0 to 255. For the HSI spectrum, the image will be converted into a saturation channel in which the image will be converted to inform of how much white colour has polluted the image. The saturation channel value varies between 0 and 1. Figure 7 shows the difference when an original image is converted to a red, green and saturation channel.

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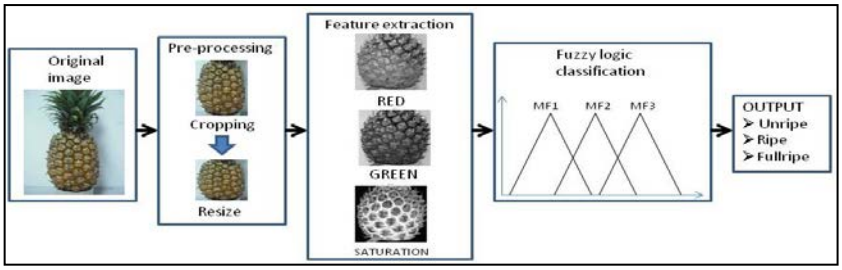

Fig 5 Flow Chart for Overall System

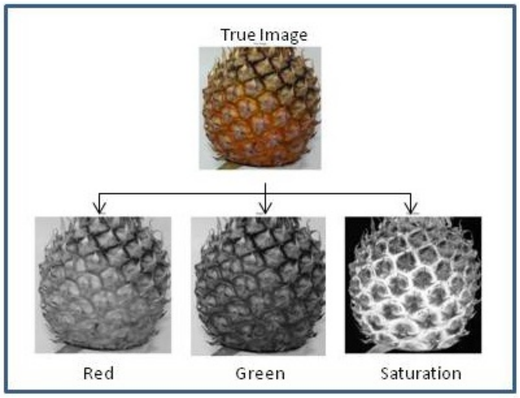

Fig 7: Images from different spectrums

3.5 Feature Selection

In this section, each item of data that been extracted will be analysed to meet the needs of this project. Each pixel will contain data of RGB and HSI colour space and each colour component will be in the range of [1 255] for RGB and [0 1] for HSI.

Therefore, a specific range will be a target to obtain a specific colour. The colours of interest will be the red and green colour. The range of the red channel will be [150 200] and the range for green channel will also be [150 200]. Blue channel will be ignored as it not containing information needed.

For the HSI colour space, the value for saturation will be from [0.3 0.5] and value for hue and intensity will be ignored. When a certain pixel lies in the set up range, counters will count the number of pixels based on the respective channel.

After the value for red, green and saturation have been collected from an image, the value will be used for classification using fuzzy logic. This will be explained in the next section.

3.6 Classification

In this section, fuzzy logic will be used to categorize each parameter from the feature extraction to produce an output. For classification, features from 40 images will be used to develop a database and 20 images as test images.

The fuzzy logic system has three inputs with a membership function for each input. The three inputs will be the number of green pixels, the number of red pixels and the number of saturation pixels respectively. The number of rules will be 12 and the number of decisions for the output will be three.

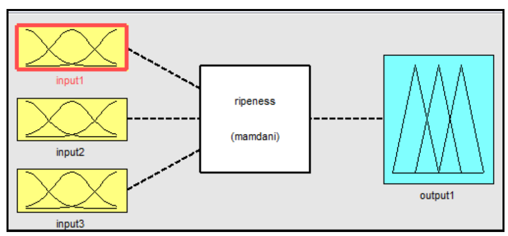

Fig 8 : Fuzzy Logic System

Figure 8 shows a diagram of the fuzzy logic system of the Mamdani type. The rules are developed based on the ripeness and maturity level. A triangular membership function is used for the inputs and also for the output membership function.

For the defuzzification of the output value, the centroid method is used. The fuzzy logic classification is developed using Matlab Fuzzy Logic Toolbox. The Rule Viewer from Matlab is shown in Figure 9.

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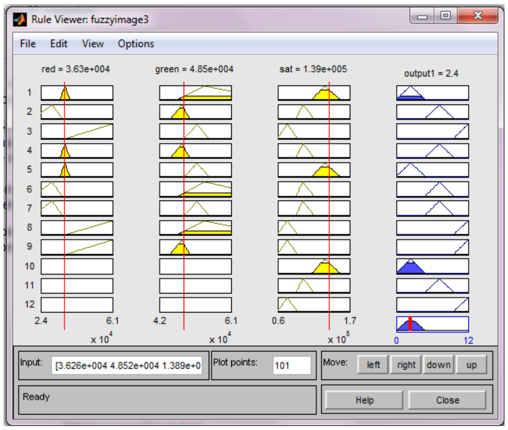


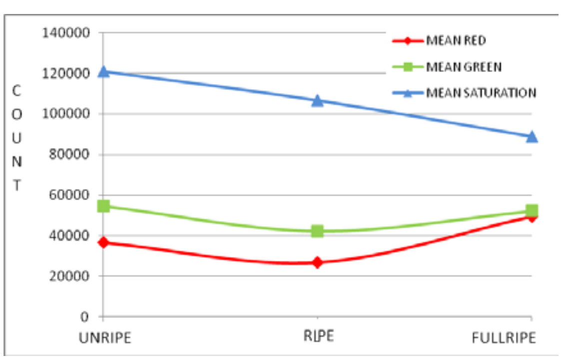
Fig 9 : Rule Viewer of membership functions and rules

The membership functions for all the inputs are developed based on the graph obtained in the feature extraction stage.

4. RESULTS AND DISCUSSION

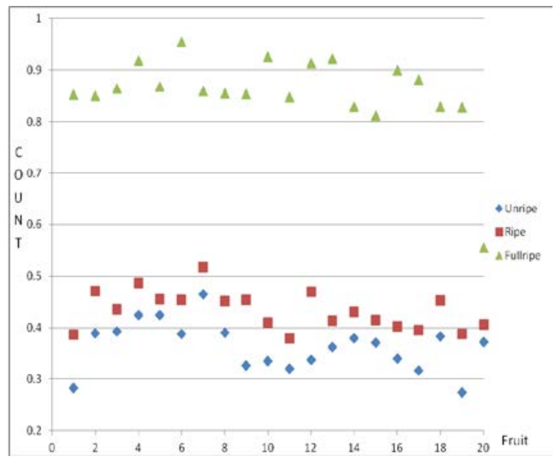
Graph 1 shows the mean value for the pixel counters corresponding to the red and green channel from the RGB spectrum colour and the response of the saturation channel from the HSI spectrum colour according to the respective levels of ripeness. The result shows that there is a slight difference for unripe fruit for the green and red count and the value decreases before increasing and achieves almost the same value as the fully ripe state.

The graph also shows that the saturation value linearly decreases as the ripeness of the pineapples increases until fully ripe. This is due to the percentage of white component with a saturation value that ranges from 0.3 to 0.5 that has been set up in this project and causes the counter for the unripe group of fruit to be higher than the others.



Graph 1 : Mean value for each ripeness level

The result from Graph 2 shows the normalized data for the test image classification through the fuzzy logic technique. The result indicates an average accuracy for ripe and unripe fruit of 85 % respectively. The highest accuracy achieved is for the fully ripe classification where all of the 20 images of fruits tested show a result between 0.55 and 1.0.



Graph 2: fuzzy logic classification for test image

Table 2 summarises the classification result using fuzzy logic which shows that using two spectrum colours, namely RGB and HSI has proved that all three ripeness levels are able to achieve a high precision of 85 % for unripe, 85 % for ripe and 100 % accuracy for fully ripe.

Table 2: Fuzzy Logic Result

Ripeness	Number of test images	Result	Accuracy
Unripe	20	17/20	85%
Ripe	20	17/20	85%
Fully ripe	20	20/20	100%

5. CONCLUSION

In this paper, an image processing technique has been developed to extract the required information to classify pineapples into three major groups of ripeness, namely unripe, ripe and fully ripe. The data obtained for the classification shows that both the unripe group and ripe group achieve 85 % accuracy and for the fully ripe group the accuracy achieved is 100 %.

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In conclusion, the image processing technique combined with fuzzy logic classification is more than able to differentiate three major group of ripeness in pineapple fruits.

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