Quest for Research Excellence On Computing, Mathematics and Statistics

Editors
Kor Liew Kee
Kamarul Ariffin Mansor
Asmahani Nayan
Shahida Farhan Zakaria
Zanariah Idrus

Faculty of Computer and Mathematical Sciences

Quest for Research Excellence on Computing, Mathematics and Statistics

Chapters in Book

The 2nd International Conference on Computing, Mathematics and Statistics (iCMS2015)

Editors:

Kor Liew Lee
Kamarul Ariffin Mansor
Asmahani Nayan
Shahida Farhan Zakaria
Zanariah Idrus

Quest for Research Excellence on Computing, Mathematics and Statistics

Chapters in Book

The 2nd International Conference on Computing, Mathematics and Statistics

(iCMS2015)

4-5 November 2015
Langkawi Lagoon Resort
Langkawi Island, Kedah
Malaysia

Publication by
Faculty of Computer & Mathematical Sciences
UiTM Kedah

ISBN 978-967-0314-26-6

Content

CHAPTER 35
A Fuzzy Rule Base System For Mango Ripeness Classification

Ab Razak Mansor, Mahmod Othman, Noor Rasidah Ali ,
Khairul Adilah Ahmad, and Samsul Jamel Elias

Abstract. Fuzzy rule base systems have been successfully applied to various classification problems due to its powerful capabilities of handling uncertainty and vagueness. This paper presents a fuzzy rule based system for the mango ripeness classification. The input and output of the system were RGB color and mango ripeness classification. In the process of fuzzification, crisp inputs are fuzzified using selected membership functions. This study attempted to decide the most suitable membership function to obtain accurate output. Three types of membership functions such as Gaussian, Triangular and Trapezoidal have been compared. The result shows that the Triangular membership function gave higher accuracy than other membership functions.

Keywords: Fuzzy Logic, Membership Function, Fuzzy Rule Base System, Mango Ripeness

Ab Razak Mansor (✉) • Noor Rasidah Ali • Khairul Adilah Ahmad • Samsul Jamel Elias
Faculty of Computer & Mathematical Sciences,
Universiti Teknologi MARA Kedah
e-mail: arazman@kedah.uitm.edu.my
Mahmod Othman[2]
Faculty of Computer &Mathematical Sciences,
Universiti Teknologi MARA Perlis
e-mail: mahmod135085@perlis.uitm.edu.my

1 Introduction

Fuzzy rule base systems have been successfully applied to various classification problems due to its powerful capabilities of handling uncertainty and vagueness [1]. For a simple system, we can obtain a fuzzy classification system using the expert experience, however it is difficult to construct the fuzzy classification system for a complex system, where the expert experience is incomplete or inconsistent. So how to model a fuzzy classification system from data has become research focus in recent years.

Generating suitable membership function (MF) is the core step of fuzzy classification system. Several methods based on heuristics, hybrid methods, fuzzy clustering algorithms, neural networks, genetic algorithms, and the entropy for the automatic generation of MFs were discussed in [2]. It is also common to find studies in which the definition of the membership functions is done empirically. In fact, the trapezoidal and triangular shapes are the most used in the literature, probably because they produce good results for most of the domains [3].

The fuzzy rule base allows the use of linguistic values of variables and imprecise relationships for modelling system manner. In recent years, more and more applications of fuzzy theory to fruits have been reported such as watermelon, banana, pineapple . They used a Mamdani fuzzy inference system to classify automatically that fruit and found good agreement between the results from fuzzy prediction and human experts [4]. Razak, Othman, Nazari, Adilah & Mansor [5] develop a methodology and algorithms to grade a mango using computer vision and classified using fuzzy logic technique.

Mansor et al. [6] aimed to analyze the mango fruit ripening index, to classify the mango fruit and to distinguish three different classes of mango fruit which is under-ripe, ripe and over-ripe. They have used RGB digital fiber optic color sensor using high intensity RGB LED light sources separately in obtaining data from mango skin. This research has verified that more than 85% of mango grading accuracy obtained by using RGB color sensor and fuzzy logic as classification algorithm. They used trapezoid membership to map linguistic variable to fuzzy set.

. In this paper an effort has been made to classify the mango ripeness by using fuzzy rule base. Basically 3 attributes of mango skin have been used as input values for the experimental data [6]. The data values used have been partioned into several intervals based on certain intermediate values of the available data values. Thereafter fuzzy rule base has been applied to the partitioned input data values. Based on the fuzzy value of the output variable, the mango ripening can be identified.

In this context various membership functions have been used for each input variable and output variable. Finally, the prediction accuracy has been calculated using the output value produced by fuzzy rule base in comparison

to the actual output value as available in the experimental data [5]. This paper is organized as follows; section 2 gives a description about the methodology we are using here. Section 3 gives the implementation fuzzy rule base on the mango and results of fuzzy size classification at section 4. Finally, some conclusions are represented in section 5.

2 Methodology

2.1 Fuzzy Set

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

$$S = \{(x, \mu_S(x)) | x \in X\} \qquad (2.1)$$

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 a 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, triangular, trapezoidal and Gaussion are used for input and output variables to represent our linguistic variables.

2.1.1 Triangular Membership Function

Let *a*, *b* and *c* represent the three vertices of the *X* coordinates and $\mu_A(x)$ represents the *Y* coordinate in a fuzzy set *A*. Where *A* is the membership value . In this equation *a* is lower boundary , *c* is upper boundary where the membership degree is zero and *b* is the center where membership degree is 1.

$$\mu_A(x)=\begin{Bmatrix} 0 & if \quad x \le a \\ \dfrac{x-a}{b-a} & if\ a \le x \le b \\ \dfrac{c-x}{c-b} & if\ b \le x \le c \\ 0 & if \quad x \ge c \end{Bmatrix}$$

2.1.2 Trapezoidal Membership Function

The trapezoidal curve is a function of $\mu_A(x)$ of vector *x*, and depends on four scalar parameters *p*, *q*, *r* and *s* where *p* and s allocate the "feet" of the trapezoid and the parameters *q* and *r* allocate the "shoulders."

$$\mu_A(x:p,q,r,s)=\begin{Bmatrix} 0 & if \quad x \le p \\ \dfrac{x-p}{q-p} & if\ p \le x \le q \\ \dfrac{r-x}{r-q} & if\ q \le x \le r \\ 0 & if \quad x \ge r \end{Bmatrix}$$

2.1.3 Gaussian Membership Function

The gaussian curve is a function of $\mu_A(x)$ of vector x, and depends on three scalar parameters *p*, *q* and *s* where *p*: center and q:width and s:fuzzification factor (in expression s=2).The gaussian membership function $\mu_A(x)$ of vector *x* have been represented by

$$\mu_A(x:p,q,s)=exp\left[-\frac{1}{2}\left|\frac{x-p}{q}^{s}\right|\right]$$

2.2 Fuzzy Rule Base System

The inputs for the fuzzy rule base system of mango grading were mango's RGB colors. Crisp input data are obtained from a color sensor [5]. Initially, fuzzy system fuzzifies the crisp data and then with a Mamdani inference system (Mamdani *et al*., 1975) applies the fuzzy rules. Finally, after defuzzification the ripeness of each mango is determined. The components of a fuzzy inference system (FIS) have been shown in Fig.1.

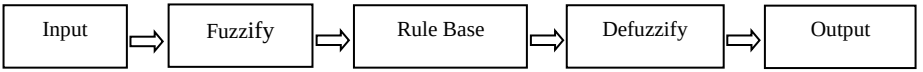

Fig.1. FIS for ripeness mango classification

3 Implementation

The implementation of a fuzzy rule based system involves several steps.The following steps illustrate the whole process of classification.

Step 1:

The input data in this study are mango color while the output is mango ripe. Input data obtained using RGB color sensor and analyzed using statistical technique as proposed in [6]. Input color comprises red, green and blue color. This RGB's color is used as input variables in the fuzzy rule system to determine the ripeness of mango. Table 3 shows the example of input data obtained in [6].

Table 3.1. Input variable comprises of Red, Green and Blue color

No.of Mango	Input Variable (Color)		
	Red	Green	Blue
1	21.4	38.6	10.8
2	25.2	45.0	12.6
3	21.0	27.7	0.0
.	.	.	.
.	.	.	.
.	.	.	.

Step 2:

The crisp data in step 1 are fuzzified using membership function. In this step, we used three different membership function in order to compare whose gives the accurate classification. These membership functions are trapezoid ,triangular and Gaussion. Initially the triangular membership function has been applied to the input variable. Triangular membership is partition evenly into three linguistic variable low, medium and high as shown in Fig.3.2 . Table 3.2 shows the interval of linguistic term in low, medium and high.

Table 3.2. Linguistic term of input variable

Linguistic Term	**Range** Red	Green	Blue
Low	0-40	0-40	0-40
Medium	20-80	20-80	20-80
High	60-100	60-100	60-100

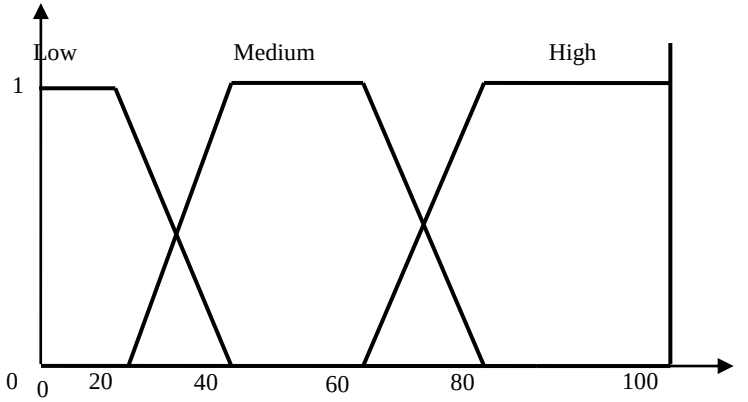

Fig.3.2. Membership function of input variable

Step 3:

The fuzzy rules have been applied to the data to estimate the ripeness of mango using fuzzy rule base. Rule are generated based on helping of human experts. A total of 24 rules statements has been created to classify mango ripe. The fuzzy rules have been shown in table 3.2.

Table 3.2. Initial fuzzy rules are determined by human experts

Rule	Red	Green	Blue	Ripeness
1	Low	Medium	Low	Unripe
2	Low	Medium	Medium	Unripe
3	Low	High	Low	Unripe
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
23	High	Medium	Low	Overripe
24	High	Medium	Medium	Overripe

Step 4:

The output variable, which is the mango ripening has three fuzzy sets of output variables unripe, ripe and overripe. The fuzzy set of output variables is shown in Table 3.3 and different output variables are shown in Fig 3.3.

Table 3.3. Fuzzy Set of output variables

Linguistic Variable	Interval
unripe	(0,0,10,40)
ripe	(10,40,60,80)
overripe	(50,80,100,100)

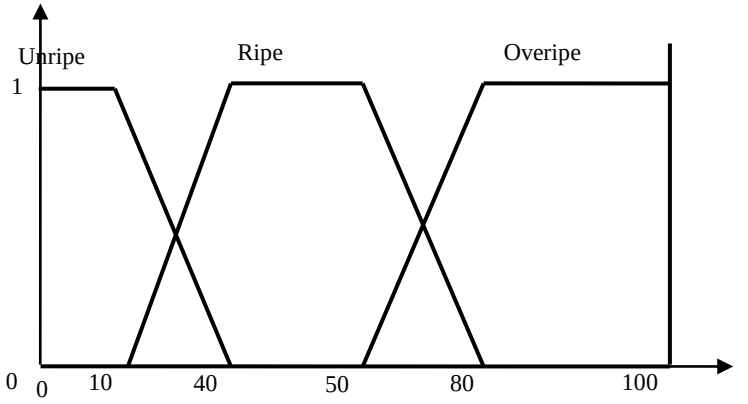

Fig.3.3. Membership function of output variable

Step 5:

The fuzzy rule base toolbox of Matlab 12 has been applied to produced the estimated output . Initially the trapezoid membership function has been applied to all input and output variables. Fig. 3.4(a) shows the snapshot of fuzzy inference system (FIS) that consists of the three inputs (red, green and blue) and one which output (category) .The snapshot of Rule editor and Rule viewer of training values of mango ripeness are shown in Fig. 3.4(b) and Fig 3.4(c).

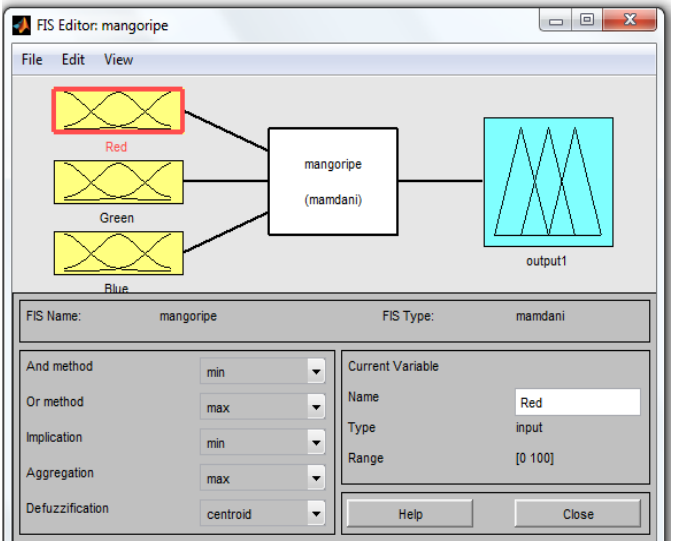

Fig.3.4(a). Fuzzy inference system for mango ripe

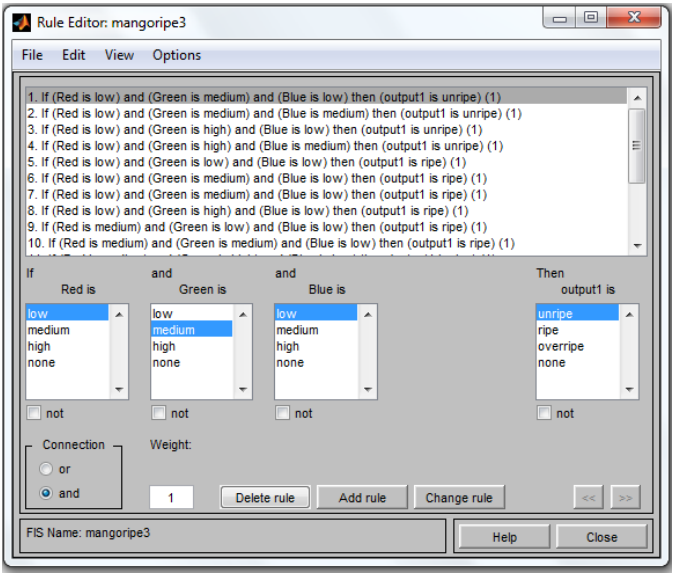

Fig.3.4(b). Rule editor

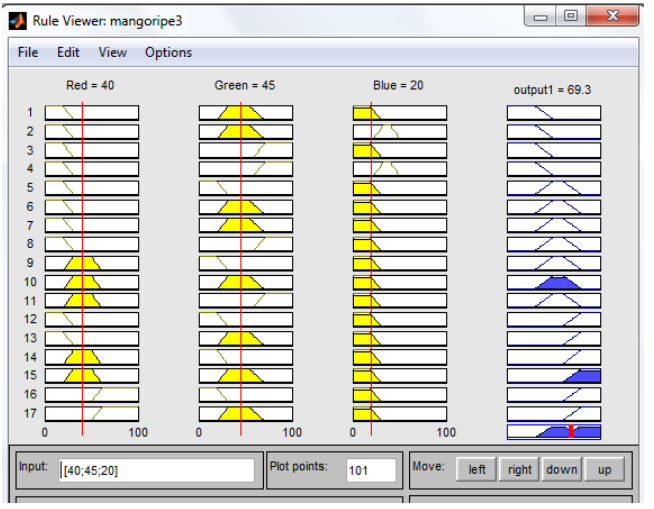

Fig.3.4(b). Deffuzzification result from the Rule Viewer

The deffuzzification results are calculated based on the centroid method. The classification of mango is determined based on the crisp logic given in Table 3.4.

Table 3.4. Fuzification Algorithms

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

Step 6:

Now Gaussian membership function has been applied to input variables. Gaussian membership is partition evenly into three linguistic variable low, medium and high as shown in Fig.3.2 The process is repeated from step 1 to step 5 to produce defuzification score as in Fig.3.2. The estimated output based on Gaussian membership function as shown in Table 4.

Step 7:

Thereafter triangular membership function has been applied to all input and output variables and repeated the same process in step 1 to step 5. Triangular membership is partition evenly into three linguistic variable low, medium and high as shown in Fig.3.2 .The estimated output based on triangular membership function as shown in Table 4.

4 Results

A Fuzzy Rule Based System in this study was implemented using Matlab's Fuzzy Logic Toolbox. In order to evaluate 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. Table 4 shows the results of defuzification score for each membership function applied in this study.

Table 4. Defuzification score among four membership function

No	RGB Color			Defuzification Score (Ripeness)		
	Red	Green	Blue	Trapezoid	Gaussion	Triangular
1	14.0	35.7	9.9	50.87	79.02	50.00
2	27.1	13.3	0.0	80.10	81.69	50.00
3	12.5	18.1	0.0	81.69	81.69	50.00
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.

The values of defuzification scores of trapezoid membership function convert to crisp logic using Table 3.4 above. Results comparison between human grader and proposed method (trapezoid) are shown in Table 5.

Table 5. Comparison of proposed fuzzy system (trapezoid) and human expert

	Fuzzy Logic Prediction					
	Mango Grade	Underripe	Ripe	Overripe	No. of mango	Correctly classified
Human expert	Underripe	5	0	0	5	100%
	Ripe	0	4	1	5	80%
	Overripe	0	1	4	5	80%
Total Observed(%)		5	5	5	15	
		100%	80%	80%		87%

In order to compare the performances of four membership technique, the prediction accuracy (A) is calculated as following equation.

$$A = \frac{N_t}{N_s} \times 100\% \qquad (4.1)$$

where N_t is the number of success prediction sample and N_s is the total number of training samples. The results are shown in Table 6, which confirms that the trapezoid membership function achieves higher accuracy than other membership function.

Table 6. The accuracy of four membership function.

Membership functions	Accuracy (%)
Trapezoid	87%
Triangular	50%
Gaussian	60%

It has been observed that the trapezoid membership function is suitable for implementation of the fuzzy rule base for mango ripening classification.

5 Conclusion

It has been shown that the fuzzy rule base system using the trapezoid membership function has given best result as compared to other membership functions. Grading results obtained from fuzzy logic show a very good agreement with the results from the human expert with more than 85% accuracy. The performance of the system can be improved by selecting the precise fuzzy rule statement.

References

[1] R. Malhotra, N. Singh, and Y. Singh, "Fuzzy logic modelling, simulation and control: a review," *Int. J. Comput. Sci. ...*, vol. 4333, pp. 183–188, 2010.

[2] M. Cintra, "A study on techniques for the automatic generation of membership functions for pattern recognition," *Congr. da Acad. ...*, 2008.

[3] M. Kaya and R. Alhajj, "Multi-objective genetic algorithm based method for mining optimized fuzzy association rules," *Intell. Data Eng. Autom. Learn. ...*, pp. 758–764, 2004.

[4] H. Naganur and S. Sannakki, "Fruits Sorting and Grading using Fuzzy Logic," *Int. J. ...*, vol. 1, no. 6, pp. 117–122, 2012.

[5] T. R. B. Razak, M. B. Othman, M. Nazari, K. Adilah, and A. R. Mansor, "Analysis," in *International Conference on Agricultural, Environment and Biological Sciences (ICAEBS'2012) May 26-27, 2012 Phuket*, 2012, pp. 18–22.

[6] A. R. Mansor, M. Othman, M. N. Abu Bakar, K. A. Ahmad, and T. R. Razak, "Fuzzy Ripening Mango Index using RGB Colour Sensor Model," *Res. -Journal Arts, Sci. Commer.*, vol. V, no. 2, pp. 1–9, 2014.

ISBN 978-967-0314-25-6