

DEFECT INSPECTION SYSTEM FOR SHAPE-BASED MATCHING USING TWO CAMERAS

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ABSTRACT

This research is regarding the application of a vision algorithm to investigate various approaches for automated inspection in of gluing process using shape-based matching application in order to control the decision making concerning jobs and work pieces recognition that are to be made during system operation in real time. A new supervised defect detection approach to detect a class of defects in gluing application is proposed. Creating of region of interest in important region of object is discussed. Gaussian smoothing features in determining better image processing is proposed. Template matching in differentiates between reference and tested image are proposed. This scheme provides high computational savings and results in high defect detection recognition rate. The defects are broadly classified into three classes: 1) gap defect; 2) bumper defect; 3) bubble defect. A new low-cost solution for gluing inspection is also included in this paper. The defects occur provides with information of height (z-coordinate), length (y-coordinate) and width (x-coordinate). This information gathered from the proposed two camera vision system for conducting 3D transformation.

Keywords: *Gaussian Smoothing, Recognition Rate, Region of Interest, Shape Matching, Template Matching.*

1 INTRODUCTION

Machine vision has become a key technology in the area of manufacturing and quality control due to the increasing quality demands of manufacturers and customers. Machine vision utilises industrial image processing through the use of cameras mounted over production lines and cells in order to visually inspect products in real time without operator intervention. Machine vision (also called "industrial vision" or "vision systems") is primarily focused on computer vision in the context of industrial manufacturing processes, be it in the inspection process itself (e.g. checking a measurement or identifying a character string is printed correctly) or through some other responsive input needed for control (e.g. robot control or type verification). The machine vision system can

consist of a number of cameras all capturing, interpreting and signaling individually with a control system related to some pre-determined tolerance or requirement.

2 BACKGROUND

In this paper, the most important applications used are shape-based matching using HALCON [1]. This application has the effect that this approach is able to handle changes in illumination, clutter, varying size, position and rotation, or even the relative movement of parts of the template projected, multiple instances can be found and multiple models can be used at the same time.

Shape based matching algorithm has 7 fundamental steps which are image acquisition, image pre-processing, image segmentation, extraction of low-level feature, grouping or

mapping to high level feature, image classification and image interpretation [2]. The crucial part is on image segmentation which is involved of de-noising technique. The segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually. On the other hand, weak or erratic segmentation algorithms almost always guarantee eventual failure. Image segmentation involves a various type of command that will lead to smoothen of the image as a result for easier execution in recognition system.

There are many techniques that provides a solution in recognizing image or object in image processing such as region [3], edge-based features [4-5], feature extraction [6], shape context [7-8], low distortion correspondences [9] and etc.. The other research is based on HALCON Application for Shape-Based Matching [10-11]. This paper is discuss mostly on the process involved in a basic shape based matching algorithm with additional of extended Region of Interest (ROI) available in HALCON that fulfils shape based matching to find object based on a single model image and locate them with sub pixel accuracy. The basic concept of defect matching using shape-based matching algorithm based on extended region of interest introduced by [1] as shown in Figure 1.

Vision-based inspection of industrial products offers low-cost, high-speed, and high-quality detection of defects. Some of the most challenging industrial inspection problems deal with the textured of the gluing process. Defects are common occurred in gluing process. To make sure the quality of gluing process, defects detection and recognition are most popular application used. Many researchers are mostly focused in welding line and also in fabric and many interesting results have been obtained [13-23]. Roughly, all these researchers can be classified as two types, one is based on radiographic inspection and the others based on artificial intelligence. The first kind of methods is to recognize welding defects manually, so the efficiency is much limited [12-14]. The second kind of methods are much better in efficiency, however the complexity of implementation is unnecessary [15-23].

The other research is focused on the welding defect [19, 23] that uses the feature extraction method to simplify image to a simple algorithm which is based on the perceptron model to recognize and classify the defects according to the data captured from the extraction method. Image of welding line is very important to the feature extraction and defect recognition in order to

recognize and classify the welding defects accurately.

In all the above research, the machine vision system has two common similarities, first is the three basic framework of the process involved; image acquisition, preprocessing and feature extraction. The second one is the two main phase in shape-based matching algorithm which is training and recognition phase. In the above research, it seems that most model based vision programs are developing for a specific task and the environment explicitly coded into the system.

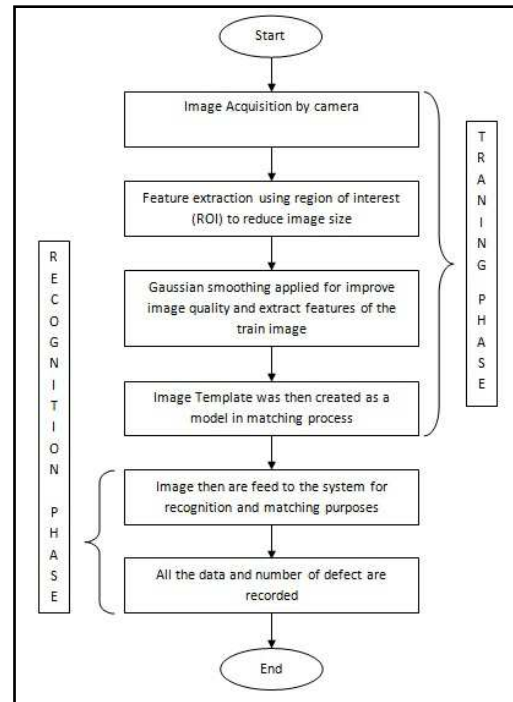


Figure 1: Basic Framework for Matching Application

3 THE PROPOSED SYSTEM

This research is design to provide a better solution in inspection system for gluing application. The proposed system helps in determining defects occur in the system that regards as an important aspect for producing quality products. The system is developed to cope with the environment such as lighting condition, scaling and rotating of the object. Three models of defects are identified through experiment called as 1) Gap Defect; 2) Bumper Defect; 3) Bubble Defect. Sample of experiment is designed using plain cardboard and has a shape of pyramid. Results obtained through the inspection system will decide whether the object is successful gluing or having defects. Every

defect occurs contains with location information in x, y and z coordinates.

3.1 Template Matching of Vision Based Defect Inspection

The main idea of this research is to recognize defects after the robot finish perform glue operation according to the specification given by the vision sensor. In order to develop a system that required intelligent in detecting defects, it's consists with too many techniques can be used but there is a wide range of different algorithm concept that each has its strengths and weaknesses. From all of these algorithms, shape-based matching algorithm was chosen to be used in this research. This is because the requirement of this research is mainly on the inspection of a constant and repetitive type of image. Besides that, because of the wide range of applications that might occurs, shape-based matching which takes only the outline edges of an object into considerations are the best fit for this research since everything has a shape. Figure 2 below shows the project development of defect inspection system by using two cameras placed at top and front position for detecting all the three coordinates known as height (z-coordinate), width (x-coordinate) and length (y-coordinate).

This research are based on HALCON software that provides a wide range of library that will helps mostly on image processing algorithm. This is important and very useful that can be manipulate into the system that meet our requirement. The basic of shape based matching application as shown in Vision-based inspection of industrial products offers low-cost, high-speed, and high-quality detection of defects. Some of the most challenging industrial inspection problems deal with the textured of the gluing process. Defects are common occurred in gluing process. To make sure the quality of gluing process, defects detection and recognition are most popular application used. Many researchers are mostly focused in welding line and also in fabric and many interesting results have been obtained [13-23]. Roughly, all these

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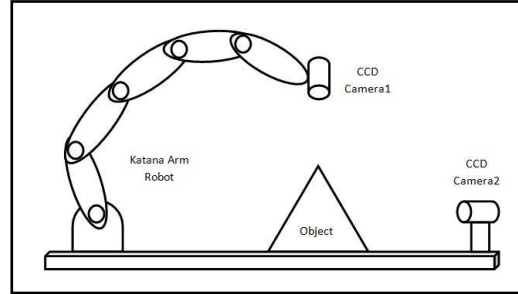
Figure 1 is based on 2 phases; training phase and recognition phase. The crucial part is in determining the best model template in training phase. In training phase, model template need to be extracted from its background by using Region of Interest (ROI) technique. This technique helps in reducing a large number of unused sizes occur by considering only the extracted region to meet the task requirement. Then, filtering method such as fill interlace technique is applied to improve the quality image of the template and remove noise which can greatly influence obtained recognition rate. Next process is to implement the median filter as effective method to remove noise occurs from the image in order to give a new life for the image look as more productive than before. The template created are then stored in the memory. As long as the template is in high quality, recognition rate for matching purposes definitely in high percents. Once

the approximate region is identified, the information needed must be separated with the model image and its background to ensure there is no other disturbances that might occur in the system.

According to Figure 4 shows the process evaluation of the template matching by using correlation method in representing relationship between template and source images. Correlation is a measure of the degree to which two variables (pixel values in template and source images) agree,

Figure 3 shows the process of Region of interest and saved as defect template for recognition phase.

Figure 2: Project Development



not necessary in actual value but in general behaviour. In correlation method, results of combination of differences between template gray level image, X_i with average gray level in the

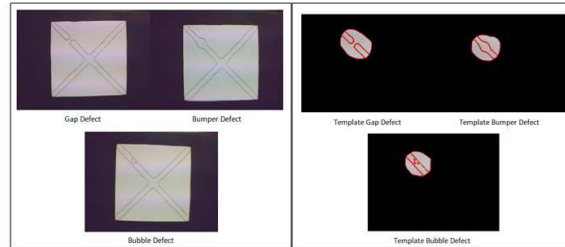


Figure 3: Region of Interest Before and After Process

At the recognition phase, template matching is used by comparing the template image with the process image pixels by pixels by referring to template image saved in the memory. The matching process moves the template image to all possible position in larger source image and computes a numerical index that indicates how well the template matches and the image in that position. The result of the template matching known as recognition rate which it depends on how much region its cover according to the template creation. Template matching is robust to noise, clutter, occlusion, and arbitrary non-linear illumination changes. Objects are localized with sub-pixel accuracy in 2D. Before hand, the template of an object must be classified first before used it in recognize similar objects in source image [24].

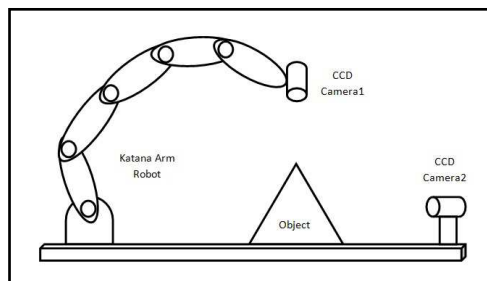
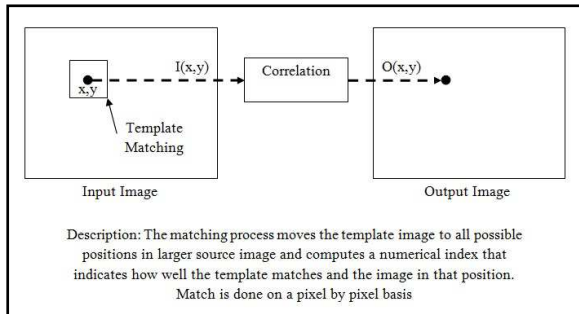
template image, X and difference between source image sections, Y_i with the average gray level of source image, \bar{y} are compared to the square root summation of the pixel differences between two images. Correlation value is between -1 and +1, with larger values representing a stronger relationship between the two images. **Error! Reference source not found.** shows the correlation relationship.

$$cor = \frac{\sum_{i=0}^{N-1} (x_i - \bar{x}) \cdot (y_i - \bar{y})}{\sqrt{\sum_{i=0}^{N-1} (x_i - \bar{x})^2 \cdot \sum_{i=0}^{N-1} (y_i - \bar{y})^2}} \quad (1)$$

where, N = template image size = column*row
Correlation value totally depends on template creation throughout the system. Without proper contribution on it, may result to poor recognition rate. The important of ROI extraction method that delivers the precise region helps in findings the same object from various types of images. Figure 5 shows the proposed algorithm that being developed through this research.

Figure 4: Template Matching Process Evaluation

Figure 5: Proposed System Algorithm for Defect Inspection System

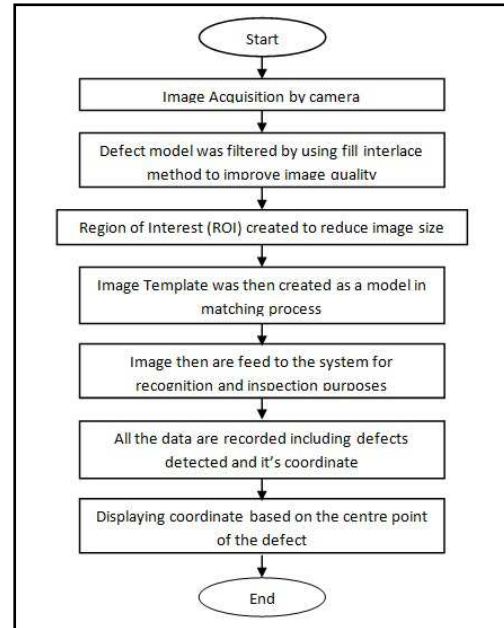


3.2 3D Representation (z-Coordinate Transformation)

Gluing process involves x, y and z-axis in determining the position according to the working space of the Katana robot arm. In previous experiment, matching process involves one camera placed at the top of the object as a purpose in identifying the object that need to go for gluing process. Renovation of this system is created by applying another camera in front of the object for purpose in reviving the z-coordinate in the image. According to [25] the method used are to find the 3D object recognition defining as x, y and z-axis by using evaluation function in order to determine better position and orientation for camera placement. Figure 6 shows the proposed method by using two cameras from the researcher.

Figure 6: Placement of two Camera of 3D Recognition

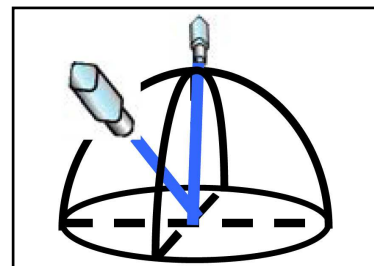
Referring to the Figure 6, this configuration has the ability to reproduce the 3D transformation according to the model template that being created in the system. The measurements of the camera takes account all the side of the object which will be process in determining the exact value of transformation with the original. From this application, the development of new proposed method by using two cameras with different



positions and orientations in purpose of determining x, y and z-coordinate for further process in this research. The renovation of this new method being proposed is used in creating a z-coordinate according to the x and y-axis from images captured. Figure 7 shows the new proposed method developed in this research.

Figure 7: Proposed two Cameras Placement in 3D Recognition

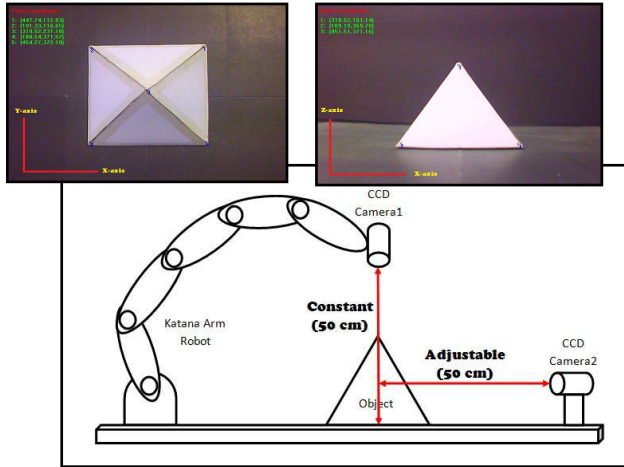
Camera placement has been developed according to the needs of the system requirement as described before. The arrangement helps in determining



z-coordinate by applying two-dimensional image.

The z-coordinate are based on pixel coordinate of 12.0 megapixels of webcam camera. In order to develop

system that involve with 3D transformation all the x, y and z-coordinate must be appointed which means the image should have length, width and height. The transformation of z-coordinate in 3D involves of two images which are taken from both camera, top and front. Before the z- coordinate are determined, two type of image must be taken through the top and front cameras as shown in Figure 8.



(a) (b)
Figure 8: (a) Captured Image from Top Camera
(b) Captured Image from Front Camera

Both images are used as a reference images for further process. The first reference image (top camera) will generate the x and y-coordinate. Then the second reference image (front camera) will generate the x and z-coordinate. Both coordinates are generate by using mathematical approach of straight line [26] according to the object specimen that has a shape of rectangle. The calculation between one points to another retrieve all the information needed to be used in pointing another point between the previous two points. Firstly, the system should identify all the edge point within both images. Then, identified the two points needed to be calculated and labelled as (x_{n-1}, y_{n-1}) and (x_n, y_n) . Then, the points are applied it into the equation to define the slope of the line in pixels coordinate.

$$m_n = (y_n - y_{n-1}) / (x_n - x_{n-1}) \quad (2)$$

After that, value of the slope and point is used in the slope-intercept equation to define the intersection of the line. $m_n = (y_n - y_{n-1}) / (x_n - x_{n-1})$

$$y_n = m_n x_n + c_n \quad (3)$$

Then, the distance in x-axis and y-axis between two points is calculated and defines it as k and l . The point will then be integrated into **Error! Reference source not found.** to find new location of the point based on the information obtained. Lastly, new point being declared and classified as one of the point needed in the system. The pointing results of both images are shown in Figure 9.

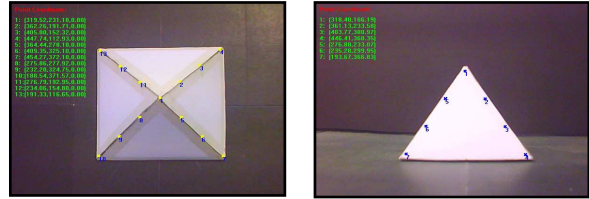


Figure 9: A New Point Appointed from Top and Front Camera

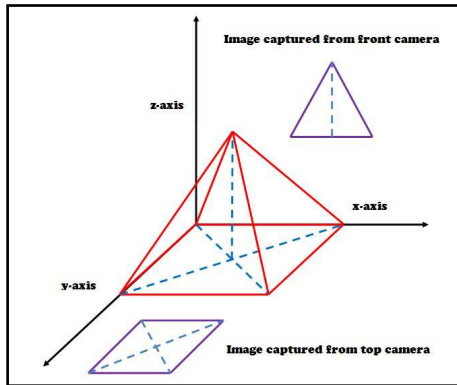
In applying glue application, the point of each coordinate must be accurate for precise operation. Therefore, the findings of this z- coordinate provide an additional data in order to minimize error of the system. In real operation, the shape of object is not exactly the same as the image taken. So, by providing a mathematical approach of straight line helps in rebuilding the z-coordinate based on their own image taken through the systems. In order to reconstruct 3D image from both 2D images, there are 3 steps to follow respectively.

1. Determining position of camera.

In order to get the exact value from both images, the object captured must be adjusted for obtaining better position from both cameras. Every centimetre different will result to inaccurate size of image. For beginning, set the top and front camera as 50 cm from base. Let the top be constant at 50 cm and front as adjustable in acquiring exact value of x-coordinate for both as shown in Figure 10.

Figure 10: The Proposed of two Camera Placements in 3D Recognition

By adjusting the position of second camera step by step, then compare the coordinate determine through the system in order to identify a better position for acquiring exact size of object from both images. The results determine should be



able to synchronize with the x-coordinate where it's as a backbone for completing the 3D image construction.

2. Comparing both images by using x-coordinate.

After step 1 completed, which means the exact position of front camera is determined. Then the next step is to ensure that both images being line in one ax in order to compare each edge point from both images. In Figure 11, each point is numbered according to the sequences. Point 1, 5, 6, 7, 8, 9 and 10 from top camera are compared with the same point from the front camera. The x-coordinate should be exactly the same by both images in claiming that the images have the same size and height can be measured through image from front camera.

Figure 11: Integration of two Image Source in Finding New z-coordinate

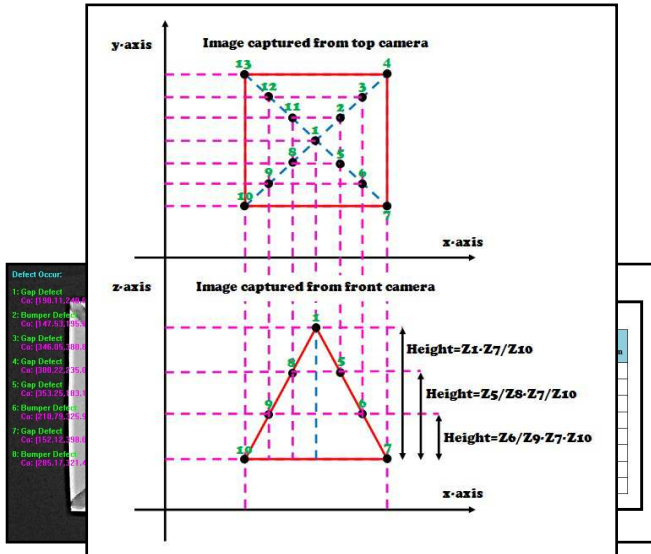
Measurement of the height (z-coordinate) of each point should be done by using mathematical approach which point 7 and 10 appointed as a reference point. All the data generated will be used as an additional data in doing glue process to ensure the systems work smoothly and efficient.

$$Height, H_n = Z_n - Z_{7,10} \quad (4)$$

3. Combining features from both images.

The next step is to combine all data gathered from step 1 and 2 for

constructing 3D image from 2D image. The height of each point appointed are being illustrated as shown in Figure 12 where the transformation of 3D image are developed. The transformation is based on



the 2 reference image that used in determining the height of each point.

Figure 12: Information Gathered from two Sources Images in Generate 3D Image from 2D Image

According to the Figure 12, the development of 3D image are based on x, y and z-plane where it's consists of length, width and height. This application helps in rebuilding data of 3D image by using two cameras which have their own position and rotation that important in classifying the 3D transformation. Hence, this method is proposed according to the needs of the system in this research.

4. EXPERIMENTAL RESULTS

The potential of the proposed visual algorithm system was the flexibility of the program to accommodate changes. 15 tested images are being tested the flexibility of the system in determining all defects occur in the tested images. The tested images are filled with all the three model defects that are already being trained in training phase and fed into the system for recognition purposes. Each defect that are match through the system will provide with its own position in the tested images act as row and column coordinate according to the

pixel coordinate in the system. This information is important as the task continuing in correcting all the defects after the matching process done its part. Correction phase consists of Katana arm robot to alter the defects to ensure that glue is in fine shape.

According to the Figure 13 shows the result of defect detection where there is total of 8 defects and all of it has been detected through the proposed system. Each of defects provides with their own location for further process. Differ from previous results, Figure 14 shows that there is one defect that is not being detected because of the bright illumination that disturbs the system from complete its task. The contour of the defects has been eliminated by the brightness itself and the system recognized it as a perfect gluing line.

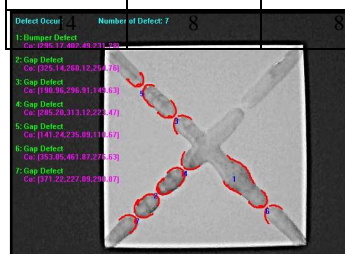
Figure 13: First Tested Image

Figure 14: Second Tested Image

The aim of this paper is to present a flexible visual system for shape based matching. Addition of feature extraction, Gaussian smoothing, template creation and template matching are proposed through this paper. Experimental results are used to verify the proposed approach. In this experiment, three defects models and their corresponding samples are used to examine this approach. This system has been tested with 15 tested images and consists of 109 defects to determine system accuracy and efficiency in detecting glue defect along gluing line. Each tested image has its own defect to be recognized by this system. All the data are recorded into Table 1.

Table 1: Recognition Rate for Proposed Defect Inspection System

Image	Total Defect	Defect Detected	Defect Detected (%)
1	8	8	100
2	7	5	71.42
3	8	8	100
4	6	5	83.33
5	8	7	87.5
6	5	3	60
7	7	7	100
8	7	7	100
9	8	8	100
10	8	8	100
11	7	7	100

12	7	7	100
13	7	7	100
Defect Occur	Number of Defect: 7	8	100
			
15	8	8	100
Total	109	103	94.5

No. Defect	Defect Name	Coordinate (pixels)			Defect Detection
		Row	Column	Height	
1	Bumper	295.17	402.49	231.28	√
2	Gap	325.14	260.32	254.76	√
3	Gap	190.96	296.91	149.63	√
4	Gap	285.20	313.32	223.47	√
5	Gap	141.24	235.09	110.67	√
6	Gap	353.05	461.87	276.63	√
7	Gap	371.22	227.09	290.87	√
8	Gap	-	-	-	-

Table 1 shows the result of defect matching by using 15 tested images. According to the results, the recognition rate of the experiment about 94.5% based on 3 model defects created through the system. This recognition rate shows that the higher accuracy can be achieved through this method. But, with the increasement of the training samples, the recognition rate would be much better. Not only that, by using a specific vision camera such as CCD camera will helps in improving the image quality as long as improving the accuracy and efficiency of the system.

From the results, it can be seen that the system's efficiency is very good produced about 94.5% recognition rate. This is because of the detection scheme that compares only the required features which are being trained according to the specific type of defects. Another advantage of the system is its simplicity and ease of use, since the matching algorithm uses a single edge detection method that was built to process the current environment during training phase instead of predetermined environment setting. This greatly reduces the time used for setting and tuning of the vision system whenever there are any changes. Not only that, this system provides an additional data such as height, length and width from the origin of the vision sensor. With this information, the application of correcting the defect will be easier in commanding the Katana robot arm to do so.

5. CONCLUSION

The aim of this paper is to present a shape based matching vision system for automatic defect detection by using 2 vision sensors as its core. In this paper a concept for a flexible ROI creation visual system was presented where the parameters and characteristics can be easily determined by the

user. The proposed visual algorithm concept is easily adaptable and extendible, so that this program can be used in most situations as seen fit by the user. This innovative approach allows the user to select and adapt the system according to their requirements. Additionally combine with 2 vision sensors provide the system with more precise location as its fit to x (width), y (length) and z (height) pixel coordinate. This system also fit with the 3D visual inspection.

6. RECOMMENDATION

This project will be continued further by applying the system with the assisting of Katana arm robot for gluing process and do the correction when defect occurs during the inspection. The system will consist of a Katana arm robot and a main pc that control the whole systems including the matching and inspection system. Simple pyramid will be used as a testing objects; the aim of the project is to show ease of implementation of the vision system in recognizing glue defects and to test its reliability and flexibility during and after the gluing process.

7. ACKNOWLEDGMENT

The authors are grateful for the support by Universiti Teknikal Malaysia Melaka (UTeM) for providing the MTUN research grant to complete this research.

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