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Development of 2-Axis Cartesian Robot with Computer Vision (CRCV) for Material Handling Orientation

Muhammad Zarith Zahadi[1,*], Farhana Ahmad Poad[1], Saizalmursidi Md. Mustam[1], Mohammad Faiz Liew Abdullah[1], Ariffuddin Joret[1], Mochamad Susantok[2]

[1] Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400 Batu Pahat, Johor, Malaysia
[2] Teknik Elektronika Telekomunikasi, Politeknik Caltex Riau, Kota Pekanbaru, Riau 28265, Indonesia

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ABSTRACT

Nowadays, the automation system is growing rapidly in manufacturing industries. It uses a lot of automated processes to prevent humans from doing dangerous tasks such as handling metal plates during the cutting process. Therefore, to fulfill the industries requirement a cartesian robot with two axis motion that is integrated with the computer vision to provide automated alignment process during the cutting process is proposed in this work. However, this paper only focuses on the software development based on the edge-detection method to provide alignment process for conveyor line robot. The technique uses a camera to capture the current position of the plate and calculate the error that needs to be aligned by the robot. The system will avoid human injury, time wasting and improve the production rate as well. As a result, this method has been proven to provide alignment error values that need to be aligned in terms of x and y axis by using the system accurately. In a nutshell, the uses of this method can easily improve the alignment time to ensure the improvement in production rate of an industry.

1. Introduction

Automation system is a complex control system that includes few tasks in its operation. Generally, automation system is important especially in manufacturing industry by making huge impact from the automation system [1]. Usually, material handling process equipped with the automation system to influence the productivity of the product [1,2]. All industries are very concerned about their level of production since it can affect the level of marketability of their products. Rate of productivity is directly proportional to the performance of the processes. Nowadays, the processes in the manufacturing industry usually depends on the automation system. The greater the efficiency of the system, the more the product that can be produced in a specific time [2-4]. One of the systems that is usually used in production systems is the conveyor system.

* *Corresponding author.*
E-mail address: muhammad.zarith97@gmail.com

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A conveyor system is a fast and efficient mechanical handling apparatus for automatically transporting loads and materials within an area [5]. The best thing about this mechanism is it can minimize human error, lowers workplace risks and reduces labour costs [5,6]. Unfortunately, even the human error has been minimized, the error is still occurred during sorting and movement of the material through the vibration of the system itself. Sometimes, the material that is going to be sorted is moving from its proper position. Due to this reason, the work is focusses on development of 2-Axis Cartesian Robot with Computer Vision (CRCV) for material handling orientation. This robot generally integrated with the conveyor line system which easily makes the targeted material loaded into its area. While the material is moving towards the bed of the system, the system that is integrated with computer vision will scan and capture the current position of the material. The orientation error will be calculated by the system and will be reoriented by the 2-axis cartesian robot which are x-axis and y-axis before the material proceeds into the next process. However, this paper focuses on the software development of the system which will cover the scanning and capture process, edge detection process and calculate orientation error process through before and after material is positioned. The orientation process will be manually adjusted and measured by the measurement equipment which are ruler, measuring tape and caliper.

Metal sheet is one of the raw materials which consists of various weight, size and thickness. It is widely used in manufacturing industries, especially in making new metal products. Usually, metal sheets are cut off by automated cutting machine which needs to be done by itself [4,7]. But the tuning or orientation of the metal sheet during the cutting process is normally done by humans which are using manual alignment method. This process might affect the cycling time and total workers needed to complete the processes [8]. Therefore, the development of CRCV that provides 2-axis cartesian robot which integrated with computer vision is proposed to handle the material handling process during the cutting process. This system is expected to play a huge role in the cutting process that might improve the efficiency and performance of the process. This positive impact will improve the rate of productivity of the product.

There are few previous works which used different methods of detection to obtain the alignment error in alignment process. One of the methods used for robotic alignment is visual guidance which is also called eye in hand robotic arm [9]. This robot uses a camera as its detector to detect the cylinder object that needs to be grabbed and slot the object into the available cylindrical space. The accuracy of the detection depends on the condition of the light which affects the quality of the image that needs to be processed. This method provides high precision positioning control with good accuracy. The computational power for this method is high since it uses the industrial computer to operate the visual detection. The method does not state the speed in frame per seconds and the computational speed of the processes. Laser sensor is also one of the methods that has been used as alignment method in robotic system. Automated grid-based robots usually use laser sensor for its detection to provide scalable alignment system which perform by the photodiode [10]. This method generally give high accuracy since the light is travelling in straight line and not affected by environmental light. However, in terms of tolerance, the method needs higher cost to obtain low tolerance since it is built with a lot of laser sensors that arranged as a grid-based detector. The method does not use the camera vision to provide visual detection to determine the positioning and to obtain the orientation that needs to be calibrated. The detection of the laser receiver is used to determine the position and the error of the current position. The computational power is low since it uses the Arduino development board to operate the laser sensor to visualize the object. In addition, the average speed and computational speed are lower since it uses a lot of inputs to obtain high precision detection. Next, the alignment method of combination of camera and laser has been used in Automated Laser Alignment and Image Processing based Robotic Carrom Player [11]. This robot provides detection from laser sensors and colour filtering by using image processing to provide accurate strikes from the robotic carrom player.

From the previous works, there are a lot of methods that can be used to provide high accuracy in alignment process. Since the proposed system is focusing on rectangular metal plate that need to be placed on the laser cutting machine, edge-detection method has been proposed to detect the edges of the plate and identify the coordinates in every corner of the plates by using the Computer Vision (CV). The process is integrated using Raspberry Pi module which is a low computational power module with high-speed processing of frame rate from its camera module with high computational speed. These results easily can be compared to the reference point of the end area of the plate to be placed. The comparison between previous works and proposed system are shown in Table 1.

Table 1
Summary of previous works and proposed system

Ref.	Method and Technique			Performance				
	Visual Detection	Positioning by CV	Orientation by CV	Accuracy	Precision	Computational power	Speed	Computational speed
[8]	✓	✓	✓	✓	✓	High	Not stated	Not stated
[9]	×	×	×	✓	Not stated	Low	Low	Low
[10]	✓	✓	×	✓	Not stated	Low	Low	Low
Proposed	✓	✓	✓	✓	✓	Low	High	High

2. System Design

Figure 1 shows the block diagram of the proposed system which are divided into two parts, part A and part B. Part A is the process of computer vision which is used to recognize the original orientation of the plates through edge-detection of image segmentation process. In this part, few calculations need to be done to verify the current position error of the plate in x-axis and y-axis that need to be reoriented. In part B, the process of robotic motion is done by using few motors and sensors. All the information from part A will be transferred to part B to complete the alignment process. This paper is focuses on part A which is the modelling of the system in software development.

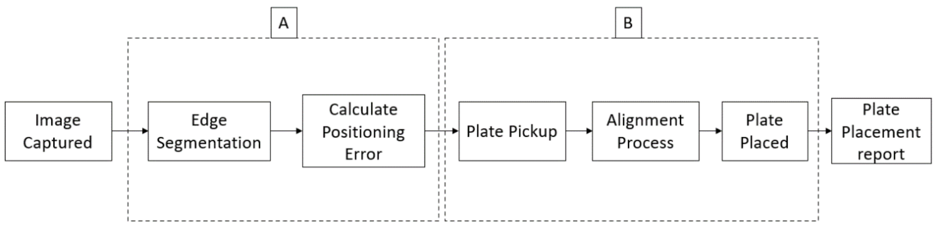


Fig. 1. Block diagram of the proposed system

Figure 2 shows the flowchart of overall system which explain on the mechanism of the proposed system. In this system, the purpose of camera module is to capture the current orientation of metal plate. Here, the metal plate supposedly to be in random orientation which are having errors in terms of x-axis and y-axis. The system will perform a few processes to obtain the positioning of the plate and will calculate the error that needs to be realigned to make the plate ready to proceed in the next process. The linear motion of 2-axis robot will easily align the current position of plate to the targeted position of plate. Usually, the process of the plate alignment will be done manually by human. In this context, the relation between human and robot is human will scan the alignment error of the plate by using their eyes and the proposed robot will capture the plate current position using camera module [9]. The captured image will be analysed through edge-detection of image segmentation process. The positioning error will be calculated to determine the motion of alignment that need to be done by the CRCV that equipped with a few sensors and actuators in hardware mechanism. Since this paper only focuses on the software development, then the observation and measurement of the plate is manually adjusted and align using bare hand.

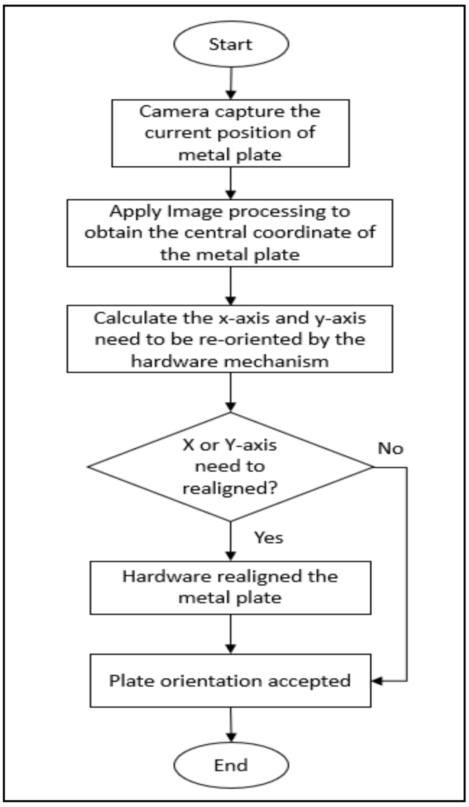


Fig. 2. Flowchart of the proposed system

2.1 Software Development

Figure 3 shows the flowchart of the software development that is divided into four processes which are image capture, pre-processing, Canny edge-detection and coordinate calculation. The capturing process will be done by smartphone camera and other process will be developed in the OpenCV using phyton language. In the testing process, the real plate is used to be captured and will be tested under few conditions of light and place. This is to ensure the camera calibration can avoid or filter the unnecessary objects during the alignment process.

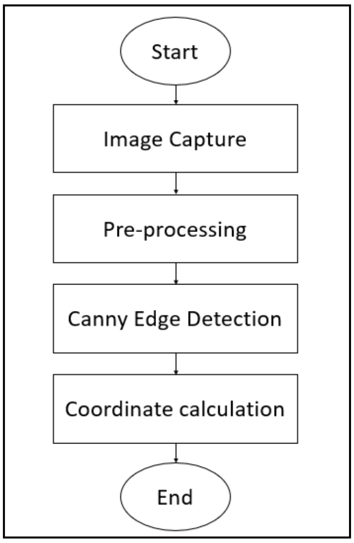


Fig. 3. Software development process flowchart

2.1.1 Image capture

The process of software development started with the image capturing process. A few images of the plate with different position as its current position is captured by using smartphone camera. The camera setting is fixed to a position only. The capturing process is done by using Bluetooth remote to overcome the vibration during the capturing process. The image that is captured during this process will undergo the future processes to obtain the error of its current position in terms of the x-axis, y-axis and the error of the angle between current plate position and the target plate position.

2.1.2 Pre-processing

The pre-processing process is divided into three which are shows in Figure 4. The pre-processing will use the image that has been capture as its input. The first step of the process is by making colour conversion which is converting the image colour from RGB to grayscale. After that, the process continued by applying the gaussian blur to provide a noise filter into an image by blurring or smoothing using Gaussian function to reduce noise level [12]. This usually using a low pass filter to reduce image noise or the details of the image. It is typically completed by convolving an image with a Gaussian kernel expression. But in this case, the process of gaussian blur is done by using the Gaussian function in OpenCV using phyton language. After the gaussian blur process is complete, the image is used in thresholding process using Otsu’s method.

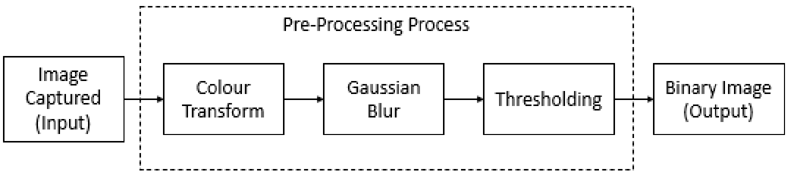


Fig. 4. Pre-processing process

This process will separate the pixel of the image into two groups which are black and white image in terms of binary pixel [13]. In this case, the detected plate in the image will be the black colour and otherwise is in the white colour. At the end of the process, pre-processing image will provide an output of binary image that will undergo the next process.

Table 2
Pseudocode of pre-processing process

Pseudocode 1: Get binary image under pre-processing process
Require: Input image
Step 1: Read image captured from the file.
Step 2: Apply color transform into the image.
Step 3: Apply Gaussian blur into the image.
Step 4: Apply thresholding into the image.
Output Binary image

2.1.3 Canny edge detection

Generally, the edge detection is the process to detect every edge of the plate by grabbing the coordinate in terms of pixel of the image. Nowadays, many researchers focussing on the edge detection with variety of algorithm [14-20]. In this work, the edge detection is done by using Canny algorithm which is called as Canny Edge detection method. It is the main process in this software development which is divided into several steps as shown in Figure 5.

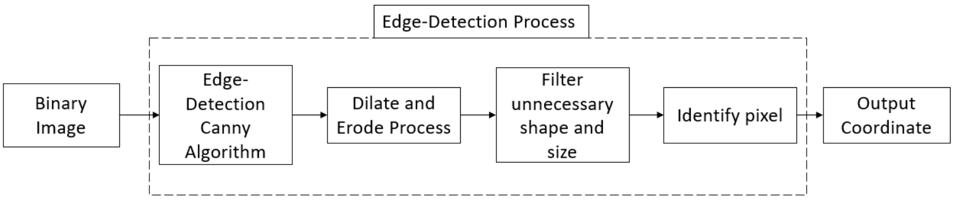


Fig. 5. Canny edge-detection process

In the beginning of edge detection process, the binary image obtained by pre-processing process is used by applying Canny algorithm into the image. This process aims to track the shape in the image which separated by the colours which in this case are black and white [22]. Since the line created is thin and influenced by some noise or pixel error, the process continued by applying dilate and erode process into the image from canny algorithm. Dilate process is a process to increase the line size of the important pixel which is done in the background and the erode process is a process to reduce the line size of important pixel which is done in foreground [23,24]. As a result, Figure 6 shows where the binary image undergo edge detection process to obtain the white tracking line surround the targeted plate image.

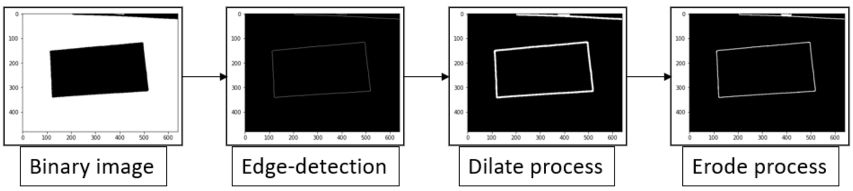


Fig. 6. Visual transformation of edge-detection process

Table 3
Pseudocode of Canny edge-detecti method

Pseudocode 2: Get output coordinate using edge detection method

Require: Binary image
 	
Step 1: Use binary image from pre-processing process.
Step 2: Apply Edge-detection of canny algorithm method.
Step 3: Apply dilate and erode process.
 	
for contour in the image, do
if contour area less than 100, then ignore.
else if contour area more than 100, then get minimum area of the rectangle.
Change the rectangle into array value and identify the pixel value.
Declare central point of the rectangle detected.
Draw rectangle.
Calculate pixel per matrix of the image.
End if
End for
Return central point and pixel per matrix.
 	
Output Central coordinate of the rectangle and pixel per matrix.

2.1.4 Coordinate calculation for orientation

The alignment process started by creating a reference rectangle object which is the targeted position which the plate should be aligned. From this rectangle, the center coordinates of plate and references are compared the difference between x-axis error and y-axis error of current position plate with the target template visual rectangle. This value will be used to undergo translation process to make the center of the plate is centered to the targeted center coordinate [24]. Figure 7 shows the visual of translation process after calculation of Δx and Δy which the pink color rectangle is the reference point that is the targeted position for alignment process while the black rectangle is the current position of plate.

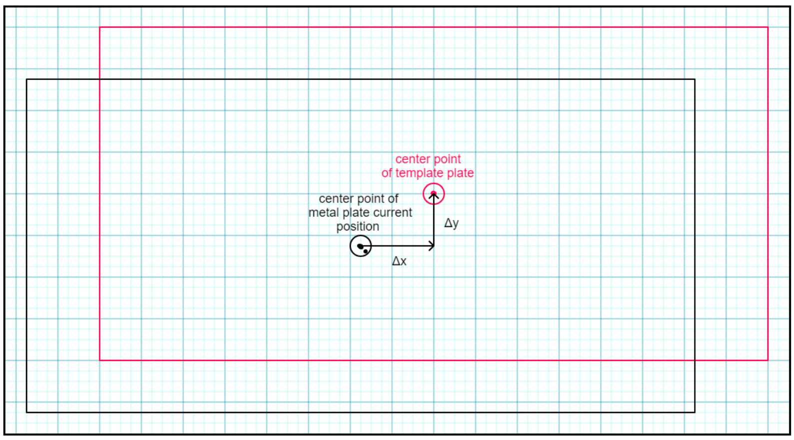


Fig. 7. Visual orientation using translation method

Table 4
Pseudocode of Canny edge-detection method

Pseudocode 3: Calculate angle need to align
Require: center and right top corner coordinate of the detected box and template
Step 1: calculate the different pixel between two central point of box detected and template.
Step 2: move the central point of box detected to the central point of template box by drawing new box to visualize it.
Step 3: calculate distance needed to be realigned for x-axis and y-axis in centimeter (*cm*)
Output X-axis and Y-axis to be aligned by the system

2.2 Real Testing Process

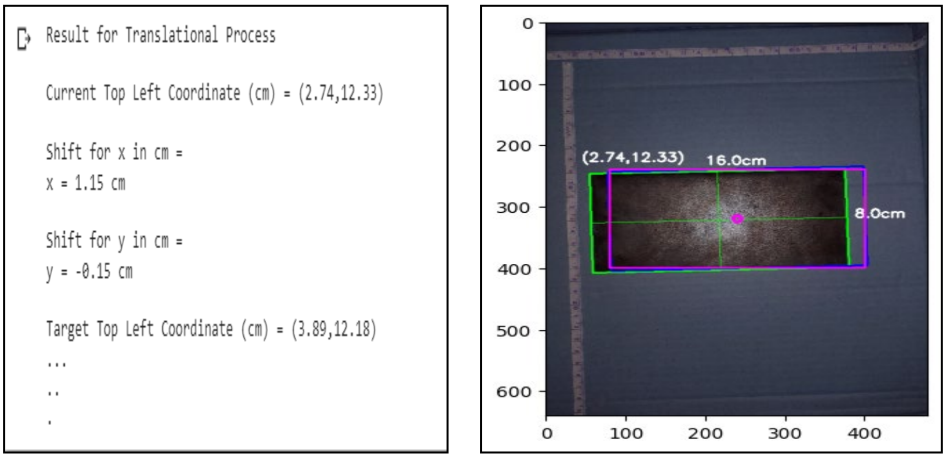
The testing process started by setting up the place for the plate orientation with 2-axis measuring tape to easily measure the initial coordinate in one of the plate corners. In this situation, the coordinate measure is in centimeters and the selected corner is top left (TL) corner. This coordinate will be used to realign the error of the plate position. Figure 8 shows the setup of the real testing process. The minimum scale that can be measured during this process is 0.1 *cm.* Realignment process is done after the plate manually moved by using bare hand towards the Δx and Δy that has been calculate during the edge detection process. After the plate has been realigned, the new current coordinate of the TL corner will be record and the image will be captured again and the error from before and after alignment will be calculated to obtain the accuracy of the system. Then, the process will be repeated to figure out the precision of the system.

Fig. 8. Testing setup

3. Result and Discussion

In this section, the testing of the system has been made and recorded to calculate the accuracy of the CRCV system. The testing process start by placing the metal plate on the random position. Then, camera will capture the current position of the metal plate and processed to obtain its top left coordinate, value of x and y need to be realigned and the target value of coordinates for top left corner depends on its current position. All the process has been repeated 15 times of random position and calculate the average value.

Figure 9(a) shows the printed result generated by the image processing process and Figure 9(b) shows the image generated after undergoing all the image processing process. From the Figure 9(b), green rectangle is the original image captured by the camera, pink rectangle indicates the template of targeting position and blue rectangle is the position of the plate should be place after shifted to the value that printed in the Figure 9(a). The coordinate printed on the top left side of the plate in the Figure 9(b) is the coordinate of its top left.



(a) (b)

Fig. 9. (a) Result generates from edge detection method (b) Image generates from edge detection method

Table 5 shows the results of the system performance after has been tested. 15 different positions have been captured by the system to be analyse in this section. The top left coordinate of the random position plate has been generated by the CRCV system to obtain the initial value and the target value. The process continues by moved the plates with the desired distance that obtain by the system. The process has been repeated for several times to generate the average value of the measurement. After the plates has been moved, the system captured again the position of the current plate after the alignment process. The measurement has been recorded in the Table 5. From this experiment, CRCV system has been obtain high accuracy of performance which is 94.093% for x-axis and 99.067% for y-axis.

Table 5
Result of the accuracy calculated from testing

Position	Top Left Coordinate before Alignment (x, y) cm		Targeted Top Left Coordinate Should be after Alignment (R)		Top Left Coordinate after Alignment (M)		Relative Error Top Left Coordinate after Alignment (RE) $RE = \left\|\frac{M-R}{R}\right\|$		Percentage of accuracy (PA) $PA = (1-RE) \times 100\%$	
	x	y	x	y	x	y	x	y	x	y
1	2.74	12.33	3.89	12.18	3.42	12.0	0.121	0.015	87.9	98.5
2	6.53	3.94	3.69	12.54	3.53	12.62	0.043	0.006	95.7	99.4
3	6.49	6.24	3.69	12.51	3.65	12.38	0.011	0.010	98.9	99.0
4	5.23	20.58	3.88	12.06	3.68	12.12	0.516	0.005	48.4	99.5
5	7.90	17.90	3.90	12.10	3.85	12.15	0.013	0.004	98.7	99.6
6	2.89	18.31	3.81	12.20	3.85	12.18	0.011	0.002	98.9	99.8
7	4.63	13.54	3.78	12.27	3.92	12.40	0.037	0.011	96.3	98.9
8	4.53	8.22	3.83	12.21	3.80	12.32	0.008	0.009	99.2	99.1
9	3.08	3.83	3.78	12.19	3.72	12.32	0.016	0.011	98.4	98.9
10	1.84	8.32	3.71	12.28	3.82	12.24	0.030	0.003	97.0	99.7
11	7.29	14.33	3.77	12.36	3.78	12.45	0.003	0.007	99.7	99.3
12	7.30	21.55	4.08	11.78	3.92	12.03	0.039	0.021	96.1	97.9
13	4.84	9.98	3.92	12.15	3.87	12.38	0.013	0.019	98.7	98.1

14	5.23	5.38	3.96	11.93	3.88	12.05	0.020	0.010	98.0	99.0
15	3.39	17.12	3.94	12.03	3.96	12.12	0.005	0.007	99.5	99.3
Average Value									94.093	99.067

4. Conclusions

In a nutshell, the overall system has been completely modelled in terms of software development. The integration of the system with the computer vision has been done perfectly which easily to be monitored the errors of the current position of the material. This system is highly recommended during the sorting process of conveyor system. Finally, the result of the performance of the system has been analyses completely in terms of x-axis and y-axis alignment process which provide high accuracy with the value of 94.093% for x-axis and 99.067% for y-axis.

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