

Design of Automatic Goods Carrier Robot System Based on Line Sensor and Fuzzy Logic Control Mamdani

Abdul Mutolib

Department of Electrical Engineering
 UIN Sunan Gunung Djati Bandung
 Bandung, Indonesia
 abdulmutoli6@gmail.com

Rina Mardiaty

Department of Electrical Engineering
 UIN Sunan Gunung Djati Bandung
 Bandung, Indonesia
 r_mardiaty@uinsgd.ac.id

Edi Mulyana

Department of Electrical Engineering
 UIN Sunan Gunung Djati Bandung
 Bandung, Indonesia
 edim@uinsgd.ac.id

Aan Eko Setiawan

Department of Electrical Engineering
 Telkom University
 Bandung, Indonesia
 aaneke37@gmail.com

Ahmad Fathonih

Faculty of Sharia and Law
 UIN Sunan Gunung Djati Bandung
 Bandung, Indonesia
 ahmadfathonih@gmail.com

Abstract— The development of control system, especially in the field of robotics was improving more progress in efforts to complete human work. One of them is an automatic goods carrier robot system that used in industry. At present, the majority of automatic goods carrier robotsystem still usea human control. In this paper, a design of automatic system for robotic goods carriers will be presented. One of the challenges in the development of a goods transport robot system is how the robot can run stably when carrying goods. This study presents a design of goods carrier robot system based on line sensors and fuzzy logic control. The input that used in this fuzzy logic system are the light and weight which obtained from the BFD-1000 sensor and barometric sensor. Meanwhile, the output of fuzzy system are the speed of right motor and the left motor, in order to stabilize the robot movement when the load was added. The simulation was is done to get the membership function value. Based on the simulation results using a case study, it is known that the load carried is 210 grams and the living sensor is sensor -2.5. Then the simulation results obtained speed of right motor PWM value of 21,9 and speed of left motor PWM value of 64,4. So that the robot runs in a straight state.

Keywords— Goods Carrier Robot, Fuzzy Logic Control Mamdani, Weight, Speed Introduction.

I. INTRODUCTION

Technology in the modern era is very helpful for human work, especially technology in the field of robotics [1]. There are several types of robots that are used by humans in doing work, one of which is a goods carrier robot, namely Automated Guided Vehicle (AGV). These robot has a wheeled actuator so that it can move from one place to another. AGV can be used to improve the efficiency and effectiveness of jobs because they can do fast without using human labor. In addition, it can improve employee safety where risks such as falling on goods. This is the reason that makes robot technology so aggressively developed. Until now, there are many industries that use robots as a tool to transport goods to move goods and to reduce human labor [2].

Many researchers used many methods for modeling the automatic movement for AGV, such as using mathematical approached [3][4], signal control [5], fuzzy logic [6][7][8][9] etc. The path followed can be a magnetic sensor or a special colored line. In addition, there are also features that are added such as speed control of the robot and the ability of the robot

to know the path to the destination. In the operation of the robot only follows the line without any speed control, even though the robot is still moving broken - broken, therefore the goods transported by the robot will fall. Then the weight sensor is added to the robot and collaborated with the line sensor then an approach using the fuzzy logic control method will make the movement of the robot smooth and the goods transported by the robot will not fall.

In this paper, a design of automation system for robotic goods carriers will be presented. One of the challenges in the development of a goods transport robot system is how the robot can run stably when carrying goods. This study presents a design of goods carrier robot system based on line sensors and fuzzy logic control. The input that used in this fuzzy logic system are the light and weight which obtained from the BFD-1000 sensor and barometric sensor. Meanwhile, the output of fuzzy system are the speed of right motor and the left motor, in order to stabilized the robot movement when the load was added.

II. MODELING SPEED OF AVG USING FUZZY LOGIC

The problem raised is how to implement the fuzzy logic control logic for the automated goods transport robot system based on line sensors and fuzzy logic control. There are two types of variables used in this study, namely the input and variables output. Where the variable input is light and weight while the variable output is the right motor speed and the left motor speed is shown in Figure 1.

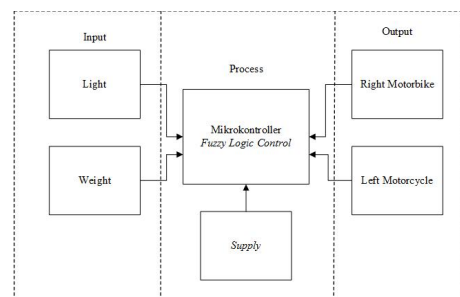


Fig. 1. The block diagram of control system.

TABLE I. LINGUISTIC TERM OF THE INPUT

Light	Linguistic Term	Weight	Linguistic Term
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(-3)-(-1)	OnceLeft	0-200	VeryLight
(-1)-0	Left	200-400	Light
0-1	TheMiddle	400-600	IsOn
1-2	Right	600-800	Weight
2-3	OnceRight	800-1000	VeryHeavy

TABLE II. LINGUISTIC TERM OF THE OUTPUT

Right Motor	Linguistic Term	Left Motor	Linguistic Term
0-426	VerySlow	0-426	VerySlow
26-81	Slow	26-81	Slow
81-132	Normal	81-132	Normal
132-183	Fast	132-183	Fast
183-255	VeryFast	183-255	VeryFast

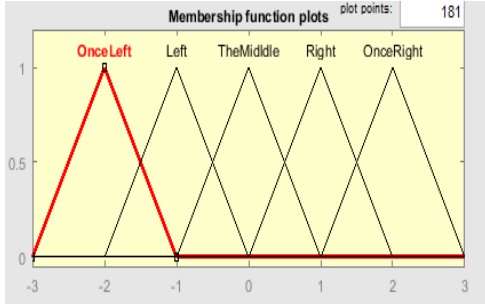


Fig. 2. Membership function of input light

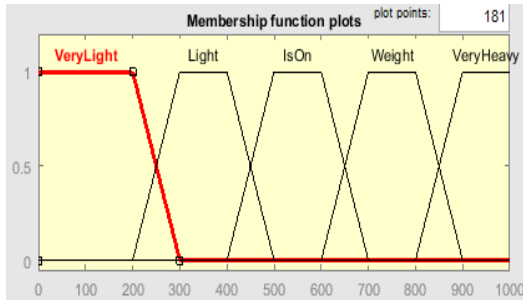


Fig. 3. Membership function of input weight

TABLE III. EQUATION TERM OF MF INPUT

μ of Light	μ of Weight
$\mu_{OnceL}[x] = \begin{cases} \frac{-3-x}{-1}, & -3 \leq x \leq -2 \\ 1, & x = -2 \\ \frac{-1-x}{1}, & -2 \leq x \leq -1 \\ 0, & -3 \geq x \geq 1 \end{cases}$	$\mu_{VeryL}[x] = \begin{cases} 1, & x \leq 200 \\ \frac{300-x}{100}, & 200 \leq x \leq 300 \\ 0, & x \geq 300 \end{cases}$
$\mu_{Left}[x] = \begin{cases} \frac{-2-x}{-1}, & -2 \leq x \leq -1 \\ 1, & x = -1 \\ \frac{-0-x}{1}, & -1 \leq x \leq 0 \\ 0, & -2 \geq x \geq 0 \end{cases}$	$\mu_{Light}[x] = \begin{cases} \frac{200-x}{-100}, & 200 \leq x \leq 300 \\ \frac{1,300-x}{500-x}, & 300 \leq x \leq 400 \\ \frac{100}{100}, & 400 \leq x \leq 500 \\ 0, & 200 \geq x \geq 500 \end{cases}$
$\mu_{VeryM}[x] = \begin{cases} \frac{-1-x}{-1}, & -1 \leq x \leq 0 \\ 1, & x = 0 \\ \frac{-1-x}{1}, & 0 \leq x \leq 1 \\ 0, & -1 \geq x \geq 1 \end{cases}$	$\mu_{IsOn}[x] = \begin{cases} \frac{400-x}{-100}, & 400 \leq x \leq 500 \\ \frac{1,500-x}{700-x}, & 500 \leq x \leq 600 \\ \frac{100}{100}, & 600 \leq x \leq 700 \\ 0, & 400 \geq x \geq 700 \end{cases}$

$\mu_{Right}[x] = \begin{cases} \frac{0-x}{-1}, & 0 \leq x \leq 1 \\ 1, & x = 1 \\ \frac{2-x}{1}, & 1 \leq x \leq 2 \\ 0, & 0 \geq x \geq 2 \end{cases}$	$\mu_{Weight}[x] = \begin{cases} \frac{600-x}{-100}, & 600 \leq x \leq 700 \\ \frac{1,700-x}{900-x}, & 700 \leq x \leq 800 \\ \frac{100}{100}, & 800 \leq x \leq 900 \\ 0, & 600 \geq x \geq 900 \end{cases}$
$\mu_{OnceRight}[x] = \begin{cases} \frac{1-x}{-1}, & 1 \leq x \leq 2 \\ 1, & x = 2 \\ \frac{3-x}{1}, & 2 \leq x \leq 3 \\ 0, & 1 \geq x \geq 3 \end{cases}$	$\mu_{VeryH}[x] = \begin{cases} \frac{800-x}{-100}, & 800 \leq x \leq 900 \\ 1, & x \geq 900 \\ 0, & x \leq 800 \end{cases}$

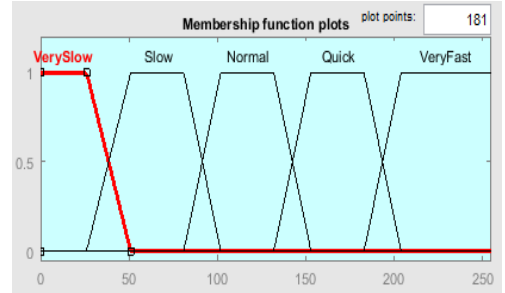


Fig. 4. Membership function output of right motor

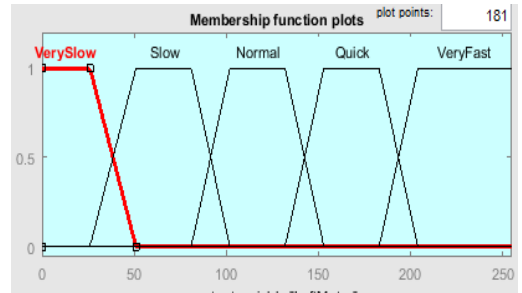


Fig. 5. Membership function output of left motor

TABLE IV. EQUATION TERM OF MF OUTPUT.

μ of Right Motor	μ of Left Motor
$\mu_{VeryS}[x] = \begin{cases} 1, & x \leq 26 \\ \frac{51-x}{25}, & 26 \leq x \leq 51 \\ 0, & x \geq 51 \end{cases}$	$\mu_{VeryL}[x] = \begin{cases} 1, & x \leq 26 \\ \frac{51-x}{25}, & 26 \leq x \leq 51 \\ 0, & x \geq 51 \end{cases}$
$\mu_{Slow}[x] = \begin{cases} \frac{26-x}{-25}, & 26 \leq x \leq 51 \\ \frac{1,51-x}{102-x}, & 51 \leq x \leq 81 \\ \frac{102-x}{21}, & 81 \leq x \leq 102 \\ 0, & 26 \geq x \geq 102 \end{cases}$	$\mu_{Slow}[x] = \begin{cases} \frac{26-x}{-25}, & 26 \leq x \leq 51 \\ \frac{1,51-x}{102-x}, & 51 \leq x \leq 81 \\ \frac{102-x}{21}, & 81 \leq x \leq 102 \\ 0, & 26 \geq x \geq 102 \end{cases}$
$\mu_{Nor}[x] = \begin{cases} \frac{81-x}{-21}, & 81 \leq x \leq 102 \\ \frac{1,102-x}{152-x}, & 102 \leq x \leq 132 \\ \frac{152-x}{21}, & 132 \leq x \leq 153 \\ 0, & 81 \geq x \geq 153 \end{cases}$	$\mu_{Nor}[x] = \begin{cases} \frac{81-x}{-21}, & 81 \leq x \leq 102 \\ \frac{1,102-x}{152-x}, & 102 \leq x \leq 132 \\ \frac{152-x}{21}, & 132 \leq x \leq 153 \\ 0, & 81 \geq x \geq 153 \end{cases}$
$\mu_{Fast}[x] = \begin{cases} \frac{132-x}{-21}, & 132 \leq x \leq 153 \\ \frac{1,153-x}{204-x}, & 153 \leq x \leq 183 \\ \frac{204-x}{21}, & 183 \leq x \leq 204 \\ 0, & 132 \geq x \geq 204 \end{cases}$	$\mu_{Fast}[x] = \begin{cases} \frac{132-x}{-21}, & 132 \leq x \leq 153 \\ \frac{1,153-x}{204-x}, & 153 \leq x \leq 183 \\ \frac{204-x}{21}, & 183 \leq x \leq 204 \\ 0, & 132 \geq x \geq 204 \end{cases}$

$$\mu_{\text{VeryF}}[x] = \begin{cases} \frac{183-x}{-21}, & 183 \leq x \leq 204 \\ 1, & x \geq 204 \\ 0, & x \geq 183 \end{cases} \quad \mu_{\text{VeryF}}[x] = \begin{cases} \frac{183-x}{-21}, & 183 \leq x \leq 204 \\ 1, & x \geq 204 \\ 0, & x \geq 183 \end{cases}$$

TABLE V. RULE FUZZY LOGIC.

Rule(s)	Input		Output	
	Light	Weight	Right Motor	Left Motor
R1	OnceLeft	VeryLight	VerySlow	Slow
R2	OnceLeft	Light	VerySlow	Slow
R3	OnceLeft	IsOn	Slow	Slow
R4	OnceLeft	Weight	Slow	Normal
R5	OnceLeft	VeryHeavy	Slow	Normal
R6	Left	VeryLight	Slow	Slow
R7	Left	Light	Slow	Slow
R8	Left	IsOn	Slow	Normal
R9	Left	Weight	Normal	Quick
R10	Left	VeryHeavy	Normal	Quick
R11	TheMiddle	VeryLight	VeryFast	VeryFast
R12	TheMiddle	Light	Quick	Quick
R13	TheMiddle	IsOn	Normal	Normal
R14	TheMiddle	Weight	Slow	Slow
R15	TheMiddle	VeryHeavy	VerySlow	VerySlow
R16	Right	VeryLight	Slow	Slow
R17	Right	Light	Slow	Slow
R18	Right	IsOn	Normal	Normal
R19	Right	Weight	Quick	Normal
R20	Right	VeryHeavy	Normal	Quick
R21	OnceRight	VeryLight	Slow	VerySlow
R22	OnceRight	Light	Slow	VerySlow
R23	OnceRight	IsOn	Slow	Slow
R24	OnceRight	Weight	Normal	Slow
R25	OnceRight	VeryHeavy	Normal	Slow

III. IMPLEMENTATION

At the top of the Robot implementation namely implementation The L293D motor driver shield is connected to the right DC motor and motor Left DC. The L293D motor driver circuit can be used for control DC motor with maximum current if there is additional power from the battery. This testing process is carried out to ensure the system is designed can go as planned. Figure 6. Shows the top series of robots.

While the lower side is used for designing the robot to install the L239D motor driver sensor component which is connected to the Arduino MEGA microcontroller as a load detector, namely a load cell sensor and a line detector, namely the BFD-1000 sensor. Figure 7. Shows the robot seen from below.



Fig. 6. The robot looks from above.

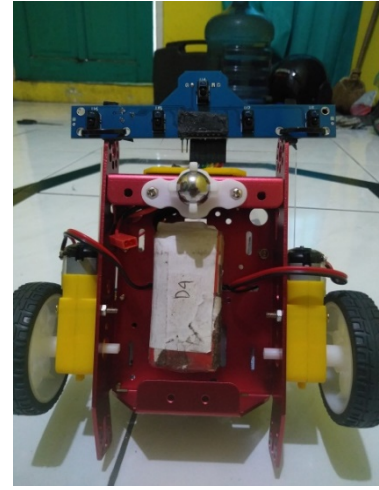


Fig. 7. The robot is visible from below.

IV. TESTING AND ANALYSIS

This testing step is aims to check whether the control model is fuzzy that has been implemented in the robot is appropriate or not yet. The results obtained from the robot control system were built, compared with manual calculations and calculation results using simulation software.

Step 1. Determine the Fuzzy Set

Light Sensor

Based on the above case, the light sensor is -2.5 . According to Figure 2 (b), the light sensor is in very left condition. So, we will calculate the truth value (μ) MF very left for the -2.5 light sensor. The calculation details will be presented as follows.

$$\mu_{\text{OnceLeft}}[2,5] \frac{-3-(-2,5)}{-1} = 0.5 \quad (1)$$

Weight

Meanwhile, the 210 gram weight is in a very light and light position with a degree of membership in accordance with the following function:

$$\mu_{\text{VeryLight}}[210] \frac{300-210}{100} = 0.9 \quad (2)$$

$$\mu_{\text{Light}}[210] \frac{200-210}{-100} = 0.1 \quad (3)$$

Step 2. The function implication

In this sub section, we substitute the value that already obtained in Equation (21) (22) (23) to the all the rule in Table 5. We used the MIN function which means we take the minimum membership degree from the input variable as its output. From the 25 rules that presented in Table 5, only four rules are used, namely [R1] and [R2]. The detail calculation will be explained as follows.

[R1] : IF light sensor is Once Left **And** weight very light **Then** Right motor is very slow and left motor slow.

$$\alpha_{R1} = \mu_{\text{OnceLeft}} \cap \mu_{\text{VeryLight}}$$

$$\alpha_{R1} = \min(\mu_{\text{OnceLeft}}, \mu_{\text{VeryLight}})$$

$$\alpha_{R1} = \min(0.5, 0.9) = 0.5 \quad (4)$$

[R2] : IF light sensor is Once Left **And** weight light **Then** Right motor is very slow and left motor slow.

$$\begin{aligned} \alpha_{R2} &= \mu_{OnceLeft} \cap \mu_{light} \\ \alpha_{R2} &= \min(\mu_{OnceLeft}, \mu_{Light}) \\ \alpha_{R2} &= \min(0.5, 0.1) = 0.1 \end{aligned} \quad (5)$$

Step 3. Defuzzification

Defuzzification is interpreting the membership degrees of the fuzzy sets into a specific decision or real value. A common and useful defuzzification technique is *center of gravity*. In the most common technique, all of these trapezoids form are then superimposed one upon another, forming a single geometric shape. Then, the centroid of this shape, called the *fuzzy centroid*, is calculated. The x coordinate of the centroid is the defuzzified value, called Z^* . In this example the output can be seen in the Rule view calculation of the matlab toolbox using the matlab software in Figure 8.

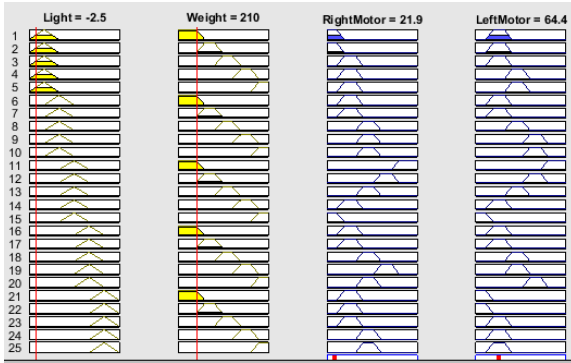


Fig. 8. Rule view (optimization / defuzzification results).

Determine the PWM speed of the right motor

$$Z^* = \frac{\int_0^{38.5} 0.5 z dz + \int_{38.5}^{51} \left(\frac{51}{25} z - \frac{1}{25} z^2 dz \right) z dz}{\int_0^{38.5} 0.5 z dz + \int_{38.5}^{51} \left(\frac{51}{25} z - \frac{1}{25} z^2 dz \right) dz}$$

$$Z^* = \frac{503,8955}{22.375} = 522.520 \quad (6)$$

Determine the PWM speed of the light motor

$$\begin{aligned} Z^* &= \frac{\int_{26}^{38.5} \left(-\frac{26}{25} z + \frac{1}{25} z^2 dz \right) + \int_{38.5}^{91.5} (0.5 z dz) + \int_{91.5}^{102} \left(\frac{102}{21} z^2 - \frac{1}{21} z^2 dz \right) z dz}{\int_{26}^{38.5} \left(-\frac{26}{25} z + \frac{1}{25} z^2 dz \right) + \int_{38.5}^{91.5} (0.5 z dz) + \int_{91.5}^{102} \left(\frac{102}{21} z^2 - \frac{1}{21} z^2 dz \right) dz} \\ Z^* &= \frac{2079,09466}{32,25} = 64.4680 \end{aligned} \quad (7)$$

V. CONCLUSION

Based on the result in the previous section, we can conclude that fuzzy logic to control the speed of robot are well implemented. The result shown that the fuzzy logic in the robot produce the speed of robot with small error compared to manual calculation and simulation.

REFERENCES

- [1] D. Kurnia, R. Mardiyati, M. R. Effendi, and A. E. Setiawan, "Rancang Bangun Robot Pemadam Api Menggunakan Kontrol Bluetooth dan Virtual Reality," *TELKA - Telekomun. Elektron. Komputasi dan Kontrol*, vol. 5, no. 2, pp. 139–146, 2019, doi: 10.15575/telka.v5n2.139-146.
- [2] Ariyanti, "Perancangan model automatic guide vehicle (agv) berbasis robot line follower untuk penerapan otomatisasi penanganan material pada industri manufaktur," *eProceedings Eng.*, vol. 10, pp. 1–10, 2016.
- [3] R. Carona, A. P. Aguiar, and J. Gaspar, "Tracking, Path Following and Point Stabilization," *Jetc*, no. November, pp. 180–185, 2008.
- [4] R. Mardiyati, B. R. Trilaksono, Y. S. Gondokaryono, and S. S. Sulaksono, "Motorcycle's trajectory tracking model based on polynomial least-squares approximation," *Adv. Sci. Lett.*, vol. 23, no. 5, pp. 4537–4541, 2017, doi: 10.1166/asl.2017.8974.
- [5] V. Jaiganesh, J. Dhileep Kumar, and J. Girijadevi, "Automated guided vehicle with robotic logistics system," *Procedia Eng.*, vol. 97, pp. 2011–2021, 2014, doi: 10.1016/j.proeng.2014.12.444.
- [6] H. Omrane, M. S. Masmoudi, and M. Masmoudi, "Fuzzy Logic Based Control for Autonomous Mobile Robot Navigation," *Comput. Intell. Neurosci.*, vol. 2016, 2016, doi: 10.1155/2016/9548482.
- [7] L. Cherroun, R. Mechougou, and M. Boumechraz, "Path Following Behavior for an Autonomous Mobile Robot Using Fuzzy Logic and Neural Networks," pp. 63–70, 2011.
- [8] A. M. Cardenas, J. G. Rázuri, D. Sundgren, and R. Rahmani, "Autonomous motion of mobile robot using fuzzy-neural networks," *Proc. - 2013 12th Mex. Int. Conf. Artif. Intell. MICAI 2013*, pp. 80–84, 2013, doi: 10.1109/MICAI.2013.15.
- [9] O. Obe and L. Dumitrache, "Fuzzy control of autonomous mobile robot," *UPB Sci. Bull. Ser. C Electr. Eng.*, vol. 72, no. 3, pp. 173–186, 2010.