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DESIGN OF AUTOMATION SYSTEM FOR CERAMIC SURFACE QUALITY CONTROL USING ARTIFICIAL NEURAL NETWORK AT BALAI BESAR KERAMIK

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***Abstract*— Indonesia ceramic tiles production is currently ranked between the fifth and sixth of the world, it shows that ceramic tiles is one of the largest commodities in Indonesia. So, ceramic quality becomes very important to be considered for it is used as one of the basic building materials. The existing ceramic testing system in *Balai Besar Keramik* is performed by the operator repeatedly. With the repetitive performances, they cause fatigue to operator that results in decreased work ability, so in the calibration and readings of measuring instruments an error occurs. To improve the accuracy level of quality control system to remain stable, it's necessary to create an intelligent device that can overcome errors that occur in the inspection process using human vision on the surfaces of defect detection of ceramic tiles that have a high level of system stability; therefore, it is required the automation system design of the image processing-based using Artificial Neural Network method with backpropagation algorithm. The process of system design is using automation design with 300 Lx light intensity, 50 cm of camera distance, based on Artificial Neural Network method with confusion matrix result obtaining accuracy rate of 96.9% for offline mode and 92.3% for realtime mode.**

Keywords*— *Ceramic Tiles; Surface Defect; Automation Design; Image Processing; Artificial Neural Network.

I. INTRODUCTION

The need for quality control and performance testing has become an integral part of production procedure [1]. Automation of the inspection procedure will almost always be automated machines that are not given to the fatigue and human inspectors [2]. Based on the data released by the *Asosiasi Aneka Industri dan Keramik Indonesia* (ASAKI), Indonesia ceramic tiles production is currently ranked between the fifth and sixth of the world, it shows that ceramic tiles is one of the largest commodities in Indonesia. So, the quality of ceramic tiles becomes very important to be considered because it is used as one of the basic building materials.

TABLE I. TILES PRODUCTION DATA [3]

Ceramic Commodities	2013	2014	2015
Tiles	430 million m^2	480 million m^2	390 million m^2
Tableware	275 million pcs	290 million pcs	290 million pcs
Sanitary	5.1 million pcs	5.4 million pcs	-
Rooftile	120 million pcs	130 million pcs	120 million pcs

Based on the observation at *Balai Besar Keramik*, the references of testing use SNI ISO 10545-2: 2010 standard, the quality inspection of ceramic tiles surface uses fluorescent lamp with color temperature of 6000 - 6500 K and the set of light meters with intensity of 3000 Lx at the center and every corner of tile being examined. The quality of ceramic tiles surface measurement is very important because it's very visible.

The existing ceramic testing system at *Balai Besar Keramik* is performed by the operator repeatedly. This is certainly very difficult and takes a relatively long-time due to the limitations on human vision and there are different perceptions among individuals [3]. With the repetitive performances, they cause fatigue to operator resulting in decreased work ability, errors of calibration and readings of measuring instruments. In order to examine ceramic surface quality to be stable, it’s necessary to create an intelligent device that can overcome the errors that occur in the inspection process using human vision.

Some researches have been already conducted to design an automation system for ceramic tiles, such the research conducted by Suryadi [4] about the design of automation system of ceramic tiles rectangularity of identification process using digital image processing with Harris Corner Detection method in *Balai Besar Keramik*, by using Sobel edge detection and Harris Corner Detection methods to determine the vertex of each ceramic quadrant, then calculating the deviation of each ceramic quadrant. This research has an average of error rate of 26.6278% seen in Table II. So, it’s necessary to develop the research that can optimize the inspection of ceramic quality based on ceramic surface.

TABLE II. ERROR CALCULATION RESULT [4]

Deviation			
1	2	3	4
29.1162%	42.4645%	28.5089%	6.4215%

Atmaja [5] has conducted the research on the optimization of ceramic tile measurement dimension and surface defect using image processing and full factorial design to know a correlation between every factor that affects error rate result. To design of experiment with consider: comparing the light intensity of 300 Lx, 600Lx, and 900Lx, also comparing the camera distance of 50 cm, 75 cm, and 100 cm. The results obtained from the research shows that the smallest error rate is obtained at a light intensity of 300 Lx with a camera distance of 50 cm by 0.0675%. In this research, the system that is designed isn’t in a realtime, so it is required the development of research that is able to classify the type of defect automatically and the realtime by using artificial intelligence.

Digital image processing can be used to detect ceramic tile rectangularity and surface defect. According to Bin and Yeganeh [6], using Sobel operator is more sensitive for the diagonal edge, while Prewitt operator is more sensitive for horizontal and vertical edges. Canny operator uses a Gaussian function and noise interference does not occur to detect an edge. So, this method is optimal for detecting ceramic defects.

The edge detection using Canny method provides very complete information, it’s because the lines are clearly connected [7]. Moreover, according to Yodha and Kurniawan [8] Canny edge detection uses Gaussian Derivative Kernel to smoothen the image appearance, and its use for image segmentation or feature extraction can improve accuracy in pattern recognition.

Artificial Neural Network is an information processing system that has learned ability on data and information that are received, ability to model a linear function, parallel commutation, and has characteristic of fault tolerance [9]. According Karunamoorthy et. al. [10], the method of defect identification on the plant using the Artificial Neural Network provides the best defect detection results for all examination methods and can be used to classify the defect.

The research conducted by Nazelliana and Widodo [11] about detection of ceramic surface defects uses image processing to obtain the feature extraction value, then it is analyzed by using data testing of Artificial Neural Network with backpropagation algorithm to get backpropagation value. This research is conducted to find the effectivity and accuracy of method used by using image processing techniques and to improve productivity, by knowing the previous production error, so the same error can be prevented for subsequent production. A thing that has to be noticed is a good pixel and high-resolution levels. The result of this research is defect classification result whether defect or not defect is based on value from Artificial Neural Network backpropagation algorithm and has accuracy value almost 90% for detecting ceramic tile defect. Artificial Neural Network with backpropagation algorithm method is very good to handle the problem of recognized complex patterns. This research doesn’t use prototype, so it is required the development of research by using prototype that can be inspected by the real.

The next research is conducted by Mishra and Shukla [12] on ceramic tiles defect detection and classification system based on artificial neural network method with Probabilistic Neural Network (PNN) algorithm can minimize learning bias and generalization variance significantly to overcome limitations of performance. The implementation of image processing analyzes the texture image to get the feature of vector value. Edge detection vertically and horizontally uses Sobel detector, and diagonally uses Roberts detector. The analysis of Probabilistic Neural Network method is applied by calculating feature vector to determine the classification of tile defect. In this research, the Confusion matrix is used to evaluate the accuracy, detection rate, and false alarm rate on the classification system. By using Artificial Neural Network method, the defect detection technique on ceramic can be done efficiently.

To improve accuracy level of quality control system on ceramic surface defect detection using smart devices that have a high level of system stability, it is required the automation system design of image processing-based using Artificial Neural Network method with backpropagation algorithm.

II. LITERATURE REVIEW

Some of the relevant researches that are concerned with the automation system for ceramic surface quality control using Artificial Neural Network have been performed.

Research conducted by Gonydjaja, et. al. [13] regarding to the detection of rectangularity ceramic defect applies morphological techniques. This research identifies and measures dimensional defects especially rectangularity using feature extraction with morphological technique to classify ceramic quality from the defect measurement results into the quality of A, B and Reject. By using image processing to convert image result into binary, then it uses morphological technique to segmented object. To obtain the edge and coordinate point of ceramic clearly, so it is conducted feature extraction process, the defect measurement process is done by calculating defect value from each corner of ceramic and then classifying the quality. This research can be applied for ceramic types of white, ebony, pine, walnut, and rookie. The average of accuracy rate using this method is 67%. The weakness of this research is the classification of B quality and Reject quality because of difficulty in detecting small defect.

Research conducted by Meena and Mittal [14] regarding to the detection of clumps and cracked ceramic tiles surface uses Sobel edge detection method. The implementation of image processing with image acquisition, then it is improved contrast using Adaptive histogram equation. Sobel operator approach is applied to identify an object by extracting image. Morphological operation is applied to segmentation results by removing unwanted objects, to extract defects from image destination to get a clearer surface display of ceramic defects. The efficiency level of this research reaches 96%.

Research conducted by Mohan and Kumar [15] regarding to automation for the crack of ceramic tiles defect detection uses Probabilistic Neural Network (PNN) method, and feature extraction using wavelet filters with cooccurrence features. Discrete Wavelet Transform represents decomposed signal into different sub band image, for Co-occurrence Matrix the factors of: Energy, Entropy, Contrast, Correlation and Homogeneity of GLCM are used. To classify defect, it is used PNN method radial basis function for network activation function. The result of this research gives the average of detection rate up to 98.177%.

Research conducted by Mohanaiah [16] regarding to texture image of feature extraction uses GLCM approach. To get the Feature value, it uses four factors of feature, namely: Energy, Inertia, Correlation, Entropy and Inverse Difference. The results of GLCM are computed by using Xilinx FPGA. The result of this research is the utilization of GLCM method to compress image so time process can be reduced, if its compared with Discrete Wavelet Technique.

III. RESEARCH METHODOLOGY

This research focuses on automation system design for quality control of ceramic surface using image processing with Artificial Neural Network method of backpropagation algorithm at *Balai Besar Keramik*. The conceptual model that is used in this research can be seen in Fig. 1.

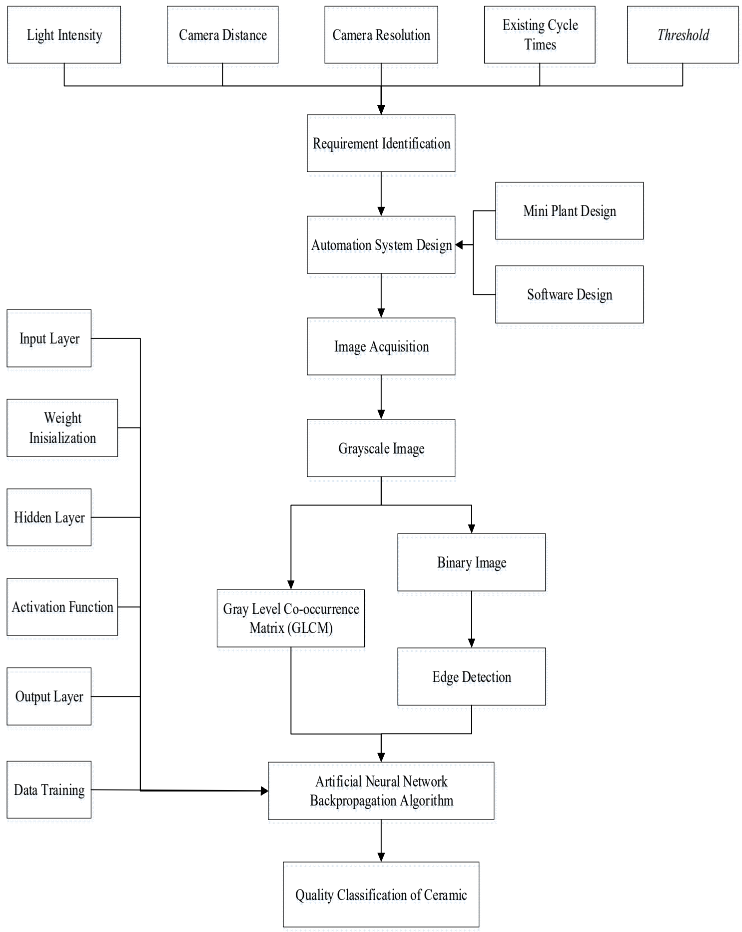


Fig. 1. Conceptual Model of Research

The initial stage is the requirement identification such as the object of a plain ceramic tile with size of 30 x 30 cm, the required light intensity at least 300 Lx, 50 cm camera distance perpendicular to the ceramic, 8MP camera resolution, existing cycle time measurement 104 seconds, and threshold 0,05 based on the previous research. The next step is that the automation system design is the design of mini plant with image processing based on the requirement identification, both of software and hardware can be seen in Fig. 2.

The next step is image acquisition to take an image that is needed. The image result is converted into grayscale level and binary image. The method that is used for edge detection in this research is Canny detection method.

Feature extraction is used to obtain feature value of ceramic. This research uses 16 Gray Level Co-Occurrence Matrix (GLCM) factors proposed by Haralick in 1973, including [17]: Autocorrelation, Contrast, Correlation, Cluster Prominence, Cluster Shade, Maximum Probability, Dissimilarity, Energy, Entropy, Homogeneity, Variance, Sum Average, Sum Variance, Entropy Sum, Difference Variance, Difference Entropy and Additional Number of Object.

In the use of neural network architecture, this algorithm uses multi-layer perceptron so that there are three layers used, namely: input layer, hidden layer, and output layer. The input layer used is the value of the selected GLCM process. The last step is the result of the whole system design of the classification surface defect of ceramic between two output parameters, that is normal and defect.

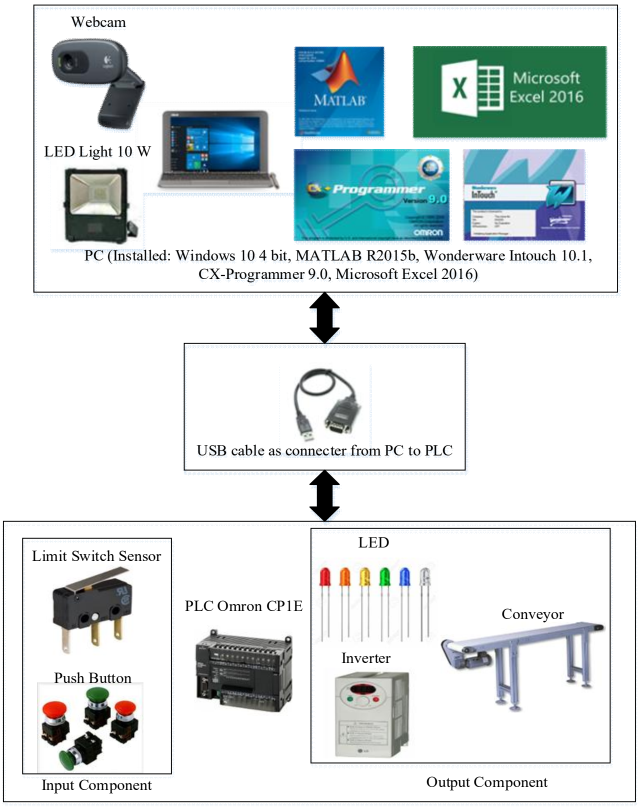
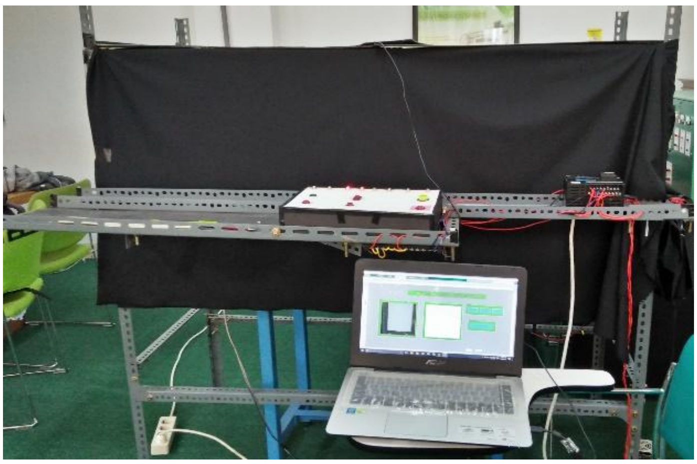


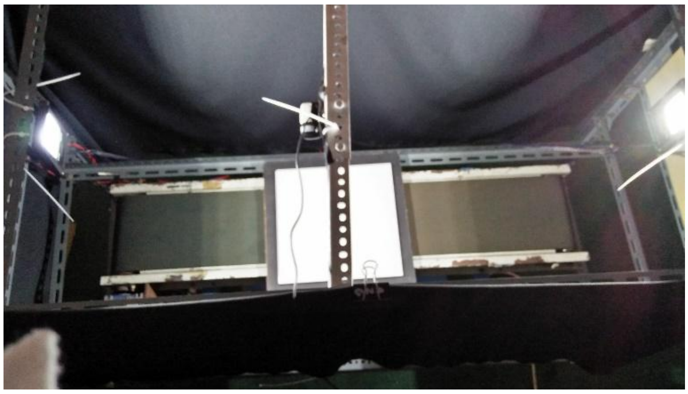
Fig. 2. Hardware and Software Requirement

IV. Results And Discussion

The result of system design consists of integration between software design using MATLAB application for image processing and classifying, CX-Programmer for controlling on PLC, and Wonderware Intouch for monitoring, and hardware design consists of Rig as a frame, conveyor, 300 Lx of LED light, inverter, 8 MP webcam with distance of 50 cm, PLC OMRON CP1E, limit switch sensors to detect an object, PC / Laptop, and also black cotton to cover the Rig.



(a)



(b)

(c)

Fig. 3. Design of Automation System (a) front view, (b) top view, and (c) bottom view

Human Machine Interface (HMI) design uses Wonderware Intouch 10.1 software to describe communication between operator and system that can be seen in Fig. 4.

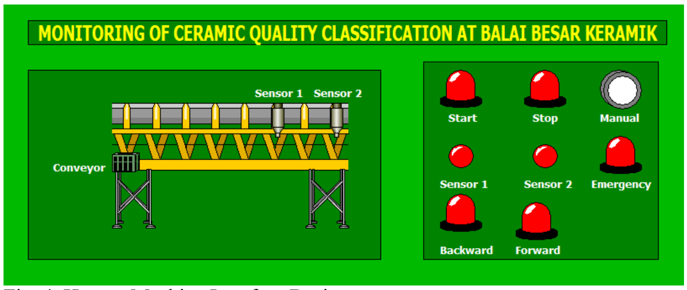


Fig. 4. Human Machine Interface Design

A. Image Acquisition

The first stage is image acquisition aiming to connect the image of ceramics which takes on conveyor using the webcam that is connected to the main program to do image processing. Example of image acquisition of ceramic can be seen in Fig. 5.

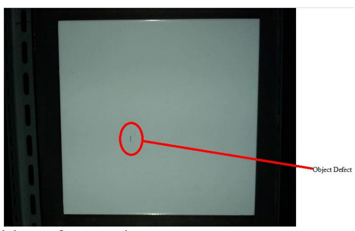


Fig. 5. Image Acquisition of Ceramic

B. Grayscale

The next process is to convert image from RGB to gray scale to obtain a matrix by entry numbers between 0 and 1 that indicate the pixel brightness used as input for GLCM because it can process grayscale image only, not in RGB. Example of grayscale image can be seen in Fig. 6.

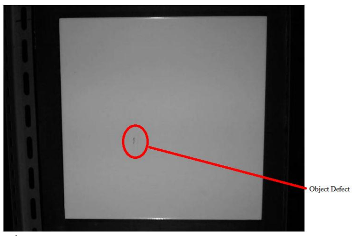


Fig. 6. Grayscale Result

C. Binary Image

The binary image is a black and white image color in a matrix with an entry numbers between 0 or 1 to identify the existence of an object from the background. It aims to focus the shape of the ceramic tile image that is taken. Example of binary image can be seen in Fig. 7.

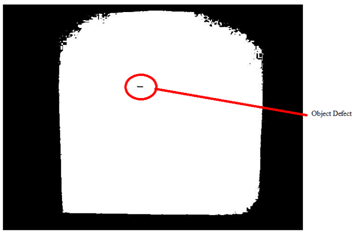


Fig. 7. Binary Result

D. Edge Detection

Edge detection is used to show the boundary of the ceramic object with the background, the edge detection used is Canny detection, because this method uses two thresholds to detect strong and weak edges to obtain the edge of the ceramic. With Canny detection, the edge of ceramic on image will appear like a line at the boundaries of each edge of the ceramic. Example of Canny edge detection can be seen in Fig. 8.

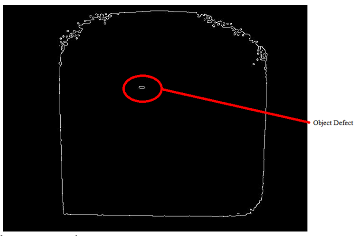


Fig. 8. Canny Detection Result

E. Feature Extraction

From the calculation of feature extraction value of data training, it is known that the result of GLCM values are as follows in Table III.

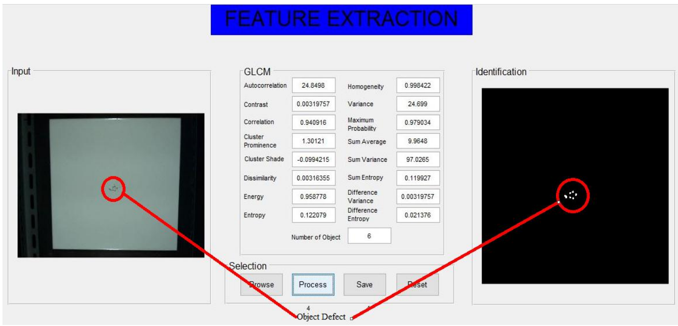


Fig. 9. GLCM Value

TABLE III. GLCM VALUE OF EXTRACTION FEATURE

Number of Sample	**8**	**9**	**10**
Autocorrelation	24.4571	24.8999	24.8498
Contrast	0.0062534	0.00596993	0.00319757
Correlation	0.954542	0.823306	0.940916
Cluster Prominence	2.30088	0.523722	1.30121
Cluster Shade	-0.480984	-0.136306	-0.0994215
Dissimilarity	0.00570913	0.00457524	0.00316355
Energy	0.879632	0.970234	0.958778
Entropy	0.270448	0.0981969	0.122079
Homogeneity	0.9972	0.99785	0.998422
Variance	24.3138	24.7509	24.699
Maximum Probability	0.936122	0.984948	0.979034
Sum Average	9.87775	9.97721	9.9648
Sum Variance	92.6356	97.7457	97.0265
Sum Entropy	0.266776	0.0936562	0.119927
Difference Variance	0.0062534	0.00596993	0.00319757
Difference Entropy	0.0348537	0.0277674	0.021376
Number of Object	0	4	6

From the calculation of the average it is known that the value of Contrast, Dissimilarity, Homogeneity, and Difference Variance has a very small value difference between normal and defect of ceramic, so that value can't be used as input in Artificial Neural Network.

F. Artificial Neural Network

Input layer used is the value of 13 factors selected by GLCM process result, they are mentioned as follows: Autocorrelation, Contrast, Cluster Prominence, Cluster Shade, Dissimilarity, Entropy, Variance, Sum Average, Sum Variance, Entropy Sum, Difference Variance, Difference Entropy and Number of Object.

In this research, to determine the optimum network it is used trial and error technique. Parameters used in this research are three kinds of samples (training, validation, and testing), the number of hidden layers, epoch, the performance and accuracy. Input layer is not used in the parameter of trial error because it has been defined in GLCM result that use 13 input layers.

Three kinds of samples used in parameters are randomly divided to 23 data samples. Training sample is presented to the network during training, and the network is adjusted according to its error. Validation sample is used to measure network generalization, and to halt training when generalization stops improving. Testing sample has no effect on training and so it provides an independent measure of network performance during and after training.

The number of hidden layers is determined based on three types. The first use number of hidden layer is 10, the default number for Artificial Neural Network toolbox in MATLAB. Second, the use number of hidden layers is 13, it's shown that comparison between input layer and hidden layer is equal. The last number of hidden layer is 39, it's based on proportional comparison of 3 :1 between hidden layer and input layer. Because there is no constancy about the number of hidden layers in Artificial Neural Network; therefore, this research uses trial error mode for determining number of hidden layer. The Neural Network Architecture can be seen in Fig. 10.

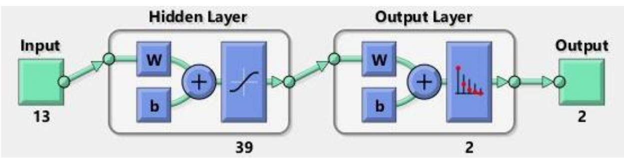


Fig. 10. Neural Network Architecture

TABLE IV. OUTPUT OF ARTIFICIAL NEURAL NETWORK

No Sample	ANN Output		Binary Conversion		Target	
	O1	O2	O1	O2	O1	O2
8	9.855072	9.69805	1	0	1	0
9	94.25051	85.5271	1	0	1	0
10	0.195777	0.479453	0	1	0	1

The result of Artificial Neural Network can be seen in Fig. 11.

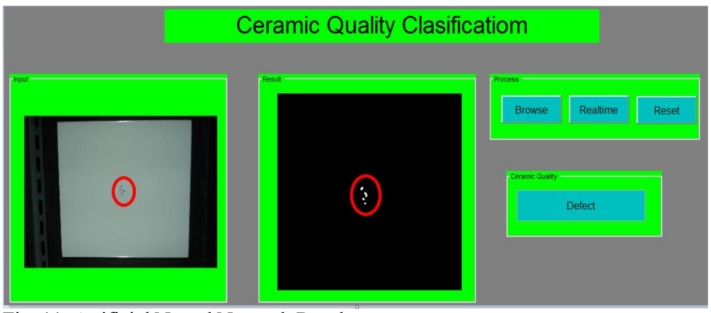


Fig. 11. Artificial Neural Network Result

G. Offline Mode

In offline mode, input that is used is image acquisition result that isn't integrated for each component. Offline mode is used for data training as a process and basic learning Artificial Neural Network. Data training used for offline mode consists of 32 data, they are 16 normal images and 16 defect images on ceramic surface.

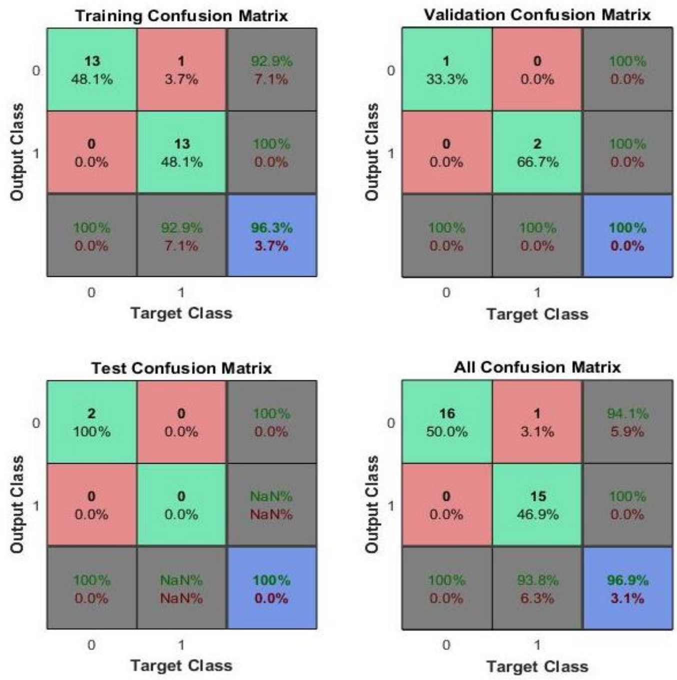


Fig. 12. Confusion Matrix Offline Mode

Based on Fig. 12., it shows that the accuracy of training process is 96.3%, since there is a bias in the class 1 output on the detection of ceramic defects. The validation and testing of confusion matrix have 100% perfect accuracy. So, the accuracy total of confusion matrix is 96.9%.

H. Realtime Mode

In the realtime mode, input that is used is image acquisition result that is integrated for each component, so that testing of ceramic surface defect from taking an image until the classification result in the automation system directly. Realtime mode is used for testing classification process based on improvement scenario. Data that is used for realtime mode consist of 13 data, they are 8 normal images and 5 defect images of ceramic surface.

The process begins when system is running, the HMI monitoring system will be connected to webcam to take ceramic image. When start button is ON, conveyor carrying a ceramic tile will move forward, later when ceramic is contacted with limit switch sensor, the status of limit switch sensor is ON, so conveyor will stop automatically and webcam that precise on the ceramic will take and store ceramic image that will be processed into main program.

The stored image will be processed to be able to identify ceramic surface defect in the main program of MATLAB, and the result of ceramic quality will be seen in the interface of Graphical User Interface (GUI). After the classification is done, limit switch will be OFF automatically and conveyor will move forward again until the end process.

Fig. 13. Confusion Matrix Realtime Mode

Based on Fig. 13. above, it shows that the accuracy of the training process is 90.9%, since there is a bias in the class 2 output on the detection of ceramic defects. The validation and test of confusion matrix have 100% perfect accuracy. So, the accuracy total of confusion matrix is 92.3%.

V. Conclusion

Based on the research of automation design for ceramic surface quality control using Artificial Neural Network that has been conducted is based on the results of trial error neural network, the number of hidden layers of the most optimum is obtained by 39 neurons. Although it requires as many as 109 epochs which cause a long time to do calculation process, but has a high accuracy value of 96.9% and a very small of network performance value of 0.0273 on the accuracy. The number of hidden layers is obtained from the comparison between hidden layer and input layer with 3 :1 proportion for the former.

The accuracy rate of classification of surface defect for ceramic uses automation design with 300 Lx light intensity, 50 cm of camera distance, based on Artificial Neural Network method, the confusion matrix result is obtained by the accuracy rate of 96.9% for offline mode and 92.3% for realtime mode.

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