FUZZY RIPENING MANGO INDEX USING RGB COLOUR SENSOR MODEL

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ABSTRACT

Currently, the mango ripeness classification is determined manually by human graders according to a particular procedure. This method is inconsistent and subjective in nature because each grader has different techniques. Thus, it affects the quantity and quality of the mango fruit that can be marketed. In this project, a new model for classifying mango fruit is developed using the fuzzy logic RGB sensor colour model build in the MATLAB software. The grading system was programmed with a colour sensor to analyze the mango fruit ripening index. The decision making process uses fuzzy logic to train the data and also to classify or categorize the mango fruit. The model developed is able to distinguish or separate the three different classes of mango fruit. The proposed model is able to distinguish the three different classes of mango fruit automatically with more than 85% accuracy.

Keywords: Mango Grading, Fuzzy System, RGB Colour Sensor.

INTRODUCTION:

Mango is one of the famous fruits in Malaysia for both local and international markets, grown in all regions but the area of concentration is in Northern Malaysian. Currently, the demand of mangoes for local market and overseas increases every year. Malaysian mangoes are exported to Singapore, Brunei and Hong Kong. It is estimated that the annual average growth rate is 19 percent of mango exports during the period 1992-2001. This situation explains the continuous increasing value of mango exports from year to year.

The quality of mangoes must be controlled so that the fruit gets a good value for the market. Therefore, the Federal Agricultural Marketing Authority (FAMA) is responsible to ensure only a quality mango goes to the market. FAMA has launched Malaysia's Best label as a benchmarking for quality fruits. Under this label, all fruits are required to be graded and inspected according to Malaysia's Best quality specifications such as size, appearance and maturity index. It is important to inspect the index of maturity because it refers to skin colour change which also changes the internal characteristics of the fruit and level of acid sugar contents. Hence, different index of maturity will give different taste and it also can be exported to various countries depending on their distance. The colour plays an important role in determining the ripeness of a mango. Colour provides valuable information in examining the freshness of fruits and estimating its ripeness. Generally, when the ripeness of the fruits changes from one stage to another stage, the colour of the fruits also changes from one colour to another colour.

Traditionally the method of determining the ripeness of a fruit including mango fruit is done by a human grader. Two factors they consider in determining the ripeness or maturity of fruit are by looking at the colour and shape of the fruit. This is the easiest and fastest way to determine the ripeness of fruits but the level of accuracy in deciding whether that fruit is unripe, ripe or overripe is low. Furthermore, the problem with the traditional method is the in consistency of choosing the ripeness of the mangoes in the large scale. It is difficult for humans to maintain their focus when dealing with a large quantity. So, the appropriate method to determine ripening index is needed to solve those problems above.

Vision system is widely used to develop non-destructive fruit quality inspection grading which focused on fresh fruits (Khojastehnazhand & Omid, 2009, 2010; Riyadi, Rahni, Mustafa, & Hussain, 2007;Alavi, 2012). In Malaysia, the studies in automated grading system have become an interest for many researchers (Riyadi et al., 2007;Mustafa & Fuad, 2008; Jamil, Mohamed, & Abdullah, 2009). Currently, vision system has been used to classify mango more efficiently (Othman et al., 2012;Razak, Othman, Nazari, Adilah, & Mansor, 2012). All above systems are very beneficial to the agricultural industry.

The colour in a mango is the most important visible characteristic used to assess ripeness, and it is a major factor in the consumer's purchase decision. The degree of ripeness is usually estimated visually by human graders who compare the mango colour to a classification chart. Human identification of colour is complex because sensations such as brightness, intensity, and lightness are important. As colour is an indication of mango ripeness, a green to yellow gradient can also be used to assess the stage at which a mango should be harvested and consumed. The mango fruit is a climacteric fruit, and therefore, it continues maturing after it has been harvested. The colour sensor was used to detect the intensity of RGB colour at mango skin for determining the ripeness of mango. This research is a first attempt to determine the fruit ripeness by using RGB colour sensor. The results were presented and discussed. Colour sensing is an important subject in optical sensors and used by machine to sense the presence of a target such as colour (Raja & Sankaranarayanan, 2006;Seelye & Gupta, 2011) . Colour sensors can also be used for sorting by colour, for example, in packaging.

The objectives of this paper were thus to define the ripeness index based on intensity of RGB colour on mango skin, develop the calibration equation using colour values and evaluate the calibration efficiency by classifying the mango ripening index using Fuzzy Logic. Specific objectives implemented to accomplish the overall objective were to use a RGB Fiberoptic colour sensor to collect RGB data from mango fruits with three categories (i.e., unripe, ripe and over ripe); determine data colour features based on the colour signal; and develop algorithms for selecting useful colour features and classifying the ripeness mango conditions based on the colour feature sets using Fuzzy Logic.

MATERIAL AND METHODS:
FUZZY LOGIC:

Fuzzy logic starts with the concept of fuzzy sets. The fuzzy set is the set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. A fuzzy set is defined by the following expression:

$$S = \{(x, \mu_S(x)) | x \in X\} \qquad (1)$$

where $\mu_S(x) \in ([0,1])$ is the membership function (*MF*) of fuzzy set S, X is the universal set, x is an element in X, S is a fuzzy subset in X. Degree of membership for any set ranges from 0 to 1 where value of 1 represents 100% membership and 0 means 0% membership.
A MF is a curve that defines how each point in the input space is mapped to a membership value between 0 and 1. The input space is sometimes referred to as the universe of discourse. The *MFs* are usually defined for inputs and output in terms of linguistic variables. There are many forms of *MFs* such as triangular, trapezoidal, Gaussian etc. In this study, trapezoidal MFs were selected for input and output variables as they can represent our linguistic variables more effectively (Lorestani, Omid, & Bagheri-Shooraki, 2006).
The trapezoidal MF is a function that depends on three scalar parameters a, b ,c and d as shown in Fig.1.

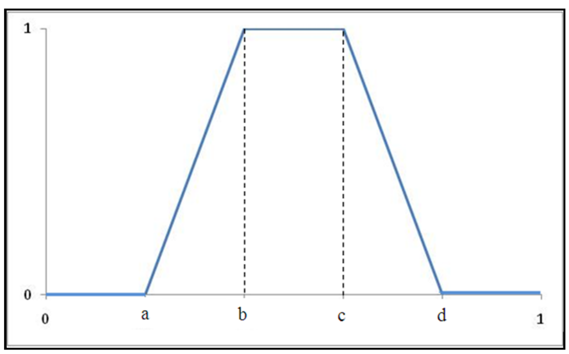

Fig. 1. Trapezoidal Membership Function

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. The *If-Then* rule statements are used to formulate the conditional statements that comprise fuzzy logic. The fuzzy If-THEN rule is presented in the following form:

$$IF\ x \text{ is A } THEN\ y \text{ is B} \qquad (2)$$

where A and B are linguistic values defined by fuzzy sets on the ranges X and Y, respectively. The *If-Then* part of the rule "x is A" is called the antecedent or premise, while the then-part of the rule "y is B" is called the consequent or conclusion.
More generally, rules have more than one premise, that is:

$$R_i : IF\ x_i \text{ is } A_i \text{ AND } y_i \text{ is } B_i \text{ THEN } z_i \text{ is } C_i \qquad (3)$$

where i = 1, 2, n (n is the number of the rules). A_i,B_i and C_i are the fuzzy sets for the inputs (x_i & y_i) and the output z_i, respectively in the i-th rule, Ri. The values of Ci are the linguistic terms such as Unripe, Ripe, Over ripe.
For mango ripeness evaluation, three attributes such as Red, Green and Blue intensity colour were used in the IF-part or antecedent of the rules. The logical operator of "AND" is used as defined by:

$$\mu_{A \cap B} = \min(\mu_A, \mu_B) \qquad (4)$$

where $\mu_{A \cap B}$ is the *MF* of intersection of fuzzy sets A and B. The μ_A and μ_B are the MFs of the fuzzy sets of A and B, respectively.

SAMPLING:

A Chokanan mangoes orchard in Universiti Teknologi MARA (UiTM) Perlis was selected as the source for providing the fruit data for this study. Mangoes which are free from abnormal features such as defects are selected for this experiment. The fruits should be varied in their surface colour and maturity level. These research samples adopted the Federal Agriculture Marketing Authority (FAMA, 2006) of Malaysia classification of Chokanan mango into six grades based on its maturity level as shown in Table 1. Then, the mangoes are grouped into unripe (Index 1 and 2), ripe (Index 3 and 4) and overripe (Index 5 and 6). Samples of 150 mangoes from three types of maturity level were used during this experiment. From 150 mangoes, 50 are unripe, 50 ripe and the other 50 are overripe.

Table 1: Chokanan Maturity Indexes (Fama,2006)

Fruit	Index	Colour
	Index 1	Dull Green
	Index 2	Light green
	Index 3	Greenish Yellow
	Index 4	Yellowish Green
	Index 5	Light Yellow
	Index 6	Yellow-orange

DATA ACQUISITION:

RGB Fiberoptic Colour Sensor from Keyence product using high intensity RGB LED light sources separately was used to acquire data from mango skin. During operation, the CZ-V's amplifier separate RGB LEDs transmit red, green and blue light onto the mango skin . The signal from each colour is converted into 16-bit data in the receiver to enable colour recognition. The CZ-V amplifier provides three detection modes: SUPER 1 (Super Intensity), COLOUR+ 1 and COLOUR. The SUPER 1 Mode detects dark targets. COLOUR+ 1 and COLOUR Modes differentiate very slight colour changes. RGB colour sensor was set to operate on Colour Mode and measurement data are stored in CZ-V21 amplifier for further processing.

Fig. 2 shows the setup of colour sensor used to acquire data from mango skin. It consists of sensor head, Fiberoptic cable and CZ-V amplifier. The sensor was set up vertically and sense 90 degree towards skin mango with a constant distance of 70 mm. All the mangoes were sensed by colour sensor in term of RGB colour intensity.

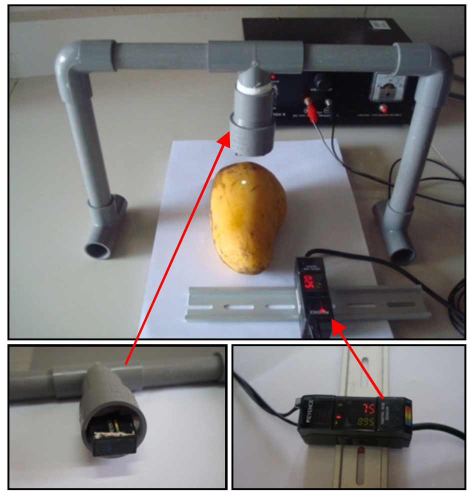

Fig. 2. RGB Colour Sensor Data Acquisition Set up.

In order to classify the mango fruit, measured data is calculated by using (5) - (7). First, the colour matching rate is calculated by

$$X = \frac{y}{999} \times 100\% \quad (5)$$

where X is a colour matching rate, y is a current colour value and 999 is reference colour value. Next, the mean value of each sample is calculated using (6),

$$M(x) = \frac{\sum_{i}^{n} x_i}{N} \quad (6)$$

where $M(x)$= mean value of R,G and B for each category. $\sum_{i}^{n} x_i$ = sum of R,G and B and N is total number of R,G and B.

Then, the data is normalized by using (7) as below:

$$F(x) = \frac{C(x) - Min(x)}{Max(x) - Min(x)} \text{x} 100 \quad (7)$$

where $F(x)$ is normalized colour value in R, G and B. $C(x)$ is a current colour value of R, G and B. $Min\ (x)$ is a minimum colour value and $Max(x)$ is a maximum colour value is taken from the lowest and highest R,G and B colour value.

THE PROPOSED ALGORITHMS FOR FUZZY MANGO CLASSIFICATION EQUATIONS:

The proposed algorithms of the fuzzy sensor mango classification model consists of five steps as listed below.

Step 1: Calculate colour matching rate using (5) and mean value using (6).
Step 2: The data is normalize by using (7).
Step 3: Develop the membership function of input and output of grading model.
Step 4: Generate the rule of grading model.
Step 5: Classify the mangoes into 3 classes of grades.

A total of 60 mangoes are used as training including 20 are unripe, 20 are ripe and the other 20 are over ripe. The algorithm of this model consisted of 5 steps:

The proposed model started by gathering the data using RGB Colour Sensor in term of red, green and blue colours. The C mode for colour sensor is used to detect the RGB colour of mango. The specified distance to take the data between colour sensor transmitter and mango is 70 mm. The area of measurement around near the stalk of the mango and give more accurate information about mango ripeness (Syahir, 2012). Twenty points are sensed by RGB colour sensor within that area. Before measurement, pure colour of red, green and blue are sensed as reference colour. The values of red, green and blue are 865, 925 , 838 respectively. The colour matching rate is calculated from measured data using (5) and mean value using (6).

The second step, all developed data in each category for each Red, Green and Blue are combined and normalized by using (7). To develop membership function of input variable and output category, the range of red, green and blue are determined for each category. Hundred and fifty mango fruit which fifty for each category are used to calculate value of range colour. These range value are used as reference and range input of fuzzy set. Table 2 showed the range data of RGB used for over ripe, ripe and unripe.

Table 2. Range of RGB Used for Over Ripe, Ripe And Unripe Mangoes.

	Red		Green		Blue	
Category	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Unripe	0	30.35	57.39	99.97	43.52	100
Ripe	28.77	64.63	27.61	69.03	20.8	58.75
Overripe	50.97	100	0	35.30	0	34.4

Then, all the data are categorised into three linguistic variables by range as shown in Table 3:

Table 3: The Range Value of Linguistic Variable

Linguistic Term	Range		
	Red	**Green**	**Blue**
LOW	0-30	0-30	0-30
MEDIUM	20-60	20-70	30-50
HIGH	50-100	70-100	40-100

To developed membership function of output, the range of output category was determined by considering all range of Red, Green and Blue for each linguistic term and described in Table 4 below.

Table 4. The Range Value of Linguistic Variable for Output Category

Linguistic Term	Range
Unripe	0-30
Ripe	20-60
Over ripe	50-100

In order to develop the rule, we refer to table 1 above and some of fuzzy inference rules are designed as follows.

Rule 1: IF (Red is Low) AND (Green is High) AND (Blue is Medium) THEN Unripe
Rule 2: IF (Red is Medium) AND (Green is Medium) AND (Blue is Medium) THEN Ripe
Rule 3: IF (Red is High) AND (Green is Low) AND (Blue is Low) THEN Over Ripe

RESULTS AND DISCUSSION:

We implement our algorithm using Matlab's Fuzzy Logic Toolbox. Fig. 3 shows the fuzzy inference system (FIS) consists of the three inputs (red, green and blue) and one which output (category) from MATLAB.

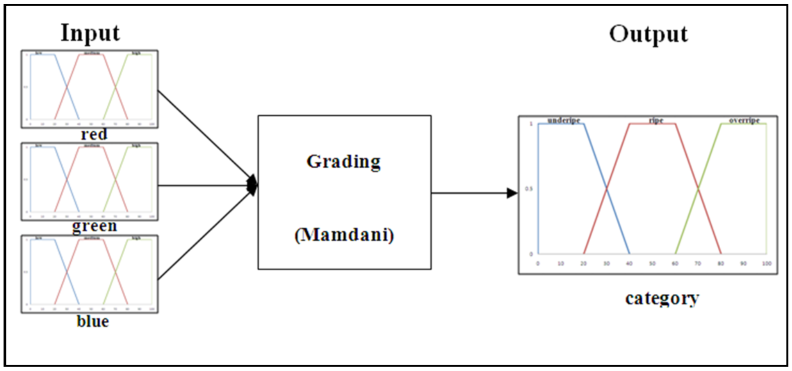

Fig. 3: The fuzzy inference system consists of three inputs and one output

All these membership functions are developed by using FIS editor and membership function editor from MATLAB. The membership function of output category is obtained firstly by setting up the range of output variable which is 100. Then, followed by setting the parameter for each category .The parameters for unripe are [0 0 20 40], the parameters for ripe are [20 40 60 80] and the parameters for overripe are [60 80 100 100]. Fig. 4 shows the membership function of output category.

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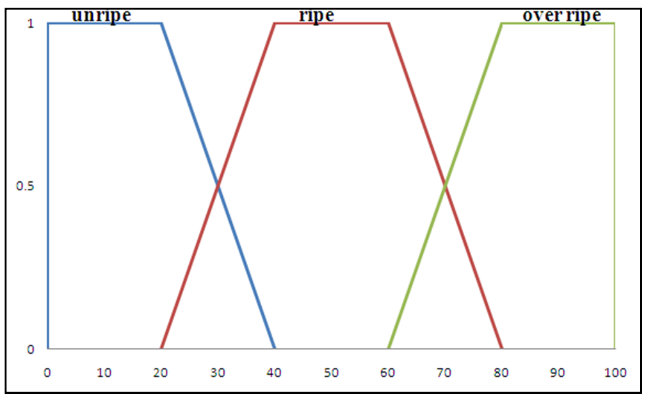

Fig.4: The membership function of output category

After the membership functions of the input and output were developed, then the rule will be created. A total of 21 rules statements have been created in step 4 used to classify the mango fruit categories. Fig. 5 shows how the rules were created using Matlab.

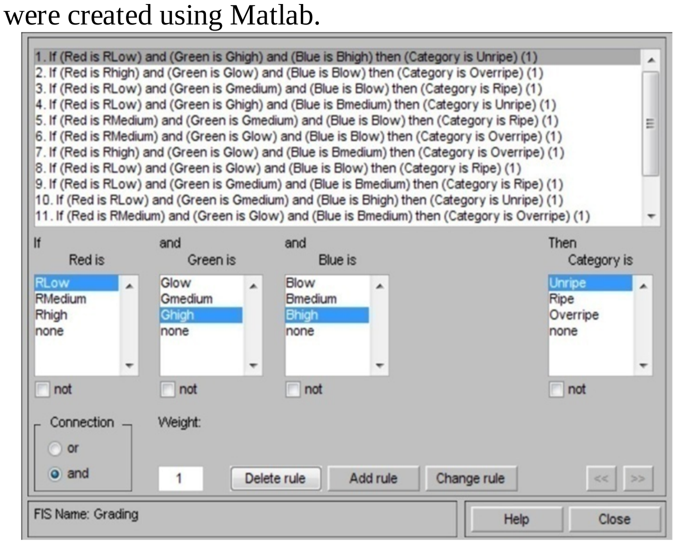

Fig. 5. Rule editor

Fig. 6 shows the rule viewer which consists of the system's input and output. It also consists of the deffuzzification results. The first to third column is representing red, green and blue values while the last column is the category of ripeness column. The last row of the last column which is category column shows the deffuzzification results where the category of mango fruit is obtained.

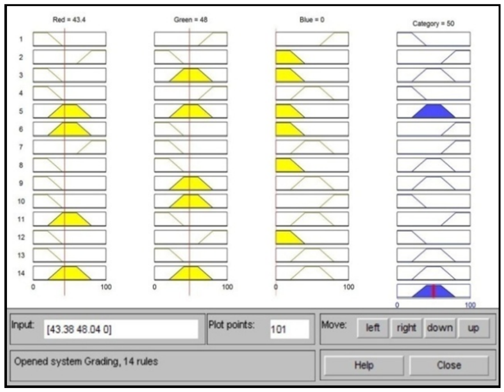

Fig. 6. Deffuzzification result from the Rule Viewer

Based on the deffuzzification results from the Fig. 7, the mango fruit fulfilled Rule 5 in the Fig. 6, where red is medium, green is medium and blue is low. The value of category is calculated by centroid method, and then the classification of mango is determined based on the crisp logic given in Table 5.

Table 5: Fuzzification Algorithms

DeffuzzificationOutput (%)	Mango Fruit Category
(category <= 30)	Unripe
(category >= 31) && (category <= 70)	Ripe
(category >= 71)	Overripe

For evaluation of the developed FIS, 15 mangoes are selected randomly from the testing sample. The intensity data of red, green and blue input of 15 mangoes are measured in order to validate mango fruit into unripe, ripe and overripe categories. Developed input data was transferred to rule viewer for classification process. Results of comparison between human grader and proposed method are shown in Table 6.

Table 6. Comparison of Proposed Fuzzy System and Human Expert in Grading of Chokanan Mango

Fuzzy Logic Prediction						
	Mango Grade	**Under ripe**	**Ripe**	**Over ripe**	**No of mango used**	**Correctly classified mango**
Human expert	Under ripe	5	0	0	5	100%
	Ripe	0	4	1	5	80%
	Over ripe	0	1	4	5	80%
Total Observed (%)		**5**	**5**	**5**	**15**	
		100%	**80%**	**80%**		**87%**

The better or good range for each colour needs to be obtained in order to improve the grading system performance. The fuzzy rules need to be added or improved especially for the fruit that lies closely between two different categories and the additional feature that incorporate differences between the categories such as texture need to be added. The results of the fuzzy logic system evaluated are against the human graders method to measure the accuracy for mango ripening index. Based on the results in Table 6, our proposed model has increased the accuracy of grading by as much as 87%. This shows that the grading system using fuzzy logic has a high potential of accurateness in grading the mango fruit.

CONCLUSION:

The research has proven that by using RGB colour sensor and fuzzy logic as classification algorithm, the accuracy of mango grading is more than 85%. Fuzzy logic is successfully applied to serve as a decision support technique in ripeness mango classification. Grading results obtained from fuzzy logic shows a very good agreement with the results from the human expert. Performance of the system can be improved by integrating with other feature such as texture. Furthermore, this research is a first attempt to determine fruit ripeness by using RGB colour sensor. The result shows that RGB colour sensor can be used accurately as data acquisition and can be applied to other classification fruits.

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