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Semi-Autonomous Navigation Robot Using Integrated Remote Control And Fuzzy Logic

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***Abstract*— Obstacle avoidance robots are designed to allow the robot to navigate in unknown environments by avoiding collisions. An obstacle avoidance robot will detect obstacles in the path and avoid them. The sensor plays an important role in the designed distance measuring system. Ultrasonic sensors are widely used in the design of distance measuring systems because ultrasonic sensors are not affected by the color of the reflecting object, the softness of the reflecting object, and are safe from interference or noise from other waves. Fuzzy logic is one of the modern controllers that can work well on non-linear systems by offering convenience in program design because it does not require a mathematical model of the process. The fuzzy-based controller is a control method that belongs to the Artificial Intelligence class. In this research, a Fuzzy Logic Control method system will be implemented to control the rotation speed of the DC motor which is caused by negligence in giving commands to the robot. Basically, this research will be applied to control using computer vision. However, the role of computer vision is replaced by a user who gives commands using a remote control. The input in this study is the distance between the robot and the obstacle using the HC-SR04 ultrasonic sensor and the input from the remote control with a maximum frequency of 2.4 GHz. Simulations have been carried out to get the value of the membership function. The simulation is carried out using a case study, where the input from the remote control is 1110 and 16 cm on the right sensor and 8 cm on the left sensor. The results of the simulation show that the speed of the right motor is 87.3 PWM and the left motor is 33.4 PWM. Based on the simulation results, the robot runs according to the rules that have been designed in the Mathlab application.**

Keywords*—*fuzzy logic control, obstacle avoidance, ultrasonic sensor, remote control.

I. Introduction

Obstacle avoidance is one of the main requirements of mobile robots, including autonomous navigation robots. The obstacle avoidance robots are designed to be able to navigate in unknown environments avoiding collisions. Sensors play an important role in the designed distance measurement system. Sensors used for distance measurement include ultrasonic sensors, infrared sensors, and lasers. Ultrasonic sensors are widely used in the design of distance measurement systems because they are not affected by the color of the reflective object, the smoothness of the reflective object, and are not affected by interference or other wave noise. By using ultrasonic sensors, the robot can detect obstacles around its path and then provide information to avoid objects immediately. However, digital control systems only work with logics 0 and 1, go or stop. It is also a robot mobility issue that suddenly stops when the obstacle you are facing is out of the robot's path [1] [2].

Since fuzzy logic does not require a mathematical model of the process, it is one of the newest controllers that can work well in nonlinear systems by providing convenience to program design [3]. Fuzzy-based controllers are control methods that belong to the class of artificial intelligence. Unlike Proportional Integral Derivative (PID) control, which uses only mathematical calculations, fuzzy controllers combine mathematical calculations with algorithms to control the robot's behavior with respect to environmental dynamics [4][5].

Of course, there have been some studies of obstacle avoidance robot warning systems using fuzzy logic or similar methods. Several previous studies have shown mobile robots being engineered to perform disaster rescue operations that occurred in static and dynamic environments [4][5][8]. In a study jointly conducted by Hee-Joo Yeo and Mun_Hyung Sung, a mobile robot controlled by a fuzzy control system avoids obstacles and tracks the path to avoid obstacles in the path, and the application of fuzzy control [5]. In 2020, research on mobile robots using the fuzzy logic method was conducted by Abdul Mutholib and others such as Alwan Abdul Zaki for industrial wall monitoring [9] and line sensor-based product transportation robots [2]. Research on robots controlled by remote control was also conducted by Mohamad Adhipramana and others in 2020. Monitor several factors that affect the water quality of the area [10].

This autopilot robot works automatically, but in this case the user and remote control assume a system that commands the robot. The problem that sometimes occurs is that the input provided to the robot is excessively disconnected, resulting in false detections of the system and incomplete robot startup. [5][6]. Due to these problems, a warning system is required so that the robot operates when an input error occurs in the system that controls the robot.

In this study, a matt logic control system is provided to control the speed of the DC motor caused by negligence to give the robot a command. Basically, this study is applied to the control with the vision of the computer. However, the role of the computer vision is replaced by the users who provide commands using the remote control.

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II. Modeling Speed of Robot Using Fuzzy Logic

A. Block Diagram System

Obstacle avoidance robot design based on fuzzy logic control can be divided into three system stages: input, process, and output as shown in Fig. 1. During the input process, two HC-SR04 ultrasonic sensors mounted on the front of the robot, namely the left and right sensors and the remote control, are used.

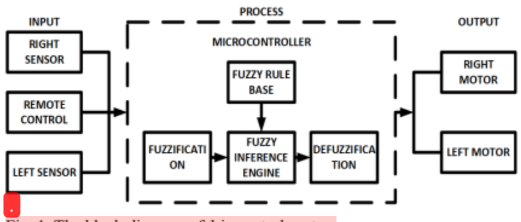

Fig. 1. The block diagram of this control system.

The obstacle avoidance robot's working method is based on fuzzy logic control, including input, processing and output. In general, all these parts are related to each other, so that a usable robot can be created.

1. The input part is a remote control and a distance sensor. The components used are three HC-SR04 ultrasonic sensors, which are used to measure and provide the distance information between the robot and the obstacle in front. The remote control provides input for the DC motor. So that the robot can move forward.
2. The processing part is the main part of this tool, because this tool processes the distance from the sensor to the obstacle and processes the input given by the remote control. In this section, the Arduino MEGA 2560 microcontroller is used to control the fuzzy logic control, and the sensor and remote control inputs are used to process the distance measurement results.
3. This output part is the final result of data processing after the Arduino MEGA 2560 receives the input of the HCSR04 ultrasonic sensor and the remote control. The output uses two DC motors, namely the right motor and the left motor.

B. Hardware Design

When designing obstacle avoidance robots based on fuzzy control logic, some electronic and non-electronic supporting components are used. It can be seen that the name and number of components needed to design Semi-Automatic Navigation Robot using Remote Control and Ultrasonic Sensors as shown in Table I.

TABLE I. Component

No	Component	Lots
1	Smart car chassis 2 WD Alumunium	1
2	Arduino MEGA 2560	1
3	Motor drivershield L293D	1
4	Motor DC	2
5	Battery Lippo 11 Volt	1
6	Ultrasonic Sensor HC-SR04	3
7	Cable	40
8	Remote Control 2.4 GHz	1
9	2.4 GHz Receiver	1

Fig. 2. illustrates the overall schematic of Semi-Automatic Navigation Robot using Remote Control and Ultrasonic Sensors.

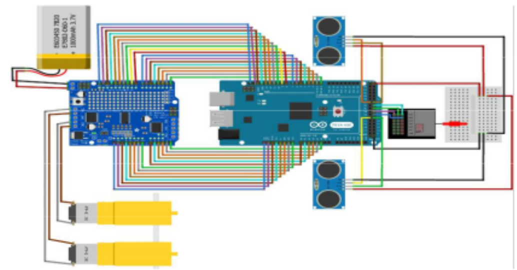

Fig. 2. Schematic robot.

C. Fuzzy Model

The modeling performed in this Matlab software consists of three input variables and two output variables. The input variable is composed of three HC-SR04 ultrasonic sensors, which are installed on the front of the robot and the placement position, namely the right sensor and the left sensor. The output variable uses two DC motors that are affected by their speed.

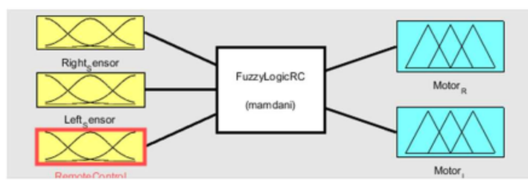

Fig. 3. Fuzzy logic design.

Due to the large number of variables used, the term linguistics should be used to facilitate the control system designed in this study. Table II shows the input language terms used.

TABLE II. Linguistic Term of Input Sensor

Distance (Centimeter)	Linguistic Term	
	Sensor right	*Sensor left*
[0 0 5 10]	Near (NR)	Near (NL)
[5 10 15 20]	Middle (MeR)	Middle (MeL)
[15 20 25 25]	Far (FR)	Far (FL)

TABLE III. Linguistic Term of Input from Remote Control

Toggle Level	Linguistic Term
[900 900 1100 1300]	Forward (Fo)
[1100 1300 1500 1500]	Stop (So)

TABLE IV. Linguistic Term of Output Motor DC

Motor Speed (PWM)	Linguistic Term	
	Right wheel	*Left wheel*
[0 0 0 0]	Stop(StR)	Stop(StL)
[0 0 50 75]	Slow (SlR)	Slow (SlL)
[50 75 125 150]	Normal (NmR)	Normal (NmL)
[125 150 200 200]	Fast (FsR)	Fast (FsL)

The robot sensor input part is divided into three fuzzy members: near and far. As shown in Fig. 6, the remote control input part is divided into two fuzzy members: forward and stop. For the whole, use a trapezoidal curve shape.

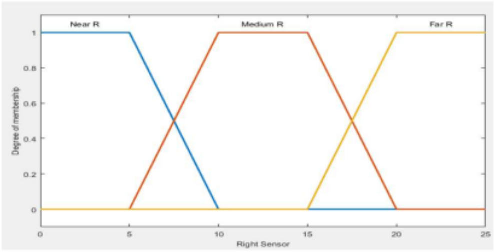

Fig. 4. MF input of right sensor.

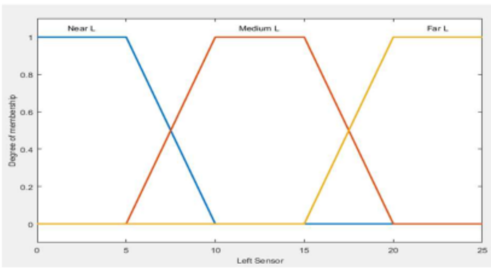

Fig.

Fig. 5. MF input of left sensor.

TABLE V. EQUATION TERM OF MF INPUT SENSOR.

μ of 2 Sensors
$\mu_N = \begin{cases} 1, & x \leq 5 \\ \frac{10-x}{5}, & 5 \leq x \leq 10 \\ 0, & x \geq 10 \end{cases}$
$\mu_{Me} = \begin{cases} \frac{x-5}{5}, & 5 \leq x \leq 10 \\ 1, & 10 \leq x \leq 15 \\ \frac{20-x}{5}, & 15 \leq x \leq 20 \end{cases}$
$\mu_F = \begin{cases} \frac{x-15}{5}, & 15 \leq x \leq 20 \\ 1, & x \geq 25 \end{cases}$

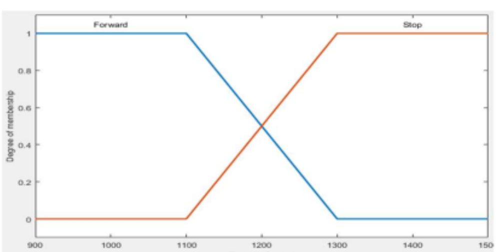

Fig. 6. MF input of remote control

TABLE VI. EQUATION TERM OF MF INPUT REMOTE CONTROL.

μ of Remote Control
$\mu_{Fo} = \begin{cases} 1, & 900 \leq x \leq 1100 \\ \frac{1300-x}{200}, & x \leq 1300 \end{cases}$
$\mu_{Me} = \begin{cases} \frac{x-1100}{200}, & 1100 \leq x \leq 1300 \\ 1, & x \leq 1500 \end{cases}$

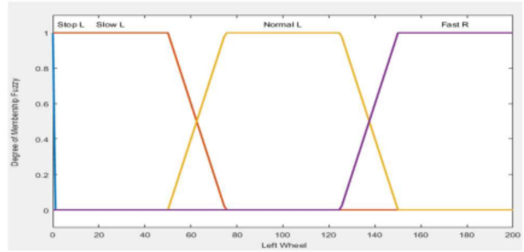

Fig. 7. MF output of left motor speed.

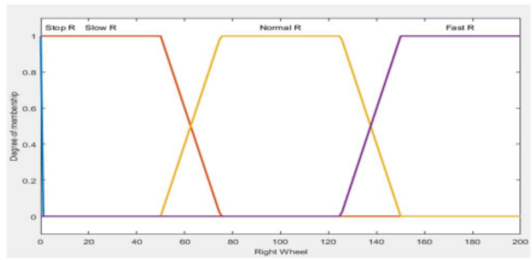

Fig. 8. MF output of right motor speed

TABLE VII. EQUATION TERM OF MF OUTPUT.

μ of Motors
$\mu_{St} = \{1, \quad 0$
$\mu_{Sl} = \begin{cases} 1, & x \leq 50 \\ \frac{75-x}{25}, & 50 \leq x \leq 75 \\ 0, & x \geq 75 \end{cases}$
$\mu_{Nm} = \begin{cases} \frac{x-50}{25}, & 50 \leq x \leq 75 \\ 1, & 75 \leq x \leq 125 \\ \frac{150-x}{25}, & 125 \leq x \leq 150 \end{cases}$
$\mu_{Fs} = \begin{cases} \frac{x-125}{25}, & 125 \leq x \leq 150 \\ 1, & x \leq 200 \end{cases}$

TABLE VIII. RULE FUZZY LOGIC.

Rules	Input			Output	
	right	***left***	***remote***	***right***	***left***
R1	Near	Near	Forward	Stop	Stop
R2	Near	Medium	Forward	Fast	Stop
R3	Near	Far	Forward	Fast	Slow
R4	Medium	Near	Forward	Stop	Fast
R5	Medium	Medium	Forward	Slow	Slow
R6	Medium	Far	Forward	Slow	Slow
R7	Far	Near	Forward	Stop	Fast
R8	Far	Medium	Forward	Slow	Slow
R9	Far	Far	Forward	Normal	Normal
R10	Near	Near	Stop	Stop	Stop
R11	Near	Meduim	Stop	Stop	Stop
R12	Near	Far	Stop	Stop	Stop
R13	Meduim	Near	Stop	Stop	Stop
R14	Meduim	Meduim	Stop	Stop	Stop
R15	Meduim	Far	Stop	Stop	Stop

R16	Far	Near	Stop	Stop	Stop
R17	Far	Meduim	Stop	Stop	Stop
R18	Far	Far	Stop	Stop	Stop

III. SIMULATION RESULT

In the test, the simulation was performed in the Mathlab application and compared with manual calculations to see the applicability of the created fuzzy control system. In this test, using the remote control to dial input 1110, the obstacle is 8 cm from the right sensor and 16 cm from the left sensor. The results of the tests that have been performed are shown below.

Step 1. Determine the Fuzzy Set

When determining the fuzzy set, we must first find the membership degree of the membership function to represent. Use the input conditions that the left sensor is 16 cm from the obstacle and the right sensor is 8 cm from the obstacle, and then the value of 8 cm is entered in the fuzzy sets CLOSE and MIDDLE, and the value of 16 cm enter the diffuse MEDIUM and FAR. The fuzzy sets are based on Table V. The equation is obtained from:

Right Sensor

$$\mu_{MeL}[8]\frac{10-8}{5} = 0{,}4 \quad (1)$$

$$\mu_{MeL}[8]\frac{8-5}{5} = 0{,}6 \quad (2)$$

Left Sensor

$$\mu_{MeL}[16]\frac{20-16}{5} = 0{,}8 \quad (3)$$

$$\mu_{FsL}[16]\frac{16-15}{5} = 0{,}2 \quad (4)$$

Step 2. The function implication

The implication function used in this process is the MIN function, because the fuzzy rule base established is an AND function. For the MIN function, the minimum degree of membership of the input variable is its output. According to the rule base shown in Table 5, in this case, the condition only displays 4 rules that provide values, namely [R2], [R3], [R5], and [R6].

[R2] : IF right sensor is Near **And** left sensor is Medium **Then** Right motor is Fast and left motor is Stop

$$\alpha_{R2} = \mu_{NR} \cap \mu_{MeL}$$
$$\alpha_{R2} = \min(\mu_{NR}, \mu_{MeL})$$
$$\alpha_{R2} = \min(0.4, 0.8) = 0.4 \quad (5)$$

[R3] : IF right sensor is Near **And** left sensor is Far **Then** Right motor is Fast and left motor is Slow

$$\alpha_{R3} = \mu_{NR} \cap \mu_{FL}$$
$$\alpha_{R3} = \min(\mu_{NR}, \mu_{FL})$$
$$\alpha_{R3} = \min(0.4, 0.2) = 0.2 \quad (6)$$

[R5] : IF right sensor is Medium **And** left sensor is Medium **Then** Right motor is Slow and left motor is Slow

$$\alpha_{R5} = \mu_{MeR} \cap \mu_{MeL}$$
$$\alpha_{R5} = \min(\mu_{MeR}, \mu_{MeL})$$
$$\alpha_{R5} = \min(0.6, 0.8) = 0.6 \quad (7)$$

[R6] : IF right sensor is Medium **And** left sensor is Far **Then** Right motor is Slow and left motor is Slow

$$\alpha_{R6} = \mu_{MeR} \cap \mu_{FL}$$
$$\alpha_{R6} = \min(\mu_{MeR}, \mu_{FL})$$
$$\alpha_{R6} = \min(0.2, 0.2) = 0.2 \quad (8)$$

Step 3. Defuzzification

Defuzzification is the process of transforming the membership degree of a fuzzy set into a definite decision or a true value. The center of gravity technique is a comprehensive and useful defuzzification method. The most common method is to stack all of these trapezoids on top of each other to create a single geometric shape. Then calculate the fuzzy centroid or center in this way. Fig. 8 shows the result of the calculation of the rule view of the MatLab toolbox using the MatLab program in this case.

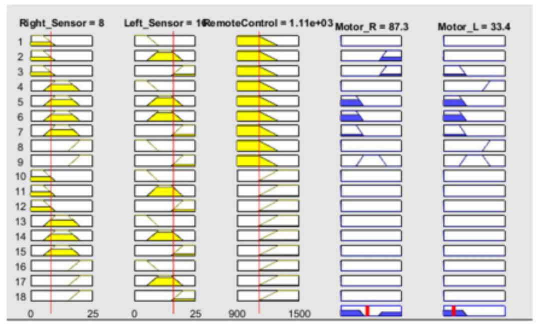

Fig. 9. MF Result of Fuzzy design in MatLab

From the test in the Matlab application, it can be seen that the right sensor is 8 cm away from the obstacle, the left sensor is 16 cm away from the obstacle, the remote control input 1110, the result output is a PWM motor, the value is 87.3 right motor and 33.4 left motor.

The *x* coordinate of the centroid is the defuzzified value, called Z^*. So, the output of this fuzzy logic:

$$Z^* = \frac{\int_0^{60} 0.6\, z\, dz + \int_{60}^{75}\left(\frac{75-z}{25}\right) z\, dz}{(60)(0.6\, dz) + \left(\frac{(15)(0.6\, dz)}{2}\right)}$$

$$Z^* = \frac{1372.5}{40.5} = 33.8 \quad (4)$$

and

$$Z^* = \frac{\int_0^{60} 0.6\, z\, dz + \int_{60}^{75}\left(\frac{75-z}{25}\right) z\, dz + \int_{125}^{135}\left(\frac{z-125}{25}\right) z\, dz + \int_{135}^{200} 0.4\, z\, dz}{(60)(0.6\, dz) + \left(\frac{(15)(0.6\, dz)}{2}\right) + \left(\frac{(15)(0.4\, dz)}{2}\right) + (65)(0.4\, dz)}$$

$$Z^* = \frac{5990.8}{69.5} = 86.1 \quad (5)$$

The test results of the Matlab application program are executed according to the designed rules. When the right sensor gets 8cm and 16cm input on the left sensor, the robot will slowly move to the left, the right motor output value is 87.3 PWM, and the left motor output value is 33, 4 PWM. These results can be seen in Figure 8. Therefore, from the implementation of the Mamdani Fuzzy Logic method in the results of the manual calculation, the right sensor is 8 cm from the obstacle and the left sensor is 16 cm from the obstacle. The right motor output is 86.1 PWM and the left motor output is 33.8 PWM. With the result of this manual calculation, it can be seen that the system is running well. The simulation results of the Mathlab application prove this, and the results are not much different from the results of the manual calculations that have been performed.

IV. Conclusion

In this study, the performance of a remote-controlled robot was verified to avoid obstacles on the way. The robot is controlled by a remote control and commands the robot to move forward. When designing the system, the Mathlab application is used to design the rules to be applied to the robot. For example, when the right sensor gets 8cm and 16cm input on the left sensor, the robot will move slowly to the left, the output value of the right motor is 87.3 PWM, and the output value of the left motor it is 33.4 PWM. The calculation results produce the right motor output of 86.1 PWM and the left motor output of 33.8 PWM. With the result of this manual calculation, it can be seen that the system is running well.

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