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Design of Automation System for Ceramic Surface Quality Control Using Fuzzy Logic Method at Balai Besar Keramik (BBK)

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Abstract. Indonesia is the world's top 10 ceramic users. Currently, the process of ceramic quality inspection in Indonesia, particularly in Balai Besar Keramik (BBK) is still done manually by human vision. Therefore, it is necessary to design a visual inspection system for digital image processing of ceramic automation using a Fuzzy Logic method. Fuzzy model is one method that can be used to determine ceramic surface quality control. This study aims to apply the fuzzy model in the design of automation system for ceramic surface quality control and describes its accuracy rate and automatic database. To perform feature extraction using GLCM extraction method to obtain autocorrelation, the sum of square (variance), and a number of the object. The information is used as input for data processing using the fuzzy model in the identification of quality of ceramic surface defect. In this research used Fuzzy model with GLCM extraction feature and process by using MATLAB software. This research used 32 training data can produce the accuracy of 96.87% and based on the real time system of 92.31% used 13 real time test data.

1 Introduction

Ceramic is the most popular type of media used in Indonesia because there are various advantages possessed, and also available for high usage and can be applied to almost all parts of the house. In addition to strong, ceramic house also does not require polishing and easy to maintain. Based on Table 1 can be seen from the export side, the export volume growth has fluctuated. The export volume of ceramics in 2013 to 2014 has increased by 4.3%, and in 2014. On the import side, the growth of ceramic import volume always increases every year. The rate of import increase of 8.6% and in 2014 to increase by 1%. Factors that cause import volumes to be higher than export volumes are that ASAKI coach is the government's very easy to include imported products without any more in-depth examination of standards, and in terms of price the difference is also cheaper than the price of ceramics in Indonesia [1].

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Table 1. Volume Export and Import Ceramic [2]

Year	2013	2014	2015
Volume Export (Ton)	295,780	337,000	336,520
Volume Import (Ton)	733,510	966,000	991,910

To fulfil the demand for export and import of ceramic products required quality products that can compete with other companies. Quality is the overall nature of a product or service that has an effect on its ability to satisfy the stated or implied needs [3]. To obtain the best quality of a product needs to consider their quality control process. In SNI ISO 13006:2010 there are six variable characteristic requirements related to the quality of ceramic tiles, namely: length and width, thickness, straightness of side, rectangularity, surface flatness and surface quality [4].

Currently, the process of ceramic quality inspection in Indonesia, particularly in BBK is still done manually by human vision. The process of ceramic quality inspection manually will cause fatigue and saturation because process performed repeatedly. There are five groups causes of fatigue, namely monotonous work, load and duration work both physically and mentally, work environment, psychological, and disease [5].

The method applied in this research is a quality control process called the Fuzzy Logic method. The method is a methodology of problem-solving control systems, suitable for implementation on systems, from simple systems, small systems, embedded systems, PC networks, multichannel or workstations based data acquisition and control systems [6-8].

There are several reasons why people use fuzzy logic, among others (1) The concept of fuzzy logic is easy to understand. The mathematical concept underlying fuzzy reasoning is very simple and easy to understand. (2) Fuzzy logic very flexible (3) Fuzzy logic has the tolerance of improper data. (4) Fuzzy logic capable of modelling very complex nonlinear functions. (5) Fuzzy logic can build and apply the experiences of experts directly without having to go through the training process. (6) Fuzzy logic can cooperate with conventional control techniques. (7) Fuzzy logic based on natural language [6-8].

In the fuzzy set theory, the role of membership degree as the determinant of the existence of elements in a set is very important. The membership value or membership degree or membership function is the main characteristic of reasoning with the fuzzy logic [9-12].

Before the advent of fuzzy logic theory, it is known that a crisp logic has a true or an unambiguous value. Conversely fuzzy logic is a logic that has a value of fuzziness between right and wrong. In fuzzy logic theory, a value can be true or false at the same time but how much truth and error a value depends on the weight of its membership [9-12].

Based on research Atmaja error rate of measurement of tile surface area obtained at light intensity 300 lx with a distance of 50 cm by 0.0675%. Influencing factors for the percentage of ceramic tile measure wide error rate are camera distance, light intensity, and interaction of both factors (camera distance and light intensity). This research to measure the accuracy rate in process quality control of ceramic surface used Fuzzy Logic method. Fuzzy Logic method used Mamdani.

2 Gray Level Co-Occurrence Matrix (GLCM)

Gray Level Co-occurrence Matrix (GLCM) is a technique for obtaining image textures using second order calculations. First-order texture measurements using statistical calculations are based on pure image values only, such as variance, and do not pay attention to the neighboring pixels [7]. In this research used for extraction features are autocorrelation and sum of square (variance).

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1. Autocorrelation:

$$\text{Autocorrelation}=\frac{\sum_{u=0}^{N}\sum_{v=0}^{N} I\,(u,v)\; I\,(u+x,v+y)}{\sum_{u=0}^{N}\sum_{v=0}^{N} I^2(u,v)} \tag{1}$$

   The autocorrelation is combination pairs as one point, and define the correlation of this point between other combination pair series [8].
   Where;
   I is the mean value of I(u,v)
   M and N are the image width and height

2. Sum of Square (Variance):

$$\text{Sum of Squares} = \sum_{i=0}^{G-1}\sum_{j=0}^{G-1}(i\text{-}\mu)^2\,.P(i,j) \tag{2}$$

   This features puts relatively high weights on the elements that differ from the average value of P(i,j). GLCM variance uses the GLCM, therefore it deals specifically with the dispersion around the mean of combinations of reference and neighbor pixels, i.e., encoding contextual (Order) information [8].

3 Methodology

3.1 Step Approach For Defect Detection

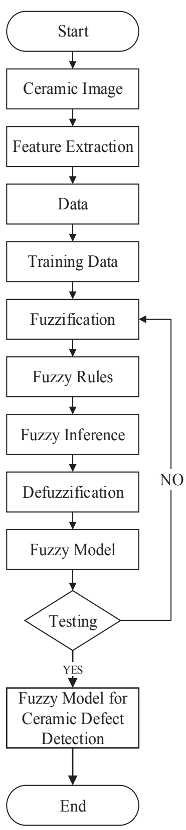

Fig. 1. Flowchart of methodology research

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The complete flow chart of our step defect detection technique has been rendered in the following Figure 1. Based on Figure 1 had eight steps, consist of capture a ceramic image, undertake feature extraction,determine the universal set in input and output variable, define fuzzy set in input and output, create fuzzy rule, fuzzy inference, defuzzification, testing of Fuzzy Model.

The first step before data processing is taking a picture for training data and testing data (real time). Training data using 32 sample consist of 16 sample normal ceramics and 16 sample defect surface ceramics. Testing data (real time) using 16 sample consist of 8 sample normal ceramics and 5 sample defect surface ceramics. Capturing picture using Webcam Logitech C525 and Logitech Webcam Software with 1.3 MP camera resolution, 300 lx light intensity, and 50 cm camera distance.

The second step uses GLCM feature extraction and Prewitt Edge Detection to count the point object in an image. It will be obtained the value that will be used to Fuzzy Model, these are autocorrelation, a sum of square (variance), and a number of the object. The next step is converting the RGB image into grayscale image. Then images that have been converted into grayscale is the feature extraction process. The GLCM method is used to know value used in the fuzzy input, these are autocorrelation, and a sum of square (variance).

The third step is the classification of fuzzy logic as the basic fuzzy model. The universal set is value that allowed to be operated in a fuzzy variable. Universal set input is a range of minimum to a maximum value of all sample data. Universal set output is divided into 2 categories consist of a defect and normal. The output of this research is linguistic values that need to convert into the numerical value, choose number 1 as a defect, and 2 as normal.

The fourth step, fuzzy set for each input variable of feature extraction divide into 9 sets and output of fuzzy sets in this research was divided into two categories, defect and normal. The allocation of the fuzzy set is done by trial and error to get a good model.

The fifth step, extraction results obtained from 32 training data are used to create the fuzzy rules of the membership function that have been searched. The greatest value of a membership function is used to create a fuzzy rule based on the relationship between fuzzy sets. This research uses 3 input characteristics and 9 degree membership. The possible rules used are 9^3, total of training data used is 32 data using 729 rules. The largest membership value is used as a representation of rules in the fuzzy set. The process for obtaining fuzzy rules through calculations using MATLAB®.

The sixth step, fuzzy inference is the process s to get the output of each rule. Each rule gives a value appropriate with the input. This research is using fuzzy inference with Mamdani Model. Mamdani Model implement the implication functions and rule composition. Implication function performed to obtain an output modification of fuzzy area from each the rule. Implication function of Mamdani Model using implication function MIN and composition rule MAX, so that the Mamdani Model often known as MAX-MIN Model.

The seventh step, Defuzzification is the last step on a fuzzy model that is to convert the result of fuzzy set value from fuzzy inference into a crisp. Therefore, the fuzzy set obtained from fuzzy inference which is the extraction result of the sample image is recovered using de fuzzifier into crisp. Defuzzifier used in this research that is centroid method, because defuzzification value obtained is able to move smoothly, the conversion from fuzzy set also run smoothly. Defuzzification process will be calculated using MATLAB® software.

4 Results and Discussion

4.1 Feature Extraction

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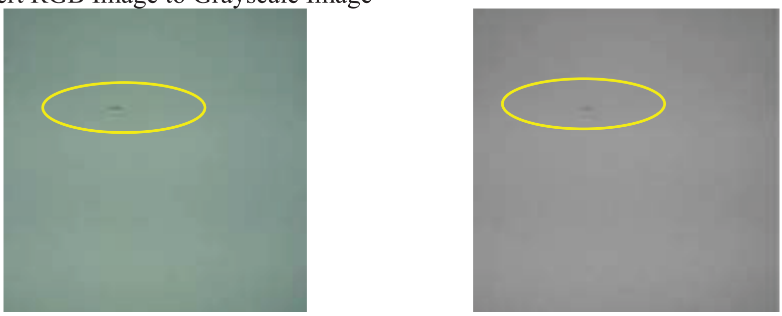
Feature extraction process is conducted with MATLAB® software. To perform the feature extraction of the image required a media interface that is contained in MATLAB® Library.

1. Convert RGB Image to Grayscale Image



(a) RGB Image (b) Grayscale Image

Fig. 2. Example RGB Image to Grayscale Image

In Figure 2 image illustration convert RGB image to grayscale image.

2. Convert Grayscale Image to Binary Image

(a) Grayscale Image (b) Binary Image

Fig. 3. Example Grayscale Image to Binary Image

In Figure 3 is the result of the grayscale image into the binary image, and identify defect point using white color.

4.2 Identify Universal Set (U) for Input

Based on data obtained from the feature extraction then the universal sets of each image as follows:

1. Autocorrelation
   The universal set for autocorrelation from the training data of feature extraction is minimum 24.1814 and maximum 34.2239. Then the universal set for number of object is U_A = [24.1814 34.2239].
2. Sum of Square (Variance)
   The universal set for sum of square (variance) from the training data of feature extraction is minimum 24.0395 and maximum 34.0558. Then the universal set for number of object is U_B = [24.0395 34.0558].
3. Number of Object

The universal set for a number of object from the training data of feature extraction is minimum 0 and maximum 4. Then the universal set for a number of object is U_C = [0 4].

4.3 Identify Universal Set (V) for Output

The minimum output value is 1 and the maximum value is 2, therefore the universal set for output V = [1 2].

4.4 Define Fuzzy Set for Input and Output

Here is the description of a fuzzy set of training data input from feature extraction and output.

1. Autocorrelation
   The membership to the variable autocorrelation function as follows. The membership function is illustrated in Figure 4.

$$\mu_{A1}[x]=\begin{cases}\frac{25.4367-x}{1.2553}; 24.1814 \le x \le 25.4367\\ 0 ; 25.4367 \le x\end{cases}$$

$$\mu_{A2}[x]=\begin{cases}0; x \le 24.1814\\ \frac{x-24.1814}{1.2553}; 24.1814 \le x \le 25.4367\\ \frac{26.6920-x}{1.2553}; 25.4367 \le x \le 26.6920\end{cases}$$

$$\mu_{A3}[x]=\begin{cases}0, x \le 25.4367\\ \frac{x-25.4367}{1.2553}; 25.4367 \le x \le 26.6920\\ \frac{27.9473-x}{1.2553}; 26.6920 \le x \le 27.9473\end{cases}$$

$$\mu_{A4}[x]=\begin{cases}0, x \le 26.6920\\ \frac{x-26.6920}{1.2553}; 26.6920 \le x \le 27.9473\\ \frac{29.2027-x}{1.2553}; 27.9473 \le x \le 29.2027\end{cases}$$

$$\mu_{A5}[x]=\begin{cases}0, x \le 27.9473\\ \frac{x-27.9473}{1.2553}; 27.9473 \le x \le 29.2027\\ \frac{30.4580-x}{1.2553}; 29.2027 \le x \le 30.4580\end{cases}$$

$$\mu_{A6}[x]=\begin{cases}0, x \le 29.2027\\ \frac{x-29.2027}{1.2553}; 29.2027 \le x \le 30.4580\\ \frac{31.7133-x}{1.2553}; 30.4580 \le x \le 31.7133\end{cases}$$

$$\mu_{A7}[x]=\begin{cases}0, x \le 30.4580\\ \frac{x-30.4580}{1.2553}; 30.4580 \le x \le 31.7133\\ \frac{32.9686-x}{1.2553}; 31.7133 \le x \le 32.9686\end{cases}$$

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$$\mu_{A8}[x] = \begin{cases} 0, \ x \le 31.7133 \\ \dfrac{x - 31.7133}{1.2553}; \ 31.7133 \le x \le 32.9686 \\ \dfrac{34.2239 - x}{1.2553}; \ 32.9686 \le x \le 34.2239 \end{cases}$$

$$\mu_{A9}[x] = \begin{cases} 0 ; \ x \le 32.9686 \\ \dfrac{x - 32.9686}{1.2553}; \ 32.9686 \le x \le 34.2239 \\ 1 ; \ x \ge 34.2239 \end{cases}$$

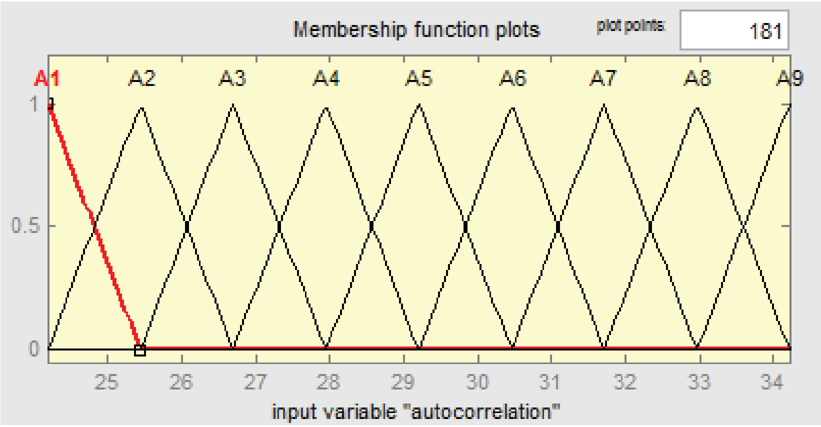

Fig. 4. Graph variable membership functions autocorrelation

2. Sum of Square (Variance)
   The membership to the variable sum of square (variance) function as follows, and the membership function is illustrated in Figure 5.

$$\mu_{B1}[x] = \begin{cases} \dfrac{25.2915 - x}{1.2520}; \ 24.0395 \le x \le 25.2915 \\ 0; \ x \ge 25.2915 \end{cases}$$

$$\mu_{B2}[x] = \begin{cases} 0; \ x \le 24.0395 \\ \dfrac{x - 24.0395}{1.2520}; \ 24.0395 \le x \le 25.2915 \\ \dfrac{26.5436 - x}{1.2520}; \ 25.2915 \le x \le 26.5436 \end{cases}$$

$$\mu_{B3}[x] = \begin{cases} 0, \ x \le 25.2915 \\ \dfrac{x - 25.2915}{1.2520}; \ 25.2915 \le x \le 26.5436 \\ \dfrac{27.7956 - x}{1.2520}; \ 26.5436 \le x \le 27.7956 \end{cases}$$

$$\mu_{B4}[x] = \begin{cases} 0, \ x \le 26.5436 \\ \dfrac{x - 26.5436}{1.2520}; \ 26.5436 \le x \le 27.7956 \\ \dfrac{29.0477 - x}{1.2520}; \ 27.7956 \le x \le 29.0477 \end{cases}$$

$$\mu_{B5}[x] = \begin{cases} 0, x \le 27.7956 \\ \dfrac{x - 27.7956}{1.2520}; 27.7956 \le x \le 29.0477 \\ \dfrac{30.2997 - x}{1.2520}; 29.0477 \le x \le 30.2997 \end{cases}$$

$$\mu_{B6}[x] = \begin{cases} 0, x \le 29.0477 \\ \dfrac{x - 29.0477}{1.2520}; 29.0477 \le x \le 30.2997 \\ \dfrac{31.5517 - x}{1.2520}; 30.2997 \le x \le 31.5517 \end{cases}$$

$$\mu_{B7}[x] = \begin{cases} 0, x \le 30.2997 \\ \dfrac{x - 30.2997}{1.2520}; 30.2997 \le x \le 31.5517 \\ \dfrac{32.8038 - x}{1.2520}; 31.5517 \le x \le 32.8038 \end{cases}$$

$$\mu_{B8}[x] = \begin{cases} 0, x \le 31.5517 \\ \dfrac{x - 31.5517}{1.2520}; 31.5517 \le x \le 32.8038 \\ \dfrac{34.0558 - x}{1.2520}; 32.8038 \le x \le 34.0558 \end{cases}$$

$$\mu_{B9}[x] = \begin{cases} 0 ; x \le 32.8038 \\ \dfrac{x - 32.8038}{1.2520}; 32.8038 \le x \le 34.0558 \\ 1 ; x \ge 34.0558 \end{cases}$$

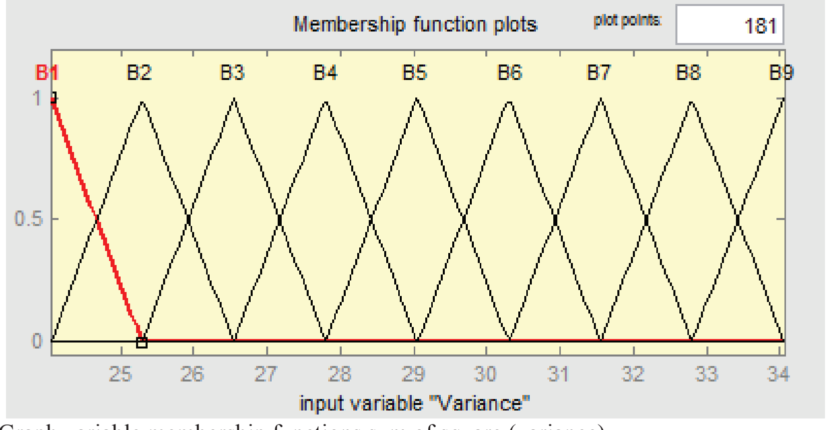

Fig. 5. Graph variable membership functions sum of square (variance)

3. Number of Object
   The membership to the variable number of object function as follows. The membership function is illustrated in Figure 6.

$$\mu_{C1}[x] = \begin{cases} \dfrac{0.5 - x}{0.5}; 0 \le x \le 0.5 \\ 0; x \ge 0.5 \end{cases}$$

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$$\mu_{C2}[x] = \begin{cases} 0;\ x \le 0 \\ \dfrac{x - 0}{0.5};\ 0 \le x \le 0.5 \\ \dfrac{1 - x}{0.5};\ 0.5 \le x \le 1 \end{cases}$$

$$\mu_{C3}[x] = \begin{cases} 0,\ x \le 0.5 \\ \dfrac{x - 0.5}{0.5};\ 0.5 \le x \le 1 \\ \dfrac{1.5 - x}{0.5};\ 1 \le x \le 1.5 \end{cases}$$

$$\mu_{C4}[x] = \begin{cases} 0,\ x \le 1 \\ \dfrac{x - 1}{0.5};\ 1 \le x \le 1.5 \\ \dfrac{2 - x}{0.5};\ 1.5 \le x \le 2 \end{cases}$$

$$\mu_{C5}[x] = \begin{cases} 0,\ x \le 1.5 \\ \dfrac{x - 1.5}{0.5};\ 1.5 \le x \le 2 \\ \dfrac{2.5 - x}{0.5};\ 2 \le x \le 2.5 \end{cases}$$

$$\mu_{C6}[x] = \begin{cases} 0,\ x \le 2 \\ \dfrac{x - 2}{0.5};\ 2 \le x \le 2.5 \\ \dfrac{3 - x}{0.5};\ 2.5 \le x \le 3 \end{cases}$$

$$\mu_{C7}[x] = \begin{cases} 0,\ x \le 2.5 \\ \dfrac{x - 2.5}{0.5};\ 2.5 \le x \le 3 \\ \dfrac{3.5 - x}{0.5};\ 3 \le x \le 3.5 \end{cases}$$

$$\mu_{C8}[x] = \begin{cases} 0,\ x \le 3 \\ \dfrac{x - 3}{0.5};\ 3 \le x \le 3.5 \\ \dfrac{4 - x}{0.5};\ 3.5 \le x \le 4 \end{cases}$$

$$\mu_{C9}[x] = \begin{cases} 0\ ;\ x \le 3.5 \\ \dfrac{x - 3.5}{0.5};\ 3.5 \le x \le 4 \\ 1\ ;\ x \ge 4 \end{cases}$$

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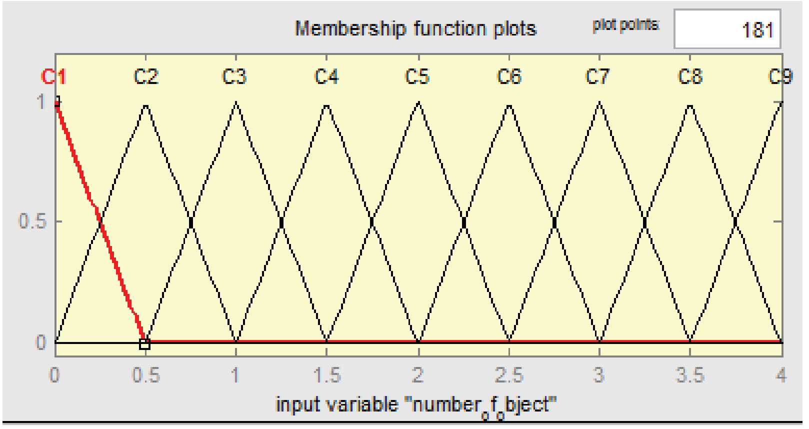

Fig. 6. Graph variable membership functions number of object

4. Output
   Output of fuzzy sets in this research were divided into two categories, defect and normal. It was presented using triangular membership function on the interval [1 2]: The fuzzy set is illustrated in Figure 7.

$$\mu_{DEFECT}\,[x]= \begin{cases} 2 - x;\ 1 \leq x \leq 2 \\ 0;\ x \geq 2 \end{cases}$$

$$\mu_{NORMAL}\,[x]= \begin{cases} 1 - x;\ 1 \leq x \leq 2 \\ 1;\ x \geq 2 \end{cases}$$

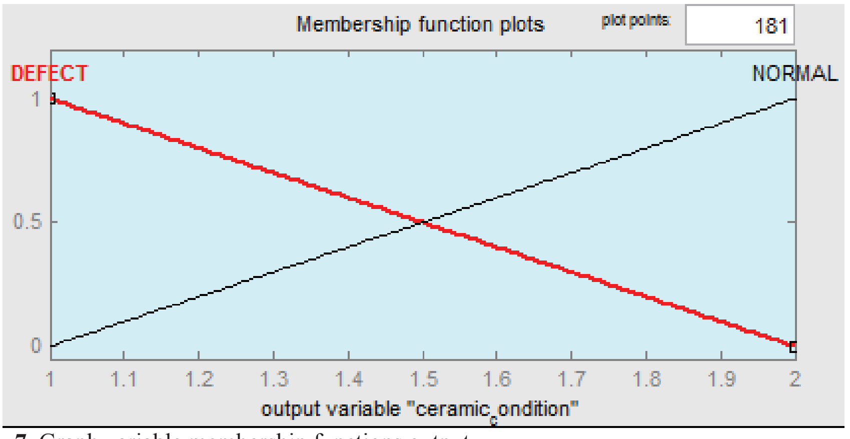

Fig. 7. Graph variable membership functions output

4.6 Create Fuzzy Rule (If – Then)

Here is an example of the fuzzy rule of figure nine. This rule is formed after the feature extraction, so it will produce 3 as input. Figure 8 is a sample training data image and the result of feature extraction shown in Table 2.

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Fig. 8. Sample Training Data Image

The following are the results of the sample training data image extraction.

Table 2 Results of The Sample Training Data Image Extraction

Data	Result of Extraction
Autocorrelation	24.9187
Sum of Square (Variance)	24.7652
Number of Object	2
Detection	Defect

Extracted from the images grouped in a fuzzy set of input

1. Autocorrelation

   Autocorrelation of the sample training data image extraction is 24.9187. Fuzzy set on the input autocorrelation divided into 9 fuzzy set A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, A_9. X = 24.9187 can be included in the A1 and A2.

   $\mu_{A1}(24.9187) = \frac{25.4367\text{-}24.9187}{1.2553} = 0.4127$, so membership function $A_1 = 0.4127$

   $\mu_{A2}(24.9187) = \frac{24.9187 - 24.1814}{1.2553} = 0.5873$, so membership function $A_2 = 0.5873$

   $\mu_{A3}(24.9187) = 0$, membership function $A_3=0$

   $\mu_{A4}(24.9187) = 0$, membership function $A_4=0$

   $\mu_{A5}(24.9187) =0$, membership function $A_5=0$

   $\mu_{A6}(24.9187) =0$, membership function $A_6=0$

   $\mu_{A7}(24.9187) =0$, membership function $A_7=0$

   $\mu_{A8}(24.9187) =0$, membership function $A_8=0$

   $\mu_{A9}(24.9187) =0$, membership function $A_9=0$

   Then,
   Max = (μ_{A1}, μ_{A2}, μ_{A3}, μ_{A4}, μ_{A5}, μ_{A6}, μ_{A7}, μ_{A8}, μ_{A9})
   Max = (0.4127, 0.5873, 0, 0, 0, 0, 0, 0, 0) = 0.5873
   Therefore, autocorrelation of the extracted sample training data image into the fuzzy set A_2.

2. Sum of Square (Variance)
   Sum of Square (Variance) of extracting the sample training data image is 24.7652. The set of fuzzy input sum of square (variance) is divided into 9 fuzzy set that ire B_1, B_2, B_3, B_4, B_5, B_6, B_7, B_8, B_9. X = 24.7652 can be included in the set B_1 and B_2.
   $\mu_{B1}(24.7652) = \frac{25.2915 - 24.7652}{1.2520} = 0.4204$, so membership function B_1=0.4204
   $\mu_{B2}(24.7652) = \frac{24.7652 - 24.0395}{1.2520} = 0.5796$ so membership function B_2=0.5796
   $\mu_{B3}(24.7652) = 0$, membership function B_3=0
   $\mu_{B4}(24.7652) = 0$, membership function B_4=0
   $\mu_{B5}(24.7652) =0$, membership function B_5=0
   $\mu_{B6}(24.7652) =0$, membership function B_6=0
   $\mu_{B7}(24.7652) =0$, membership function B_7=0
   $\mu_{B8}(24.7652) =0$, membership function B_8=0
   $\mu_{B9}(24.7652) =0$, membership function B_9=0
   Then,
   Max = (μ_{B1}, μ_{B2}, μ_{B3}, μ_{B4}, μ_{B5}, μ_{B6}, μ_{B7}, μ_{B8}, μ_{B9})
   Max = (0.4204, 0.5796, 0, 0, 0, 0, 0, 0, 0) = 0.5796
   Therefore, sum of square (variance) of the extracted sample training data into the fuzzy set B_2.
3. Number of Object
   Number of Object of the training data image extraction is 2. The set of fuzzy on the number of objects is divided into 9 fuzzy set that are C_1, C_2, C_3, C_4, C_5, C_6, C_7, C_8, C_9..
   X = 2 can be included in the set C_4 and C_5.
   $\mu_{C1}(2) = 0$, membership function $C_1 = 0$
   $\mu_{C2}(2) = 0$, membership function $C_2 = 0$
   $\mu_{C3}(2) = 0$, membership function $C_3 = 0$
   $\mu_{C4}(2) = \frac{2 - 2}{0.5} = 0$, so membership function C_4= 0
   $\mu_{C5}(2) = \frac{2 - 1.5}{0.5} = 1$, so membership function C_5= 1
   $\mu_{C6}(2) = 0$, membership function $C_6 = 0$
   $\mu_{C7}(2) = 0$, membership function $C_7 = 0$
   $\mu_{C8}(2) = 0$, membership function $C_8 = 0$
   $\mu_{C9}(2) = 0$, membership function $C_9 = 0$
   Then,
   Max = (μ_{C1}, μ_{C2}, μ_{C3}, μ_{C4}, μ_{C5}, μ_{C6}, μ_{C7}, μ_{C8}, μ_{C9})
   Max = (0, 0, 0, 0, 1, 0, 0, 0, 0) = 1
   Therefore, number of object of the extracted training data image into the fuzzy set C_5.

Table 3 is the fuzzy set grouping of the training data image.

Table 3 Results of the extraction and classification of fuzzy sets of the training data image

Data	Result of Extraction	Membership Function	Fuzzy Set
Autocorrelation	24.9187	0.5873	A_2
Sum of Square (Variance)	24.7652	0.5796	B_2
Number of Object	2	1	C_5
Ceramic Condition	Defect	Defect	V_{Defect}

Based on Table 3 the rules from the feature extraction result of training data image as follows:
"IF autocorrelation is A_2 AND variance is B_2 AND number of object is C_5 THEN Ceramic Condition is V_{Defect}"

4.7 Fuzzy Inference

Here is an example of inference calculation manually. Example use the ninth image shown in Table 4.

Table 4 Result of Extraction Sample Image Data

Data	Result Extraction
Autocorrelation	24.9187
Variance	24.7652
Number of Object	2
Ceramic Condition	Defect

Based on the results of the ninth image obtained extract the greatest value of the implications is the value MIN 0.5796. Then the composition is modified into a fuzzy area. The area from the output is illustrated in Figure 18.

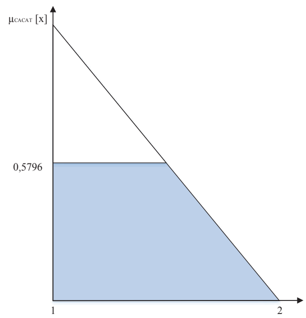

Fig. 9. MIN Results implications rules Sample Image Data

From the area results ninth data obtained would then be determined the implications of the membership function in the following ways:

1. The range is divided into two parts, namely D1 and D2 with a1 which is the boundary from the two areas as shown in Figure 10.

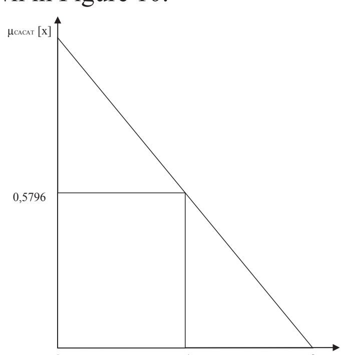

Fig. 10. Illustration Picture Implications Rules Division MIN

2. Then it would be determined value of a_1
   The point a_1 is between the intersection of the lines y = 2 − x and y = 0.5796.

$$y_1 = y_2$$
$$2 - x = 0.5796$$
$$x = 1.4204$$

Therefore, the composition of the membership function results are as follows:

$$\mu[x] = \begin{cases} 0.5796 \; ;1 \le x \le 1.4204 \\ 2\text{-}x \; ;1.4204 \le x \le 2 \end{cases}$$

The result of fuzzy inference using Mamdani Method, the output still as a fuzzy set, therefore need to convert of fuzzy set into crisp using defuzzification.

4.8 Defuzzification

The centroid is calculating crips set by taking the center point of the fuzzy area. This is the formula:

$$x^* = \frac{\int_a^b z\mu(z)dz}{\int_a^b \mu(x)dz}$$

The result of fuzzy inference:

$$\mu[x] = \begin{cases} 0.5796 \; ;1 \le x \le 1.4204 \\ 2\text{-}x \; ;1.4204 \le x \le 2 \end{cases}$$

Using Centroid Method get formula:

$$x^* = \frac{\int_1^{1.4204} (0.5796)xdx + \int_{1.4204}^2 (2\text{-}x)xdx}{\int_1^{1.4204} (0.5796)dx + \int_{1.4204}^2 (2\text{-}x)dx}$$

$$x^* = \frac{0.2948+0.2710}{0.2436+0.1679}$$

$$x^* = \frac{0.5658}{0.4115}$$

$$x^* = 1.3749$$

The defuzzification result of the sample image is 1.3749, which means that the ninth image is DEFECT. Defuzzification process is calculated using MATLAB.

4.9 Defect Detection for Training Data

The following Table 5 shows the test results of 32 training data. The table data training consist of data training, real output, output model, and information. The result of identification of training data as much as 32 data resulted 1 wrong data, where 1 data that should be normally identified defect. This result is determined from Deffuzification values for defects ≤ 1.5 and Deffuzification values for normal > 1.5.

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Table 5 Results of Training Data

Data	***Real Output***	***Output Model***	***Information***
Data Training 1	NORMAL	NORMAL	TRUE
Data Training 2	NORMAL	NORMAL	TRUE
Data Training 3	NORMAL	NORMAL	TRUE
Data Training 4	NORMAL	NORMAL	TRUE
Data Training 5	NORMAL	NORMAL	TRUE
Data Training 6	NORMAL	NORMAL	TRUE
Data Training 7	NORMAL	NORMAL	TRUE
Data Training 8	NORMAL	DEFECT	FALSE
Data Training 9	DEFECT	DEFECT	TRUE
Data Training 10	DEFECT	DEFECT	TRUE
Data Training 11	DEFECT	DEFECT	TRUE
Data Training 12	DEFECT	DEFECT	TRUE
Data Training 13	NORMAL	NORMAL	TRUE
Data Training 14	NORMAL	NORMAL	TRUE
Data Training 15	NORMAL	NORMAL	TRUE
Data Training 16	NORMAL	NORMAL	TRUE
Data Training 17	NORMAL	NORMAL	TRUE
Data Training 18	NORMAL	NORMAL	TRUE
Data Training 19	NORMAL	NORMAL	TRUE
Data Training 20	NORMAL	NORMAL	TRUE
Data Training 21	DEFECT	DEFECT	TRUE
Data Training 22	DEFECT	DEFECT	TRUE
Data Training 23	DEFECT	DEFECT	TRUE
Data Training 24	DEFECT	DEFECT	TRUE
Data Training 25	DEFECT	DEFECT	TRUE
Data Training 26	DEFECT	DEFECT	TRUE
Data Training 27	DEFECT	DEFECT	TRUE
Data Training 28	DEFECT	DEFECT	TRUE
Data Training 29	DEFECT	DEFECT	TRUE
Data Training 30	DEFECT	DEFECT	TRUE
Data Training 31	DEFECT	DEFECT	TRUE
Data Training 32	DEFECT	DEFECT	TRUE

To determine the accuracy of this training data, use the following formula:

$$\text{Accuracy Rate} = \frac{\text{Number of True}}{\text{Total Data Training}} \text{x} 100\%$$

$$\text{Accuracy Rate} = \frac{31}{32}\text{x}100\%$$
$$\text{Accuracy Rate} = 96.87\%$$

Therefore, the accuracy rate used fuzzy model with triangle representation of membership function, Mamdani method of fuzzy inference, centroid method of defuzzification, and 729 rules the obtained accuracy rate 96.87%.

4.10 Defect Detection for Testing Data (Real Time)

Automatic ceramic inspection design based on ceramic defect detection, the results of the system are shown in Table 6.

Table 6 Result of System in Real Time Process

Data	*Real Ouput*	*Output Model*	*Deffuzification*	*Information*
Data Test 1	NORMAL	NORMAL	1.63277	TRUE
Data Test 2	NORMAL	NORMAL	1.62542	TRUE
Data Test 3	NORMAL	NORMAL	1.6361	TRUE
Data Test 4	NORMAL	NORMAL	1.63807	TRUE
Data Test 5	NORMAL	NORMAL	1.63451	TRUE
Data Test 6	NORMAL	NORMAL	1.63918	TRUE
Data Test 7	NORMAL	NORMAL	1.63201	TRUE
Data Test 8	NORMAL	NORMAL	1.63903	TRUE
Data Test 9	DEFECT	DEFECT	1.36873	TRUE
Data Test 10	DEFECT	DEFECT	1.3673	TRUE
Data Test 11	DEFECT	DEFECT	1.36595	TRUE
Data Test 12	DEFECT	DEFECT	1.36672	TRUE
Data Test 13	DEFECT	NORMAL	1.62537	FALSE

This research tested fuzzy logic model using Logitech C525 webcam, camera resolution of 1.3 MP or image size of 640 x 480 pixel, camera distance of 50 cm, and light intensity of 300 lx. The result of identification of training data as much as 13 data resulted 1 wrong data, where 1 data that should be normally identified defect. This result is determined from deffuzification values for defects ≤ 1.5 and deffuzification values for normal > 1.5. To determine the accuracy of this training data, use the following formula:

$$\text{Accuracy Rate} = \frac{\text{Number of True}}{\text{Total Data Training}}\text{x}100\%$$
$$\text{Accuracy Rate} = \frac{12}{13}\text{x}100\%$$
$$\text{Accuracy Rate} = 92.31\%$$

Therefore, the accuracy rate used fuzzy model with triangle representation of membership function, mamdani method of fuzzy inference, centroid method of defuzzification, and 729 rules the obtained accuracy rate 92.31%.

5 Conclusion

In this research used Fuzzy model with GLCM extraction feature and process by using MATLAB software. In the extraction feature used three variabel inputs consist of autocorrelation, sum of square (variance), and number of object. Accuracy rate of ceramic inspection process using design of automatic ceramic defect detection with light intensity 300 lx, 50 cm camera distance and 1.3 MP camera resolution or 640 x 480 pixel image size using fuzzy logic on ceramic defect with training data of 96.87% and accuracy based on the real time system of 92.31%.

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