Design of Automatic Under Water Robot System Based on Mamdani Fuzzy Logic Controller

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***Abstract*— Underwater robot is one of the robots that maneuver under water. This robot is controlled using a remote control or more commonly known as ROV. However, when controlled by the remote often interruptions or connections are often disconnected. Therefore, it is necessary to make an underwater robot that can move automatically. In this study a discussion about automatic underwater robot simulation using the fuzzy method. Simulations performed on Matlab software to get a model of each membership function and get the value of the output. The sensor used is an ultrasonic water resist sensor and the motor used is a brushless motor. The parameters used are for the input is the front sensor distance, rear sensor distance and bottom sensor distance while the output parameters used are the right motor speed, left motor speed, right bottom motor speed and bottom left motor speed. The number of rules used is 125 rules. In this research, a case study with a distance sensor value of 30 cm, 30cm and 60 cm was completed. Then using the simulation, the output value as follows: PWM value for right motor is 17.3 PWM value for left motor 110 while for PWM value for motor bottom is 80. From the values it can be concluded that the robot in the maneuver turns right with the position at a medium height.**

Keywords— Robot, Underwater, Control, Fuzzy logic, Sensor.

I. Introduction

Robot technology is widely applied in various fields of life. Some are used in industry, observation, education and others. The progress of robot technology cannot be separated from the many uses of the microcontroller chip as the brain and the control center of a robot. There are several types of robots that are generally divided into two groups namely manipulator robots and robots that can move (mobile robots). Manipulator robots are characterized by having arms (arm robots) and are widely used for industrial robots. While mobile robots are robots that can move to move even though the robot will also be installed manipulators. Robots that can move (mobile robots) can be grouped again into three namely land robot (ground robot), water robot (underwater robot), and flying robot (aerial robot) [1].

Underwater robot is a robot that can maneuver under water. This robot is usually controlled using a cable or also called (ROV) but in its implementation if using a cable, the robot's movement will be more limited by the length of the cable. Furthermore, in Cecep Ahmad Fauzi's research entitled "Underwater Robot Building Design using ROV-Based Ballast System (Remotely Operated Vehicle) with 433Mhz Frequency" a study was conducted using retome as a robot control using 433MHZ frequency. From this study, it was concluded that when the robot is in the water but the surface of the water is above the ground level the robot can be controlled normally. However, when the robot is controlled in water whose water position is below ground level, the robot will easily lose its range signal [2]. From the following problems it is necessary to make an automatic system in order to maximize the performance of the underwater robot. This robot is designed with the fuzzy logic control method by using an ultrasonic water resist sensor as a proximity sensor and a dc motor as a propeller.

II. Modeling Speed for Motor Propeller Using Fuzzy Logic

In this case consists of 3 input variables and 4 output variables. For variable input, the front sensor, rear sensor, and bottom sensor are used. As for the output, variable speed sensor right, left sensor speed, bottom right sensor speed, and bottom left sensor speed are used [10,11].

A. Fuzzyfication

The data used in this study are data from the front sensor, rear sensor, bottom sensor, right motor speed, left motor speed, right bottom motor speed and bottom left motor speed.

1. Front Sensor

The front censor variable is formed into five sets namely Sdek, Dek, Tengah, Jau and SaJau. For this set the trapezoidal form is used to show the degree of membership. The degree of membership of the front sensor can be seen in Figure 1.

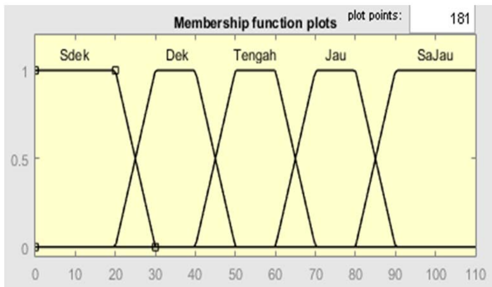

Fig. 1. Membership function front sensor

The membership function equation for the front sensor variable, expressed by equation (1), equation (2), equation (3), equation (4), and equation (5).

$$\mu_{Sdek}[x] = \left\{ \begin{array}{c} 1, x \leq 20 \\ \dfrac{30-x}{10}, 20 \leq x \leq 30 \\ 0,\ x \geq 30 \end{array} \right\} \quad (1)$$

$$\mu_{Dek}\,[x] = \left\{ \begin{array}{c} \dfrac{20-x}{-10},\ 20 \leq x \leq 30 \\ 1,\ 30 \leq x \leq 40 \\ \dfrac{50-x}{10},\ 40 \leq x \leq 50 \\ 0,\ 20 \geq x \geq 50 \end{array} \right\} \quad (2)$$

$$\mu_{Tengah}[x] = \begin{cases} \frac{40-x}{-10}, & 40 \le x \le 50 \\ 1, & 50 \le x \le 60 \\ \frac{70-x}{10}, & 60 \le x \le 70 \\ 0, & 40 \ge x \ge 70 \end{cases} \quad (3)$$

$$\mu_{Jau}[x] = \begin{cases} \frac{60-x}{-10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 80 \\ \frac{90-x}{10}, & 80 \le x \le 90 \\ 0, & 60 \ge x \ge 90 \end{cases} \quad (4)$$

$$\mu_{saJau}[x] = \begin{cases} \frac{80-x}{-10}, & 80 \le x \le 90 \\ 1, & x \ge 90 \\ 0, & x \le 80 \end{cases} \quad (5)$$

Rear Sensor. The rear sensor variable is formed into five sets namely SaDeB, DeBe, TengBe, JaBe and SajaBe. For this set the trapezoidal form is used to show the degree of membership. The degree of membership of the rear sensor can be seen in Figure 2.

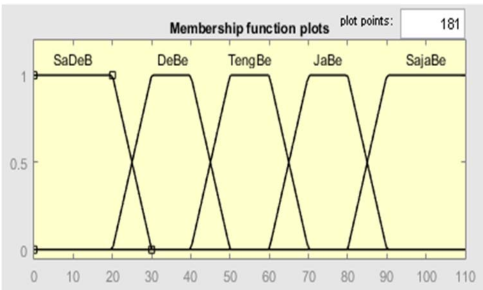

Fig. 2. Rear sensor membership function

The membership function equation for the rear sensor variable, expressed by equation (6), equation (7), equation (8), equation (9), and equation (10).

$$\mu_{SaDeB}[x] = \begin{cases} 1, x \le 20 \\ \frac{30-x}{10}, 20 \le x \le 30 \\ 0, \ x \ge 30 \end{cases} \quad (6)$$

$$\mu_{DeBe}[x] = \begin{cases} \frac{20-x}{-10}, & 20 \le x \le 30 \\ 1, & 30 \le x \le 40 \\ \frac{50-x}{10}, & 40 \le x \le 50 \\ 0, & 20 \ge x \ge 50 \end{cases} \quad (7)$$

$$\mu_{TengBe}[x] = \begin{cases} \frac{40-x}{-10}, & 40 \le x \le 50 \\ 1, & 50 \le x \le 60 \\ \frac{70-x}{10}, & 60 \le x \le 70 \\ 0, & 40 \ge x \ge 70 \end{cases} \quad (8)$$

$$\mu_{JaBe}[x] = \begin{cases} \frac{60-x}{-10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 80 \\ \frac{90-x}{10}, & 80 \le x \le 90 \\ 0, & 60 \ge x \ge 90 \end{cases} \quad (9)$$

$$\mu_{saJaBe}[x] = \begin{cases} \frac{80-x}{-10}, & 80 \le x \le 90 \\ 1, & x \ge 90 \\ 0, & x \le 80 \end{cases} \quad (10)$$

2. Bottom Sensor.

The lower sensor variable is formed into five sets namely SDa, Da, Middle, High and High. For this set the trapezoidal form is used to show the degree of membership. The degree of membership of the lower sensor can be seen in Figure 3.

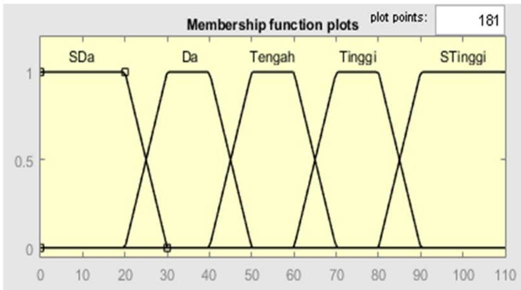

Fig. 3. Membership function of the sensor below

The membership function equation for the rear sensor variable, expressed by equation (11), equation (12), equation (13), equation (14), and equation (15).

$$\mu_{SDa}[x] = \begin{cases} 1, x \le 20 \\ \frac{30-x}{10}, 20 \le x \le 30 \\ 0, \ x \ge 30 \end{cases} \quad (11)$$

$$\mu_{Da}[x] = \begin{cases} \frac{20-x}{-10}, & 20 \le x \le 30 \\ 1, & 30 \le x \le 40 \\ \frac{50-x}{10}, & 40 \le x \le 50 \\ 0, & 20 \ge x \ge 50 \end{cases} \quad (12)$$

$$\mu_{Tengah}[x] = \begin{cases} \frac{40-x}{-10}, & 40 \le x \le 50 \\ 1, & 50 \le x \le 60 \\ \frac{70-x}{10}, & 60 \le x \le 70 \\ 0, & 40 \ge x \ge 70 \end{cases} \quad (13)$$

$$\mu_{Tinggi}[x] = \begin{cases} \frac{60-x}{-10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 80 \\ \frac{90-x}{10}, & 80 \le x \le 90 \\ 0, & 60 \ge x \ge 90 \end{cases} \quad (14)$$

$$\mu_{STinggi}[x] = \begin{cases} \frac{80-x}{-10}, & 80 \le x \le 90 \\ 1, & x \ge 90 \\ 0, & x \le 80 \end{cases} \quad (15)$$

3. Right motor.

The right motor variable is formed into five sets namely SaLamKa, LamKa, NormalKa, CepKa and SaCepKai. For this set the trapezoidal form is used to show the degree of membership. The degree of membership of the right motor can be seen in Figure 4.

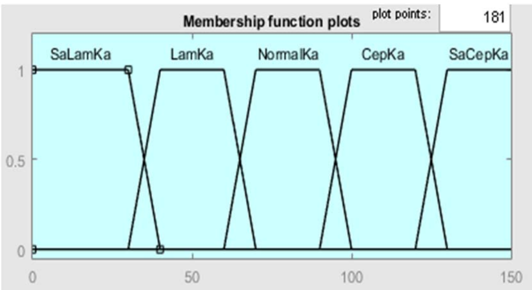

Fig. 4. Right motor membership function

The membership function equation for the right motor variable, expressed by equation (16), equation (17), equation (18), equation (19), and equation (20).

$$\mu_{SaLamKa}[x] = \left\{\begin{array}{c} 1, x \leq 30 \\ \frac{40-x}{10}, 30 \leq x \leq 40 \\ 0,\ x \geq 40 \end{array}\right\} \quad (16)$$

$$\mu_{NormalKa}[x] = \left\{\begin{array}{c} \frac{60-x}{-10}, 60 \leq x \leq 70 \\ 1,\ 70 \leq x \leq 90 \\ \frac{100-x}{10},\ 90 \leq x \leq 100 \\ 0,\ 60 \geq x \geq 100 \end{array}\right\} \quad (17)$$

$$\mu_{NormalKa}[x] = \left\{\begin{array}{c} \frac{60-x}{-10}, 60 \leq x \leq 70 \\ 1,\ 70 \leq x \leq 90 \\ \frac{100-x}{10},\ 90 \leq x \leq 100 \\ 0,\ 60 \geq x \geq 100 \end{array}\right\} \quad (18)$$

$$\mu_{CepKa}[x] = \left\{\begin{array}{c} \frac{90-x}{-10},\ 90 \leq x \leq 100 \\ 1,\ 100 \leq x \leq 120 \\ \frac{120-x}{10},\ 120 \leq x \leq 130 \\ 0,\ 60 \geq x \geq 90 \end{array}\right\} \quad (19)$$

$$\mu_{SaCepKa}[x] = \left\{\begin{array}{c} \frac{130-x}{-10},\ 120 \leq x \leq 130 \\ 1,\ x \geq 130 \\ 0,\ x \leq 120 \end{array}\right\} \quad (20)$$

4. Left Motorcycle.

The left motor variable is formed into five sets namely SaLamKi, LamKi, TengKi, CepKi and SaCepKi. For this set the trapezoidal form is used to show the degree of membership. The degree of membership of the left motor can be seen in Figure 5.

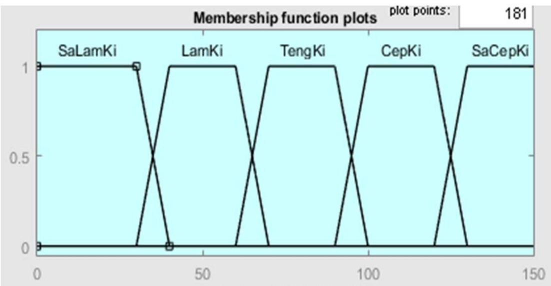

Fig. 5. Left motor membership function

The membership function equation for the left motor variable, expressed by equation (21), equation (22), equation (23), equation (24), and equation (25).

$$\mu_{SaLamKi}[x] = \left\{\begin{array}{c} 1, x \leq 30 \\ \frac{40-x}{10}, 30 \leq x \leq 40 \\ 0,\ x \geq 40 \end{array}\right\} \quad (21)$$

$$\mu_{LamKi}[x] = \left\{\begin{array}{c} \frac{30-x}{-10},\ 30 \leq x \leq 40 \\ 1,\ 40 \leq x \leq 60 \\ \frac{70-x}{10},\ 60 \leq x \leq 70 \\ 0,\ 30 \geq x \geq 70 \end{array}\right\} \quad (22)$$

$$\mu_{TengKi}[x] = \left\{\begin{array}{c} \frac{60-x}{-10},\ 60 \leq x \leq 70 \\ 1,\ 70 \leq x \leq 90 \\ \frac{100-x}{10},\ 90 \leq x \leq 100 \\ 0,\ 60 \geq x \geq 100 \end{array}\right\} \quad (23)$$

$$\mu_{CepKi}[x] = \left\{\begin{array}{c} \frac{90-x}{-10},\ 90 \leq x \leq 100 \\ 1,\ 100 \leq x \leq 120 \\ \frac{120-x}{10},\ 120 \leq x \leq 130 \\ 0,\ 60 \geq x \geq 90 \end{array}\right\} \quad (24)$$

$$\mu_{SaCepKi}[x] = \left\{\begin{array}{c} \frac{130-x}{-10},\ 120 \leq x \leq 130 \\ 1,\ x \geq 130 \\ 0,\ x \leq 120 \end{array}\right\} \quad (25)$$

5. Bottom Right

Motor. The Bottom right motor variable is formed into five sets namely SaLamBaw, LamBaw, NorBaw, CepBaw and SaCepBaw. For this set the trapezoidal form is used to show the degree of membership. The degree of membership of the Bottom right motor can be seen in Figure 6.

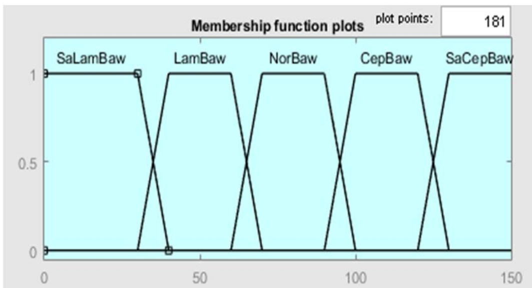

Fig. 6. Membership function of the motor Bottom the right

The membership function equation for the bottom right motor variable is expressed by equation (26), equation (27), equation (28), equation (29), and equation (30).

$$\mu_{SaLamBaw}[x] = \left\{\begin{array}{c} 1, x \leq 30 \\ \frac{40-x}{10}, 30 \leq x \leq 40 \\ 0,\ x \geq 40 \end{array}\right\} \quad (26)$$

$$\mu_{LamBaw}[x] = \begin{cases} \frac{30-x}{-10}, & 30 \le x \le 40 \\ 1, & 40 \le x \le 60 \\ \frac{70-x}{10}, & 60 \le x \le 70 \\ 0, & 30 \ge x \ge 70 \end{cases} \quad (27)$$

$$\mu_{NorBaw}[x] = \begin{cases} \frac{60-x}{-10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 90 \\ \frac{100-x}{10}, & 90 \le x \le 100 \\ 0, & 60 \ge x \ge 100 \end{cases} \quad (28)$$

$$\mu_{CepBaw}[x] = \begin{cases} \frac{90-x}{-10}, & 90 \le x \le 100 \\ 1, & 100 \le x \le 120 \\ \frac{120-x}{10}, & 120 \le x \le 130 \\ 0, & 60 \ge x \ge 90 \end{cases} \quad (29)$$

$$\mu_{SaCepBaw}[x] = \begin{cases} \frac{130-x}{-10}, & 120 \le x \le 130 \\ 1, & x \ge 130 \\ 0, & x \le 120 \end{cases} \quad (30)$$

6. Motor Bottom Left.

The left lower motor variable is formed into five sets, namely SaLamBaw1, LamBaw1, TengBaw1, JauBaw1 and SaJauBaw1. For this set the trapezoidal form is used to show the degree of membership. Degree of membership of the motor under the left can be seen in Figure 7.

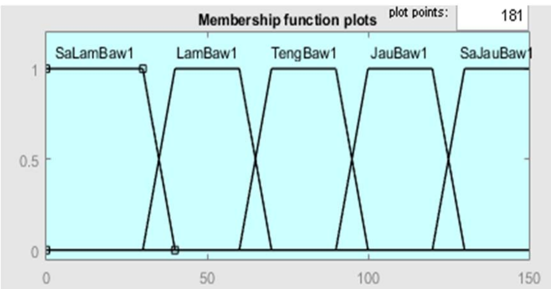

Fig. 7. Membership function of the motor under the left

The membership function equation for the lower left motor variable, is expressed by equation (31), equation (32), equation (33), equation (34), and equation (35).

$$\mu_{SaLamKa}[x] = \begin{cases} 1, & x \le 30 \\ \frac{40-x}{10}, & 30 \le x \le 40 \\ 0, & x \ge 40 \end{cases} \quad (31)$$

$$\mu_{LamKa}[x] = \begin{cases} \frac{30-x}{-10}, & 30 \le x \le 40 \\ 1, & 40 \le x \le 60 \\ \frac{70-x}{10}, & 60 \le x \le 70 \\ 0, & 30 \ge x \ge 70 \end{cases} \quad (32)$$

$$\mu_{NormalKa}[x] = \begin{cases} \frac{60-x}{-10}, & 60 \le x \le 70 \\ 1, & 70 \le x \le 90 \\ \frac{100-x}{10}, & 90 \le x \le 100 \\ 0, & 60 \ge x \ge 100 \end{cases} \quad (33)$$

$$\mu_{CepKa}[x] = \begin{cases} \frac{90-x}{-10}, & 90 \le x \le 100 \\ 1, & 100 \le x \le 120 \\ \frac{120-x}{10}, & 120 \le x \le 130 \\ 0, & 60 \ge x \ge 90 \end{cases} \quad (34)$$

$$\mu_{SaCepKa}[x] = \begin{cases} \frac{130-x}{-10}, & 120 \le x \le 130 \\ 1, & x \ge 130 \\ 0, & x \le 120 \end{cases} \quad (35)$$

B. *Rule Base*

After making the membership function, the rule is then made. This rule aims to make the system has an approach like human thought. The fuzzy rule base can be seen in Figure 8.

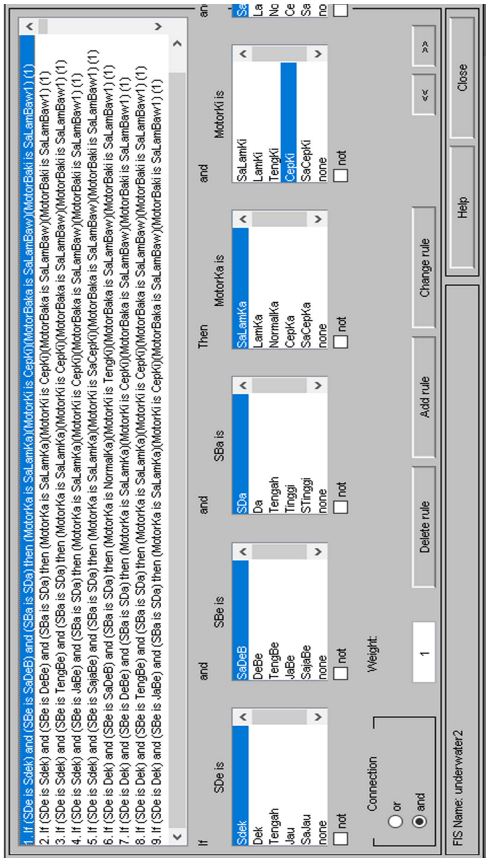

Fig. 8. Fuzzy rule base

C. *Simulation*

After the fuzzy rule base is made, the simulation is then made. In this study a simulation was carried out with a case study. If it is estimated that the measurement results are 30 cm front sensor, 30 cm rear sensor and 60 cm bottom sensor. in the fuzzy application click view then click rule. Then enter all values into the application that has been made. Figure 9 is the result of the simulation.

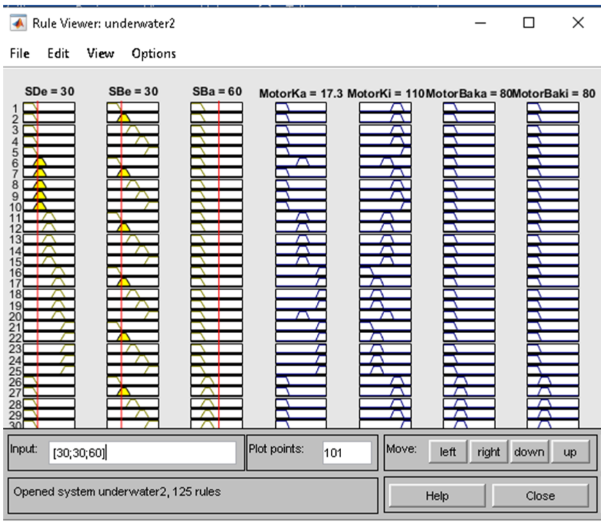

Fig. 9. Simulation results

From the simulation results obtained the value of the right motor 17.3, 110 left motor, right motor down 80 and left motor below 80. With this value means the maneuvered robot turns right with the robot in the middle.

III. CONCLUSION

In this study the simulation was conducted to get a model of each membership function and get the value of the output. The sensor used is an ultrasonic water resist sensor and the motor used is a brushless motor. The parameters used are for the input is the front sensor distance, rear sensor distance and bottom sensor distance while the output parameters used are the right motor speed, left motor speed, right bottom motor speed and bottom left motor speed. The number of rules used is 125 rules. In this research, a case study with a distance sensor value of 30 cm, 30cm and 60 cm was completed. Then using the simulation, the output value as follows: the PWM value for the right motor is 17.3 The PWM value for the left motor 110, while for the lower motor PWM value is 80. from the following values it can be concluded that the robot in the maneuver turns right with the position at a medium height.

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