Shape-Based Matching Vision System in Flexible Manufacturing System

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***Abstract*— This research is regarding the application of a vision algorithm to monitor the operations of a system in order to control the decision making concerning jobs and work pieces recognition that are to be made during system operation in real time. This paper stress on the vision algorithm used which mainly focus on the shape matching properties of the product. The main focus of this paper is on the development of an adaptive training phase of the vision system, which is the creation of a flexible Region of Interest capability that is able to adapt to various type of applications and purposes depending on the users' requirements. Additionally, an independent stand-alone control scheme was used to enable this system to be used in various types of manufacturing configurations. The system was tested on a number of different images with various characteristics and properties to determine the reliability and accuracy of the system in respect to different conditions and combination of different training traits.**

Keywords: Flexible Region of Interest, Shape Recognition, Image Processing, Template Matching, FMS sequence control

I. INTRODUCTION

A flexible manufacturing system is an adaptive and dynamic system that cater to a wide range of different jobs where each involves a set of operations that are required to be done at a predetermine workstation. Flexible and agile manufacturing is of increasing importance in advancing factory automation that keeps a manufacturer in a competitive edge. Flexibility signifies a manufacturing system's ability to adjust to customers' preferences and agility means the system's speed in reconfiguring itself to meet changing demands. Both together make it possible for manufacturer to respond instantly to the market. To achieve a fully flexible automated system, one of the supporting systems is machine vision. Machine Vision[1] is the application of computer vision to industry and manufacturing sectors, mainly focused on machine based image processing. It is also the study of methods and techniques whereby artificial vision system can be constructed and usefully employed in practical applications[2].

II. BACKGROUND

In most FMS literatures, it can be seen that the current FMS are still not flexible enough and there are a lot of constrains when researchers attempt to find the most optimize scheduling algorithm in their research. Whether the researchers are trying to improve an existing FMS, simulating or designing a new FMS, the main objective is to find the shortest lead time and higher utilization of facilities. There are a lot of different approach that was studied, scheduling algorithm like taboo search[3], heuristic approach[4], filtered-beam-search[5], branch and bound[6] by using different control theory such as fuzzy logic[7,8], neural network[4], genetic algorithm[9,10] and many more. The common point that most of these article share are most likely the set of dispatching rules, including Earliest Due Date, Shortest Processing Time, First Come First Serve, Most Work Remaining, Least Work Remaining, Longest Operation Processing Time and many more. All of these rules are used depending on the type of manufacturing systems and also the objects being manufactured.

Despite many claims that FMS investment should be viewed as a strategic investment in flexibility, the main disadvantage with FMS technologies lies, paradoxically, in its inflexibility. FMS are flexible in that they can, in the short-term, produce a range of known products[11]. However, the complexity necessary to automatically achieve short-term flexibility makes it difficult to introduce new families of products into the system, and certainly much more difficult than in a manual shop. Similarly, when new machines are to be added (or old ones updated) it can be very costly. Changes in system configuration require time-consuming, expensive alteration to the software[12,13] particularly in complex Western Systems.

In the area of Machine Vision inspection system, a lot of different approaches have been studied intensively and plenty of machine vision software are available. B. Mehenni and M.A. Wahab[14] studies on the Automatic Pattern Recognition and Inspection System (APRIS). They divide pattern recognition and inspection problems into two distinct classes, which checks the product for completeness and searching for blemishes and other flaws. They used an ASIC implementation system together with FPGAs based static RAM technology from Xilinx to produce their prototype. Another visual inspection for quality assessment are studied by Piuri V. and Scotti F.[15]. The aim of their research is to develop a defect detection system for melamine laminated particle board. They extract knowledge from the printed matter to guarantee higher defect detection capabilities, the main criteria consider is the texture, color and shape features. Denni Kurniawan and Riza Sulaiman[16] studied the design and implementation of automatic visual inspection system in automatic control system based on Programmable Logic Controller (PLC). The visual inspection system are developed using Visual C++ 6.0 and Vision SDK 1.2 from Microsoft. The aim of their research is to inspect the size of the bottles of the MAPS bottling system. Another research based on HALCON application for Shape-Based Matching is done by Xuebin Xu, Xinman Zhang, Jiuqiang Han, Cailing Wu[17]. They describe the process involved in a basic shape based matching algorithm and the detail programming language used by HALCON.

In all the above research, the machine vision system and software used has two common similarities, first is the three basic framework of the process involved; image acquisition, preprocessing and feature extraction/selection; second is the two phases required for shape matching, the training phase and the recognition phase. In the above research, it seems that most model based vision programs are develop for a specific task and the environment is implicitly coded into the system. Therefore it is difficult to modify the knowledge or extend the scope of such system, and it also requires long development time.

The aim of this research is the design and implementation of a machine vision system for industrial application. The focus of this research will be on shape-based matching, selective Region of Interest and the independent control scheme that can be applied to any flexible manufacturing system, particularly automated visual inspection and vision for automated assembly.

III. RESULTS

Vision System

The vision system in this research used is based on HALCON, a machine vision software that provides a comprehensive vision library that we can manipulate into a new system that suits our requirement. The basic concept of image matching is shown in Figure. 1.

At the training phase, after all the training parameters are determine by the user, an edge detection library are applied to extract the edges of the image, these edges are then saved as a template that will be used for the recognition phase. At the recognition phase, images are then fed to the system to be matched against the template that was created in the training phase.

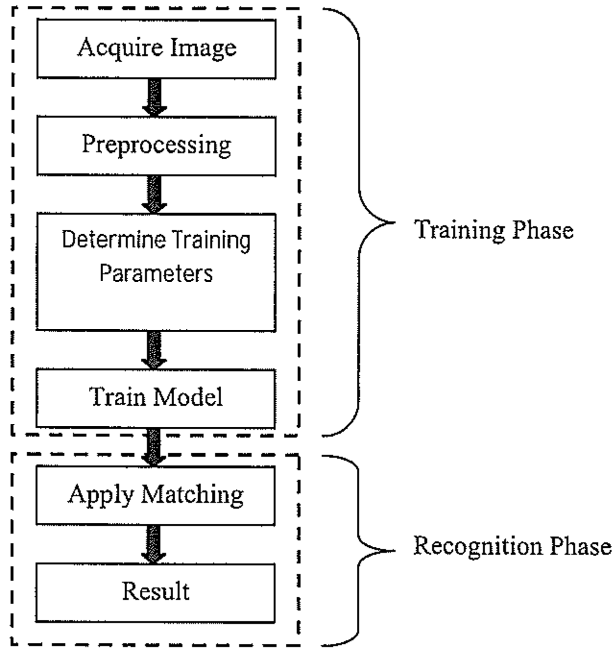

Fig.1: Basic framework for image matching

As stated above, the aim of this research is the design of the vision algorithm so that it is able to be implemented in a Flexible Manufacturing System. Without the pre-knowledge of the objects that are going to be applied, the system is designed to be flexible and smart so that it can be applied without much modification. Therefore the focus will be on the Determine Training Parameters Phase (User define Feature Selection). In order to achieve flexibility and uncertain changes, the main training parameters are determined by the user manually which are located at the user interface.

Feature Selection is a very important part in this system. It not only enables the user to select the critical features, it also minimizes the size of the required matching template therefore saving computation time and operation process. The Feature Selection is done by creating a Region of Interest (ROI), the program is written so that the ROI can be created freehand by using mouse. Furthermore, multiple ROI can be created and combine into one complex ROI.

The compelling reason for using multiple ROI is because we are able to extract the object from the background by selecting only the critical criteria that is required to differentiate the wanted object from the background.

Control System

In order to extend the flexibility and adaptability of the system to accommodate different types of FMS configurations, instead of a centralized control scheme, a separate stand-alone control scheme is suggested. In the suggested control scheme, each component of the FMS will act independently, each component (process) will consist of their own machine vision (camera), controller (PC software), and actuator plant (PLC software). This suggested control scheme are able to adapt to system of various flexibility type, where as the dispatching rules utilize are only the first come first serve rules. The suggested control scheme will be shown in Figure 2. This control method does not consider about the overall system input, it considers only the input at its own region and gives the output signal for the next process only. Combine with the vision system, the overall control is very simple, for example when Object A is detected Signal A will be produce to turn on Program A, the same goes to Object B, C and so on.

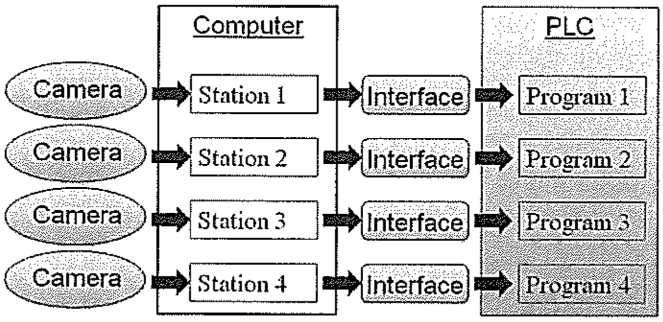

Figure 2: Control Scheme of the suggested system

IV. Discussion Of Results

The potential of the proposed visual algorithm system was the flexibility of the program to accommodate changes.

At the Feature Selection section, firstly we look at the significance of multiple selective ROI. The system is tested on an image that consists of a combination of objects of different characteristic and requirement.

The first step is to create the ROI, the ROI is drawn by holding the left mouse click while circling the wanted shape. After selecting the ROI, all other image not in the ROI will be removed. The image selected will then go through the vision algorithm for further processing. Major advantages of multiple selective ROI is that the user can decide on the criteria that they required from a combination of different ROI as one object or each ROI as separate objects. An experiment has been done to test the flexibility of the program, a DIP switch has been selected as the main object for this experiment.

In this case, the program is train with the reduce picture of the switch of the DIP Switch. The program will then search for the switch when images are feed to it. The reference image is shown in Figure 3. Figure 3a shows the ROI creation and Figure 3b shows the extracted image used to train the system.

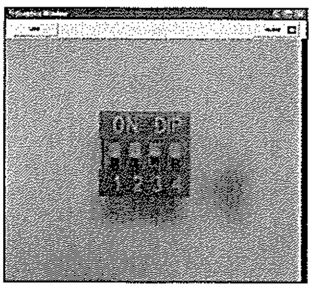

Figure 3

Figure 3: The reference image of a DIP switch used in the experiment.

Case 1. Checking the Number Of Switches

Start with capturing the image, we then draw the ROI using mouse around the wanted object. The image containing the wanted characteristic will be used as matching template.

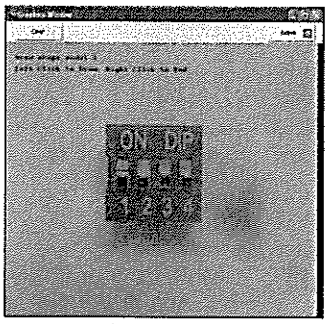

Figure 3a

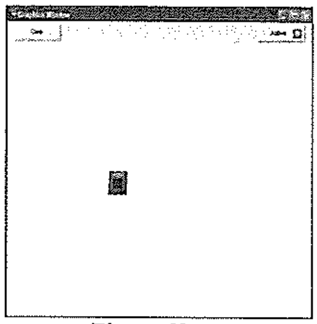

Figure 3b

Figure 3a: The ROI creation
Figure 3b: The extracted image from the ROI

The matching process is done by using several different switch position configurations and the results are satisfying as long as the object is in the work area. Figure 3c, 3d and 3e shows the result when different images are feed to it.

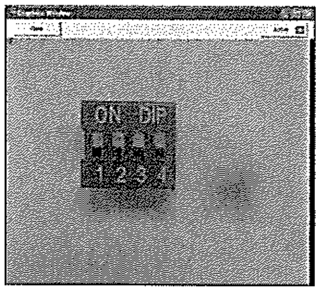

Figure 3c

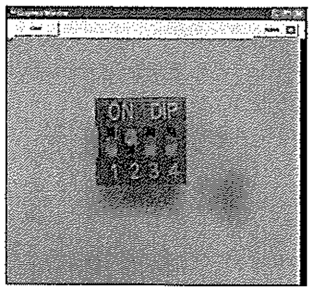

Figure 3d

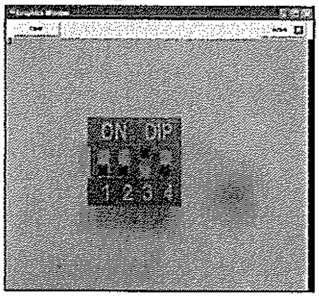

Figure 3e

Figure 3c, 3d & 3e: Results of the test image.

Case 2. Checking the Position Of Switches

In this case, the program is train to detect the required switch configuration, which is switch 1 and 3 must be on, the other two switch 2 and 4 can be in any configurations. The reference image is shown in Figure 4. Figure 4a shows the ROI creation and Figure 4b shows the extracted image used to train the system.

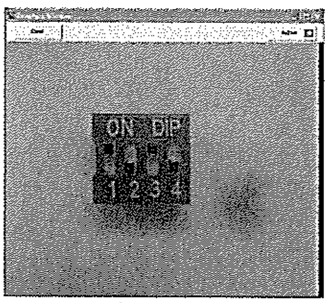

Figure 4

Figure 4: The reference image of a DIP switch with switch no 1 and 3 at the on position being used in the experiment.

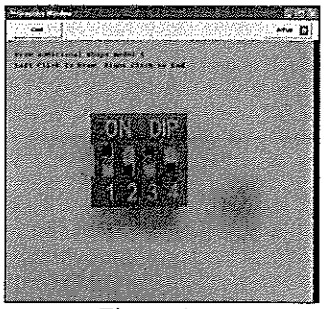

Figure 4a

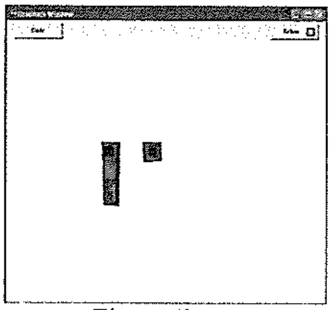

Figure 4b

Figure 4a: The ROI creation
Figure 4b: The extracted image used to train the system

The ROI consists of the number 1 with the on position of the switch above it and the on position of the switch 3. The Number 3 is not included because both small ROI combined into one ROI causing the distance of the two switches to be set still.

Object detection is achievable as long as the position of switch 1 and 3 are at the on position. With no concern on the switch position of the other two switch. Figure 4c, 4d and 4e shows image that satisfied the above conditions while Figure 4f shows image that does not satisfy the above conditions. Object is no longer detected when the switch position is not at the required position.

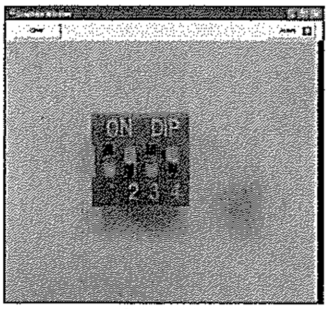

Figure 4c

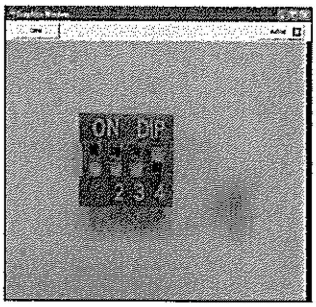

Figure 4d

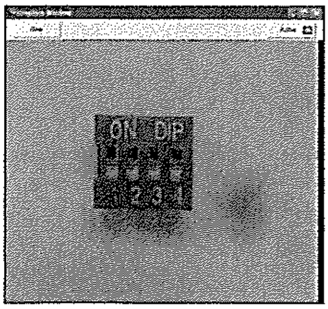

Figure 4e

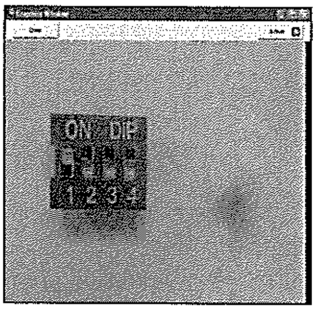

Figure 4f

Figure 4c – 4f: The images used to test the system and its results.
Figure 4c – 4e: Images are successfully detected as long as switch 1 and 3 are at the on position.
Figure 4f: The image is not detected because the required characteristics are not meet.

As for the FMS control scheme, the stand-alone control can be easily adapted to different types of manufacturing configurations since it only affect its own input region and the consequence output action.

It is then tested by setting up the system into a system with two pick and place arm and was driven by two conveyor belt as its transportation means, the pick and place system will act as a simple representative of the manufacturing environment.

The integration is simple and easy, after the users have determine what action that needs to be done when certain input is detected, just need to connect those output from the system into the PLC. Changes can also be done easily by just exchanging the output wires without the fuss of reprogramming the system. For example, initially the requirement is to locate Object A and Object B into Location A and Location B while all unrecognized object will be send to the second conveyor belt (assume Location C), then the requirement changes into when Object A and Object B is found, send it to Location C and when an unrecognized object is found it is send to Location A. The current wiring connections are output A connected to PLC program A, output B connected to PLC program B and output C connected to PLC program C.

From the given changes, the only modifications needed to be done are to reconnect output A and output B to trigger PLC Program C while output C to trigger PLC program A. There are a lot more different kinds of combinations that can be done depending on the requirements and also depending on how the users train the vision system. A combination of flexibility of the vision system and of the wiring connection makes this system's adaptability enormous.

V. Conclusion

The aim of this paper is to present a shape based matching vision system for Flexible Manufacturing System. 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 the stand-alone control concept, this system can be applied to various types of manufacturing configurations.

VI. Future Planning

This project will be continued further by applying the system to another system with a different configuration type. The system will consist of a robotic arm that serves as the transportation means and with three more process stations that is control by PLC. The aim of the project is to show the ease of implementation of the vision system and also to test its reliability and flexibility.

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