Object Detection Robot Using Fuzzy Logic Controller Through Image Processing

M Khairudin¹, S Yatmono¹, AC Nugraha¹, M Ikhsani¹, A Shah² and ML Hakim¹

¹Departement of Electrical Engineering Education, Faculty of Engineering, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
²Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak, Malaysia

E-mail: moh_khairudin@uny.ac.id

Abstract. This study presents a robot movement in tracking 2D objects. This input image is transformed into another image by certain techniques. In this study, by utilizing image processing, the robot can work to detect objects in the form of hexagons. Apart from detecting the detected shape, this image processing is also for detecting color. So that a hexagon-shaped 2D object will be detected with the magenta color that has been set in advance. The movement of this robot is to follow the motion of objects horizontally. While the object is shifted to the right, the robot will move to the right, and if the object is shifted to the left, the robot will move to the left. Robot movement is controlled by fuzzy logic. There are 5 membership functions to divide the object’s position area and 5 membership functions output to adjust the speed and direction of the robot’s motion.

Keywords: object detection robot; image processing; fuzzy logic; tracking.

1. Introduction

Robot is a form of technological advancement that continues to develop. Robots are often used as a substitute for humans in doing certain things that are repetitive and seem boring [1]. In practice, there are several robots that in addition to replacing human positions are also made with shapes that are tailored to their needs [2]. The path follower robot or often known as the line follower is one of the basic forms of the robot [3]. The robot follows the form of a magenta-colored hexagon 2D object that the author made is the minimum form of a robot that can follow objects automatically. This robot is equipped with a sense of sight in the form of a webcam connected to a computer [4] [5]. With a fuzzy logic control system, it can help smooth robot movements in the decision making process.

This kind of robot has been made in every robot visual sensing practice as a final project. Development of color-based object detection robot with camera sensor was built by [6] [7]. It performed four different techniques namely path length, time spent, energy consumption and average speed of mobile robots through soft computational programming to obtain a comparative study [8]. Using the reward function to find out the actual distance, size and shape of the obstacles, and then combined the Markov decision and the fuzzy interference system to find the optimal real-time path planning and ensure the humanoid robot can monitor the unknown and the environment [9]. To complete the task, [10] revealed several tasks to achieve efficient mobile robot removal in unknown environments, namely coverage area, exploration, surveillance, missions to find and save avoiding obstacles and keeping attention to robot obstacles.
Several techniques used in image processing include Intensity Adjustment, Histogram Equalization, Thresholding, Motion Blur, Canny, Median Filtering, etc. Image processing can be used for tracking \cite{11} \cite{12}. Tracking is a job to follow and identify the movement of objects caught on camera \cite{13} \cite{14}. Tracking using image processing can be used in various fields. In the factory it can be used for automatic sorting and warehouse management. Whereas in the military field it can be used to track enemy movements or identify bullet movements \cite{15}. Besides that, it can be used for disease detection based on the color of the tongue which will be made next.

The advantage of the robot in this study is the use of a fuzzy logic control system in image processing for motion determination. Fuzzy logic is used as a decision making to move right or left. So that the robot can find objects that remain in the center. Robot following objects can be applied in all aspects of human work based on vision and movement. Like the automatic driver, it can also be implemented using the development of a robot.

2. Object detection robot using image processing

This study used research method used in making the robot following the 2D magenta colored hexagon object is research and development. In short, the process of making a robot begins with analyzing needs, designing the shape of the robot, developing a program design using fuzzy, applying it to 2D object detection robots, and evaluating at each stage of the process.

![Figure 1. Laboratorium scale of object detection robot](image)

Figure 1 shows the results of the robot design with a webcam camera as a source of vision, two servo motors included in a 2D object detection robot equipped with Arduino and a computer for visual programming and fuzzy logic. In Figure 2, it is clearly seen the relationship of each of these components.
The specifications for 2D object detection robots can be seen in Table 1.

| No | Component       | Specification                        |
|----|-----------------|--------------------------------------|
| 1  | Power supply    | USB 5V                               |
| 2  | Data processing | Arduino Uno R3                       |
| 3  | Actuator        | Dua Motor Servo Parallax             |
| 4  | Camera          | Logitech c170                        |
| 5  | GUI             | Visual Studio 2012                   |
| 6  | Body            | Robot Paralax                        |
|    | Height          | 20 cm                                |
|    | Width           | 15 cm                                |
|    | Length          | 20 cm                                |

Figure 3 presents the flow chart of robot work order. By using any technique of programming, the fuzzy calculation process will be faster.
3. Findings and discussion

In brief, the working principle of the robot in tracking this object is as follows. First the camera detects a magenta colored hexagon 2D object. This detection process uses image processing. Through filtering the colors first so that only the magenta color remains. After that, blur it so that the shape becomes more angular. Canny filtered to display edges or lines that function to detect the shape of the object. With the filter, the number of points and exterior angles from the detection results is 6 points and the exterior angles from the hexagon = 360/6 = 60 degrees. While it is appropriate to detect a magenta colored hexagon 2D object. The next step is to determine the midpoint of the object stored in the center-\(x\) variable. The value from center-\(x\) is then entered into the fuzzy logic, the resulting motor speed value is stored in variable \(x\) and sent to Arduino via the serial port.

Furthermore, the Arduino microcontroller will process the data according to the value received. The calculation results are recorded in a file called test.txt on the desktop. The process is gradually displayed on the screen on the computer. The following are the steps in the Visual Studio program code.
1. Declaration of library EmguCV
2. Declaration of the used variable
The mat function is used to display the view from the camera and those that have been through the process. The source is taken by the direct camera, blur is for those that have been blended, canny is for the outline, draw is for coloring the outline to red, the output is for the results that already have a blue line and a red dot as a sign that a magenta colored hexagon 2D object is detected.
3. Call the video capture function to start recording using the camera and start the serial port so that it can communicate with Arduino.
4. Perform a color filter on the imageGrabbed function when the image is captured, set with Hue Saturation and Value on the trackbar.
5. Blur the image to make it more faceted
6. Outline with canny
7. Start detecting the shape of the hexagon, count the number of points detected, and make a red line on the mat draw.
8. Detect a hexagon with exterior angle = 360/6 = 60 tolerance of 15 degrees then between 45 to 75 degrees.
9. If the shape is correct, start calculating the positions of the six points and calculate the midpoints.
10. Displays the picture in the picture box
11. Position the trackbar to adjust the color filter and canny lines
12. Call fuzzy logic, display on label12 and send serial data.
13. Save data to test.txt

The distribution of membership functions for input and output can be seen in Figures 4 and 5. The input consists of 5 membership functions and the output consists of 5 membership functions with 5 rules. The Fuzzy logic calculations to determine the motor speed and direction of movement of the car robot using a mamdani method.

![Figure 4. Membership Function of input](image-url)
Fuzzy logic process is applied to Visual Studio code using C# programming language. The process starts with the fuzzy variable declaration, then defuzzification, rule process, defuzzification, calculating the center of gravity and producing the motor speed value. The following is an explanation of the stages.

1. Declaration of variable fuzzy
2. Fuzzyfication
3. Calculating for rule
4. Defuzzyfication
5. Center of Gravity
6. Function on fis was called in object detection process

The program source of Arduino was functioned to receive the data serial that in the form of char data or numeric.

1. Declare the variables and libraries for servo motors
2. Declare the left and right servo data legs and initiate serial communication
3. Read serial data and convert from char to integer
4. Write down the motor speed value, 1500 means the motor is idle. This condition causes the paralax servo will move clock-wise if it is given an input of 1700. Otherwise will move on counterclock-wise if it is given an input of 1300.
5. Resets data to [space] or non-zero blank when preparing a new data.

The robot performance in tracking 2D objects can be seen in Figure 6. If the object located on the left, then the robot will move to the left. In otherway when the object located on the right, the robot will move to the right.
As for the robot performances on movement to the left when the 2D objects were located on the left, it can be seen in Figure 7.

While the performances of robot for moving towards the center the 2D objects were located on the center, it can be seen in Figure 8.
4. Conclusion

This study has shown the performances of a robot that can move as expected. The robot moves based on the input in the form of a magenta-colored hexagon 2D object that remains in the center. The robot movements were controlled by fuzzy logic. With fuzzy logic, the robot can detect the movement of 2D objects. If the 2D object moves to the right, the robot can follow the direction of the 2D object's movement. Likewise, if a 2D object moves to the left and another direction, the robot can move to follow the 2D object.

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