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A 3D SUPERVISED SHAPE-BASED MATCHING APPROACH USING 2D IMAGES FOR DEFECT DETECTION

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ABSTRACT

This paper proposed the application of vision algorithm using shape-based matching approach to investigate various approaches for automated inspection in gluing process. This approach to identify the defect occurs in gluing process in automation industry. The processes involve using new supervised defect detection approach to detect a class of defects such as gap, bumper and bubble defect. The combination of creating of region, Gaussian smoothing and template matching being implemented in shape-based matching to provide provides high computational savings and results in high defect detection recognition rate. 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. Results regarding this method approximately 95.4% recognition rate better than other researchers in welding and fabric field approximately 94.3% and 92% respectively. This result is based on 15 tested images with approximately 100 defects occur and being tested for 10 times to get better recognition rate.

Keywords: Gaussian smoothing, recognition rate, region of interest, shape matching, template matching.

INTRODUCTION

HALCON [1] is the most ponderous applications used for shape-based matching in this paper is capable in administrating 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 primitive steps which are image acquisition, image pre-processing, image segmentation, eradication of low-level feature, grouping or mapping to high level feature, image classification and image interpretation [2]. De-noising technique is the compelling part involving on image segmentation. 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 sharpen of the image as a result for simplicity in execution of recognition system.

Diverse techniques such as region [3], edge-based features [4], feature extraction [5], shape context [6], low distortion correspondences [7] and etc. cater a solution in recognizing image or object in image processing. HALCON Application for Shape-Based Matching [8-12] is the other research related scope. Upon scrutinizing through this research paper, it is mostly describing 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 obtain object based on a single model image and locate them with sub pixel accuracy. Shown in Figure-1 [1] is the basic concept of defect matching using shape-based matching algorithm based on extended region of interest.

Low-cost, high-speed, and high-quality detection of defects is what vision-based inspection of industrial products has to offer. Problems dealing with the textured of the gluing process are some of the most challenging industrial inspection. Defects are common occurred in gluing process. Defects detection and recognition are most popular application used to certify the integrity of gluing process. Most researchers are mostly centralizing their abstraction in welding line and also in fabric and many interesting results have been retrieved [13-24]. Practically, 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 descry welding defects manually, so the efficiency is much limited [13-15]. The second kind of methods are much surpassing in efficiency, however the complexity of implementation is unnecessary [16-24].

The other research is pinpointing on the welding defect [20, 24] that uses the feature extraction method to simplify image to a simple algorithm which is based on the perceptron model to descry and codify the deficiency according to the data yielded from the extirpation method. Image of welding line is very important to the feature eradication and defect recognition in order to recognize and classify the welding defects precisely.

In a nutshell, correlating these researches, the machine vision system has two common resemblance, first is the three basic framework of the process involved; image acquisition, pre-processing 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.

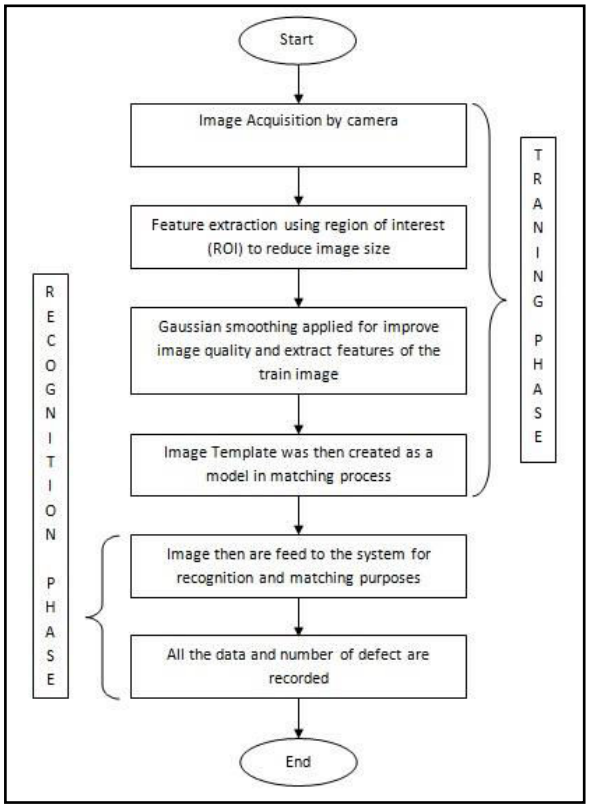


Figure-1. Basic framework for matching application.

METHODOLOGY

This fact-finding and systematic analysis is set to design to provide a better elucidation in inspection system for gluing application. The proposed system plays a vital key role in certainty of defects occurs in the system that regards as a substantial demeanor for producing quality products. The system is developed to cope with the environment such as lighting condition, scaling and rotating of the object. Gap Defect, Bumper Defect and Bubble Defect are the three models of defects identified through experiment. 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.

TEMPLATE MATCHING FOR PROPOSED SYSTEM

The preeminent conception of this research is to perceive deficiency after the robot completely perform gluing procedure prior to the blueprint 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. It is due to the requirement of this research is basically on the inspection of a constant and repetitive type of image. Acts as another supporting ideas, it is also because of the vast dimensions 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).

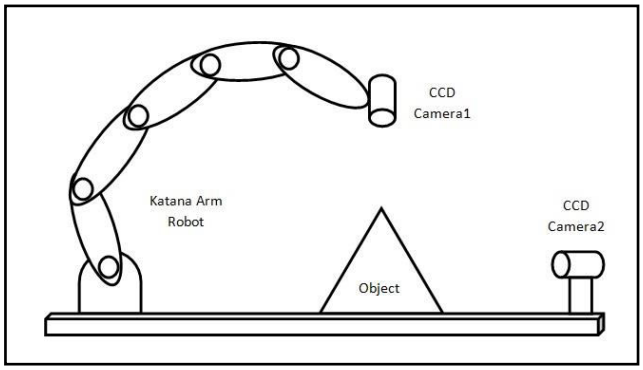


Figure-2. Project development.

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

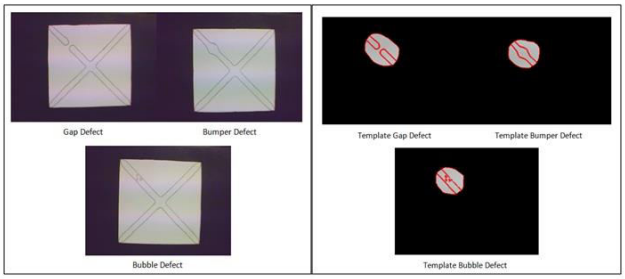


Figure-3. Region of interest before and after process.

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 [22].

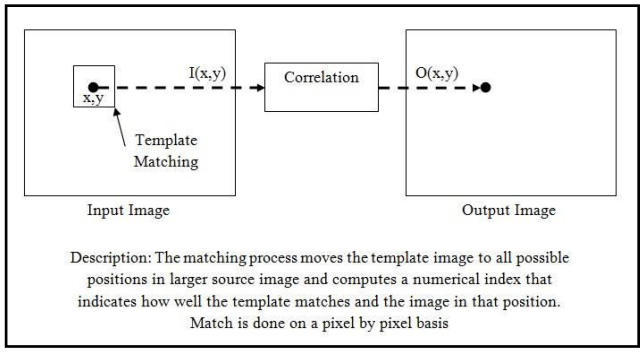


Figure-4. Template matching process evaluation.

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, not necessary in actual value but in general behaviour. In correlation method, results of combination of differences between template gray level image, with average gray level in the template image, and difference between source image sections, with the average gray level of source image, ẏ 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. Equation 1 shows the correlation relationship.

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

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.

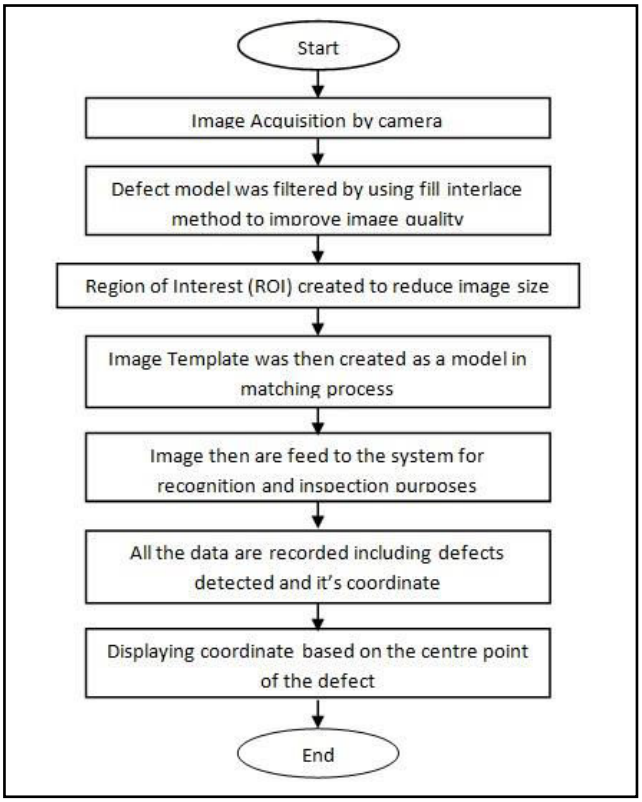


Figure-5. Proposed system algorithm for defect inspection system.

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 [26] 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.

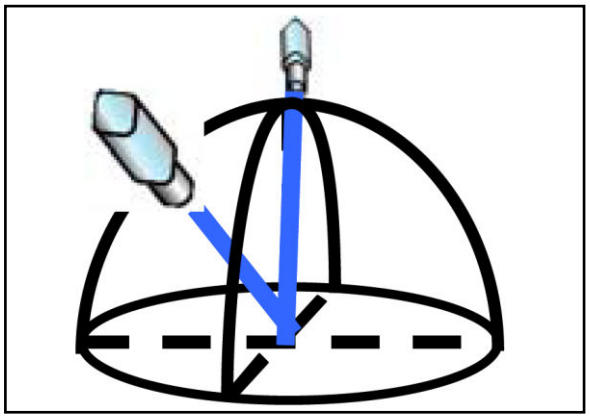


Figure-6. Placement of two camera of 3D recognition.

Referring to the Figure-6, this configuration has the ability to emulate the 3D transformation bestowed 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. The development of new proposed method by using two cameras with different positions and orientations in purpose of determining x, y and z-coordinate gives the additional data for further process. 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.

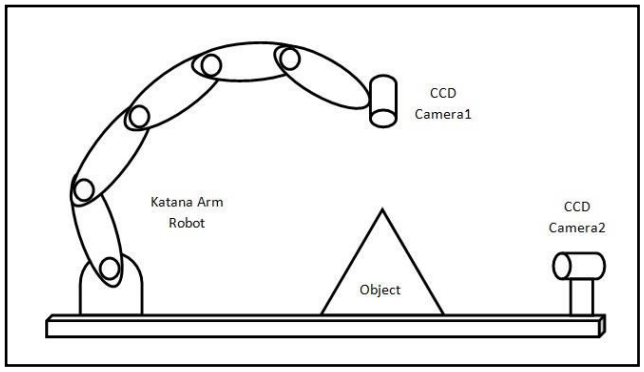
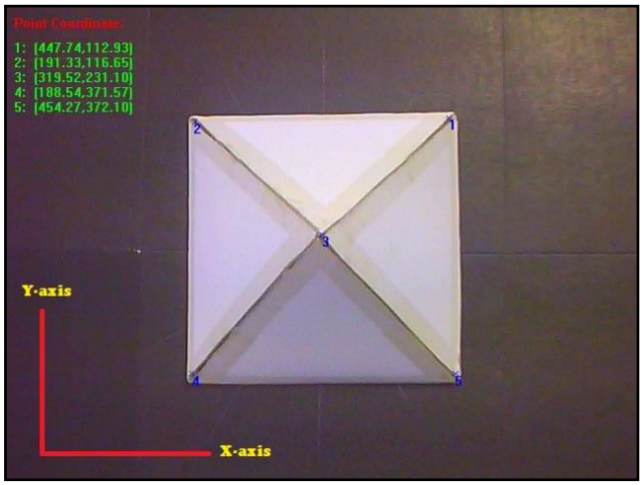
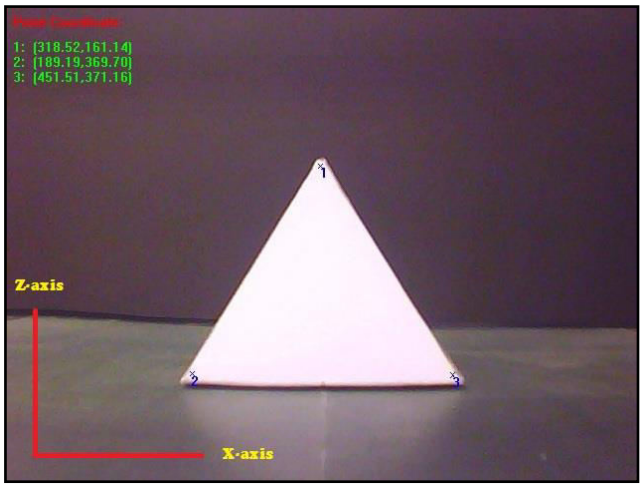


Figure-7. Proposed two cameras placement in 3d recognition.

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



(a)



(b)

Figure-8. (a) Captured image from top camera and (b) captured image from front camera.

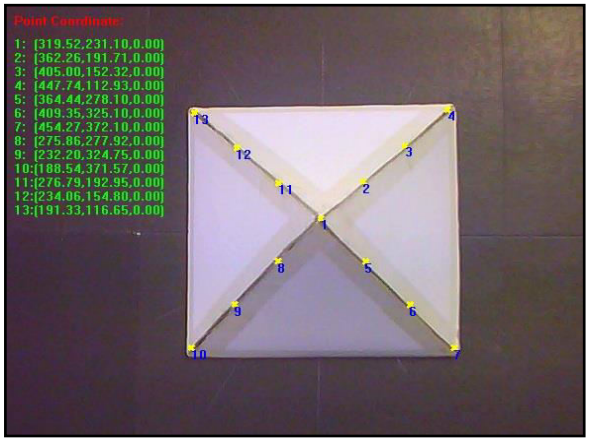
Both images are used as a reference images for further process. The x and y-coordinate is yielded from the first reference image (top camera). Then, the x and y-coordinate is generated from the second reference image (front camera). Both coordinates are generating by using mathematical approach of straight line [27] 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.

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

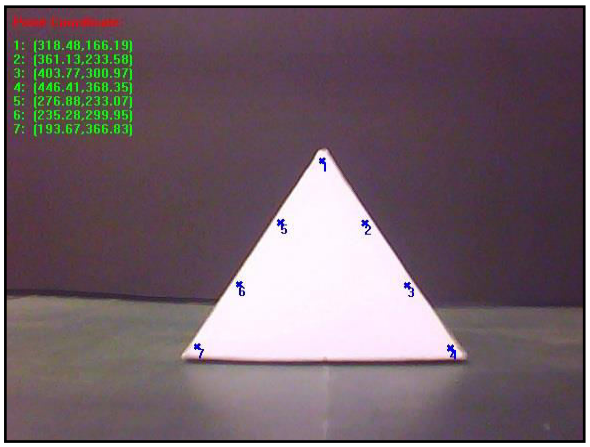
After that, value of the slope and point is used in the slope-intercept equation to define the intersection of the line. $m_n = (y_n - y_{n-1}) / (x_n - x_{n-1})$

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

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 Equation 3 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.



(a)



(b)

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 outcome of this z- coordinate provides an additional data in order to detract error of the system. In real operation, the shape of object is not exactly identical as the image taken. Hence, by providing a mathematical approach of straight line helps in rebuilding the z-coordinate based on their own image taken through the systems.

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.

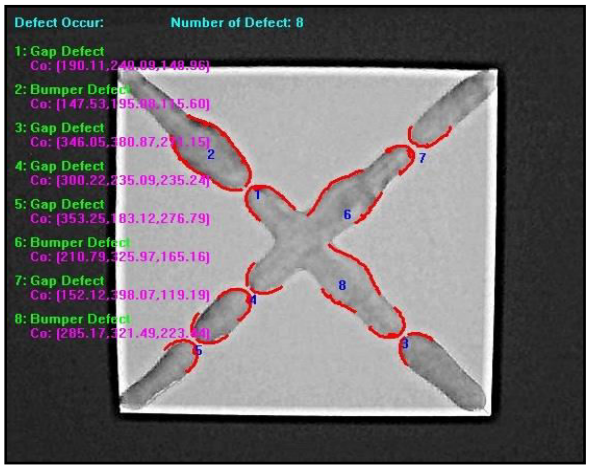


Figure-10. First tested image.

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. Contradicting 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.

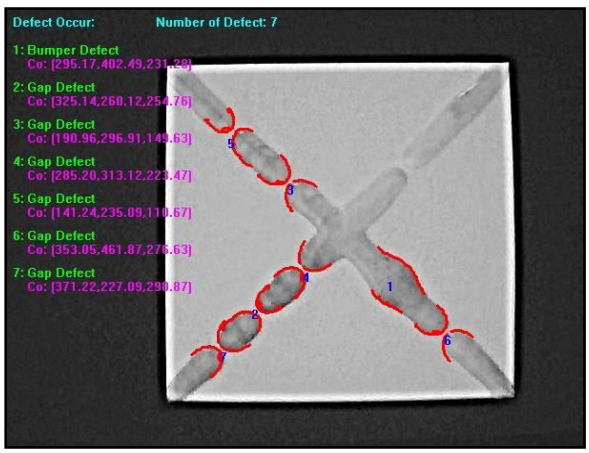


Figure-11. Second tested image.

The major scope 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 100 defects to predispose 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.

Testing	Total defect	Defect detected	Defect detected (%)
1	100	97	97
2		95	95
3		96	96
4		96	96
5		95	95
6		94	94
7		96	96
8		96	96
9		94	94
10		95	95
Total Percentage (%)			95.4

Table-1 shows the result of defect matching by using 15 tested images and the experiment was repeated 10 times to determine the precision of defect's matching. According to the results, the recognition rate of the experiment about 95.4% 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.

DISCUSSIONS

From the results, it can be seen that the system's efficiency is very good produced about 95.4% 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. The comparison of results from other experiments can be found in the literatures. Although the experiments setup, objective and methods are not entirely similar but basically the goal of each experiment is to develop a vision system in inspection for defect detection in industry. Even though gluing application is still new, but the technique in inspection are still the same with welding and fabric application just difference in how to analyze characteristic of each defects.

Table-2 shows the comparison between glue defect detection with both weld and fabric defect detection. The comparison is based on the method being used in introducing training and recognition phase. Each defect detection recognition rate are evaluated using pattern recognition which compares pixels by pixels between model template trains through training phase with the object tested capture from recognition phase. Pixels matching between both models will be calculated known as Score for this research.

Table-2. Comparison of results.

Detection	Weld defect	Fabric defect	Glue defect
Number of Samples	500 samples defect	Not stated	236 samples defect
Variation of Samples	6 types	>30 types	3 types
Correct Recognition Rate (%)	94.3%	92%	95.4%
Error Rate (%)	5.7%	5%	4.6%

CONCLUSIONS

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 accessibly adaptable and acceptable; hence this program can be compliant in vast locality as seen fit by the user. This avant-garde 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.

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