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The Design of Artificial Intelligence Robot Based on Fuzzy Logic Controller Algorithm

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Abstract. Artificial Intelligence Robot is a wheeled robot driven by a DC motor that moves along the wall using an ultrasonic sensor as a detector of obstacles. This study uses ultrasonic sensors HC-SR04 to measure the distance between the robot with the wall based ultrasonic wave. This robot uses Fuzzy Logic Controller to adjust the speed of DC motor. When the ultrasonic sensor detects a certain distance, sensor data is processed on ATmega8 then the data goes to ATmega16. From ATmega16, sensor data is calculated based on Fuzzy rules to drive DC motor speed. The program used to adjust the speed of a DC motor is CVAVR program (Code Vision AVR). The readable distance of ultrasonic sensor is 3 cm to 250 cm with response time 0.5 s. Testing of robots on walls with a setpoint value of 9 cm to 10 cm produce an average error value of -12% on the wall of L, -8% on T walls, -8% on U wall, and -1% in square wall.

1. Introduction

In recent years technological developments in the field of robotics have become a serious concern. This is primarily in the role of robots that can replace human jobs, especially in hazardous environments. Wheeled robots are mechanical devices capable of moving in environments with a certain degree of autonomy. Autonomous navigation is associated with the availability of external sensors that get information from the environment through visual images or distances or measurement approaches. The most commonly used sensors are proximity sensors (ultrasonic, laser, infrared, etc.) that can detect obstacles and measure the distance to the wall closest to the robot. When autonomous robot navigation moves forward in a room environment (industrial or civil building), the robot must have the ability to move through the corridor, to follow the wall, to change the angle and enter the open space area

This study uses ultrasonic sensors HC-SR04 to measure the distance between the robot with ultrasonic wave-based wall. The advantage of ultrasonic sensors is to calculate the distance to the object by calculating the time interval between the trigger signal and the echo signal. HC-SR04 has the ability to transmit and receive ultrasonic signals with an angle of reach of 15 degrees to the right and left of the direction with maximum distance to detect objects of four meters but has the possibility of error or unreadability. Maximum of sensor sensing rate is 20Hz. Fuzzy logic is an appropriate way to map an input space in an output space and has a continuous value. Excess fuzzy logic exists on the ability of language reasoning. Thus, in designing it does not require complex mathematical equations of objects to be controlled. The reason to use fuzzy logic as a controller is the fuzzy logic concept is easy to understand. The mathematical concept underlying fuzzy logic reasoning is very simple and easy to understand. In addition, fuzzy logic has a tolerance of improper data.

2. Theoritical Framework

2.1. Artificial Intelligence Robot
Artificial Intelligence Robot is an automatic robot which its motion follows the boundary walls of the track. One of the advantages is it does not need any guideline or a specific mark as the director for the robots. It works by reading and detecting a barrier or wall against the robot with the use of proximity sensor. When a change occurs, then the robot will move to then adjust the distance again. This process will be done repeatedly.

2.2. Ultrasonic Sensor HC-SR04
Ultrasonic sensor is a sensor that serves to change the physical quantity (sound) into electrical quantities and vice versa. The way the sensor works is based on the principle of the reflection of a sound wave so that it can be used to interpret the existence (distance) of an object with a certain frequency. It is referred to as an ultrasonic sensor because it uses ultrasonic waves (ultrasonic sound). HC-SR04 has 2 main components as the compiler is ultrasonic transmitter and ultrasonic receiver. The function of the ultrasonic transmitter is to emit ultrasonic waves with a frequency of 40 KHz then ultrasonic receiver captures the ultrasonic wave reflection results of an object

2.3. AVR ATmega 16 Microcontroller
AVR Microcontroller ATmega 16 has an 8-bit architecture, where all instructions are packed in 16-bit code and most instructions are executed in one clock cycle.

2.4. 12 V DC Motor
DC motor is an electric motor that requires a direct current voltage supply on the field coil to be converted into mechanical energy motion. The field coil on the dc motor is called the stator (the non-rotating part) and the anchor coil is called the rotor (the rotating part). Direct current motors, as the name implies, use indirect current or direct-unidirectional currents

2.5. DC L298 DC Motor Driver
IC H-Bridge DC L298 motor driver has two H-Bridge circuit in it, so it can be used to drive two DC motors. H-Bridge DC motor driver L298 can each deliver current up to 2A. However, in its use, H-Bridge DC L298 motor driver can be used in parallel, so the ability to deliver from H-Bridge DC motor driver L298 current to 4A

2.6. 16X2 LCD Display
LCD Display a liquid crystal or electronic device that can be used to display numbers or text. There are two main types of LCD screens that can display numerically (watches and calculators) and display alphanumeric text (coffee and mobile phones). In this numerical display the crystals are formed into bars, and in alphanumeric displays, the crystal is only set into a dot pattern. When the crystal is off, the crystal light looks the same as the background material, so the crystal cannot be seen. But when an electric current passes through a crystal, it changes shape and absorbs more light. This makes the crystals look darker than the sight of the human eye so that the point or bar shape can be seen from different backgrounds

2.7. Code Vision AVR
Code Vision AVR The use of microcontroller can work if it has filled a program, this program filling can be done using the compiler which is then downloaded into the microcontroller using downloader. Code Vision AVR has an advantage over other compilers, the existence of codewizard, this facility allows us to initialize the microcontroller we will use, codevision has provided configurations that can be set on each microcontroller chip that we will use, so we do not need to see the datasheet to simply configure the microcontroller.

2.8. Fuzzy Logic Controller
Fuzzy logic Controller calculates the output based on the number of weighted membership values in each set. The information flowing requires a fuzzy setting system. Before it becomes system output, the system requires three transformations for system input

a. Fuzzification

Fuzzification is the process of decomposing an input and / or output system into one or more fuzzy sets

b. Collection of Fuzzy Rules

After input and output are decomposed into fuzzy sets, we need a rule base that governs the behaviour of the system for each input combination. Each rule consists of one condition and one action. Conditions are interpreted from the input of fuzzy sets and actions are determined by the output of the fuzzy set

c. Defuzzification

Defuzzification is the change of a fuzzy quantity to a numerical value. The fuzzy process output can be either a logical unit of two or more fuzzy membership functions and defined in the output universe setDefuzzification is the change of a fuzzy quantity to a numerical value. The fuzzy process output can be either a logical unit of two or more fuzzy membership functions and defined in the output universe set.

2.9. ATmega 8 Microcontroller

ATMEGA 8 is a low-power 8-bit CMOS microcontroller based on enhanced RISC architecture. Most instructions are performed on one clock cycle, ATMEGA 8 has a throughput of close to 1 MPS per MHz making the design of the system to optimize power consumption versus process speed. The array of pins of the ATMEGA 8 microcontroller IC is shown in the figure below. This IC is composed of 28 pins that have certain functions

3. Research Method

3.1. Hardware Design

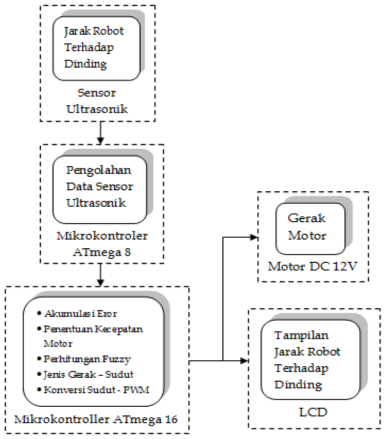

Figure 1. Artificial Intelligence Block diagram of Robotmotor DC which displayed on the LCD

Figure 1. is a block diagram of an Artificial Intelligence Robot system in which an ultrasonic sensor detects the robot's distance to the wall. Ultrasonic sensor data processing on ATmega microcontroller 8. Next microcontroller ATmega 16 duty to calculate fuzzy and determine speed of DC motor based on rule-rule on fuzzy. Sensor data and DC motor speed are displayed on the LCD

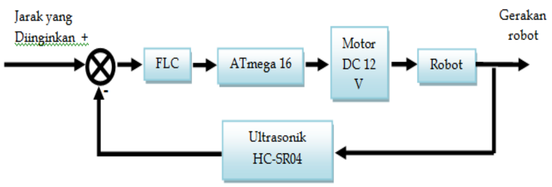

Figure 2. Artificial Intelligence Block diagram Robotmotor DC which displayed on the LCD

The 12 V DC motor is the actuator. Figure 2 shows the block diagram of a closed loop control system on Artificial Intelligence Robot. With the desired distance value is 9 cm to 10 cm. Sensor data received ATmega 8 then go into ATmega 16 which acts as a controller. Fuzzy logic is used to calculate the motor speed obtained from the calculation of the distance of the robot against the wall. Each motor has a different speed. If the robot moves less than the set point, meaning that the robot is in the near state of the wall then the right motor moves faster than the left motor. If the robot moves more than the set point, meaning that the robot is far from the wall then the right motor moves more slowly than the left motor. 12 V DC motor is the actuator and its plant is a robot with output value of DC motor speed.

Robot with output value of DC motor speed. robot with output value of DC motor speed: 1)If the distance of the sensor against the wall> 3 and ≤5 Then right motor rotation 50 PWM, left motor rotation 5 PWM. 2)If the distance of the sensor against the wall> 5 and ≤6 Then the motor rotation right 50 PWM, motor rotation left 10 PWM. 3) If the distance of the sensor against the wall> 6 and ≤7 Then the motor rotation right 50 PWM, motor rotation left 15 PWM. 4)If the distance of the sensor against the wall> 7 and ≤8 Then right motor rotation 50 PWM, left motor rotation 30 PWM. 5)If the distance of the sensor against the wall> 8 and ≤9 Then the motor rotation right 50 PWM, motor rotation left 45 PWM. 6)If the distance of the sensor against the wall> 9 and ≤10 Then the motor rotation right 50 PWM, left motor rotation 47 PWM. 7)If the distance of the sensor against the wall> 10 and ≤11 Then right motor rotation 50 PWM, motor rotation left 48 PWM. 8) If the distance of the sensor against the wall> 11 and ≤12 Then the motor rotation right 50 PWM, motor rotation left 50 PWM. 9)If the sensor distance against wall> 12 and ≤13 Then right motor rotation 15 PWM, motor rotation left 50 PWM. 10)if the sensor distance against wall> 13 and ≤14 Then right motor rotation 10 PWM, motor rotation left 50 PWM.11)if the sensor distance against wall> 14 and ≤250 Then right motor spin 15 PWM, motor rotation left 70 PWM.

4. Result and Discussion

4.1. Analysis of Artificial Intelligence Robot Movement Against the Wall

Analysis of the Artificial Intelligence Robot movement against the wall is done on the wall of the letter L, the letter T, the letter U, and the square with the set point 9 cm and 10 cm against the wall. Error values are calculated from robot motions that do not match the set point. The percentage of error values obtained with the following formula:

$$\text{Error value} = \frac{\text{hasil yang didapat} - \text{hasil yang dinginkan}}{\text{hasil yang dinginkan}} \text{ X } 100$$

Table 1. The Testing Result of Artificial Intelligence Robot on an L-letter wall

Robot's Position	Distance	Conformity to the setpoint	Error Value
L1	9-10 cm	Appropriate	0%
L2	9-10 cm	Appropriate	0%
L3	9-10 cm	Appropriate	0%
L4	9-10 cm	Appropriate	0%
L5	9-10 cm	Appropriate	0%
L6	9-10 cm	Appropriate	0%
B1	9-10 cm	Appropriate	0%
B2	8 cm	-1 cm	-11,11%
B3	5 cm	-4 cm	-44,44%
L7	7 cm	-2 cm	-22,22%
L8	8 cm	-1 cm	-11,11%
L9	9-10 cm	Appropriate	0%
L10	9-10 cm	Appropriate	0%
B4	4 cm	-5 cm	-55,55%
L11	6 cm	-3 cm	-33,33%
L12	7 cm	-2 cm	-22,22%
L13	8 cm	-1 cm	-11,11%
L14	9-10 cm	Appropriate	0%

B5	9-10 cm	Appropriate	0%
B6	6 cm	-3 cm	-33,33%
B7	7 cm	-2 cm	-22,22%
L15	7 cm	-2 cm	-22,22%
L16	7 cm	-2 cm	-22,22%
L17	8 cm	-1 cm	-11,11%
L18	9-10 cm	Appropriate	0%
L19	9-10 cm	Appropriate	0%
L20	9-10 cm	Appropriate	0%
L21	9-10 cm	Appropriate	0%
B8	7 cm	-2 cm	-22,22%
B9	8cm	-1 cm	-11,11%
The average value of error			-12%

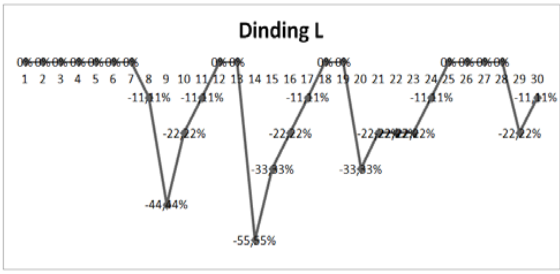

Figure 3. Graph of Error Robot Value on Wall Based Letter L

Table 2. Test Result Artificial Intelligence Robot movement on Wall T

Robot Position	Distance of Robot	Compatibility with set point	Error Value
L1	9-10 cm	Appropriate	0%
L2	9-10 cm	Appropriate	0%
L3	9-10 cm	Appropriate	0%
L4	9-10 cm	Appropriate	0%
L5	9-10 cm	Appropriate	0%
L6	11 cm	+2 cm	22,22%
B1	9-10 cm	Appropriate	0%
B2	7 cm	Appropriate	-22,22%
B3	7 cm	-2 cm	-22,22%
L7	9-10 cm	Appropriate	0%
L8	9-10 cm	Appropriate	0%
L9	9-10 cm	Appropriate	0%
L10	9-10 cm	Appropriate	0%
B4	5 cm	-4 cm	-44,44%
L11	6 cm	-3 cm	-33,33%
L12	7 cm	-2 cm	-22,22%
L13	8 cm	-1 cm	-11,11%
L14	9-10 cm	Appropriate	0%
B5	9-10 cm	Appropriate	0%
B6	6 cm	-3 cm	-33,33%
B7	9-10 cm	Appropriate	0%
L15	9-10 cm	Appropriate	0%
L16	9-10 cm	Appropriate	0%
L17	9-10 cm	Appropriate	0%

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L18	9-10 cm	Appropriate	0%
B8	9-10 cm	Appropriate	0%
B9	5 cm	-4 cm	-44,44%
L19	6 cm	-3 cm	-33,33%
L20	8 cm	-1 cm	-11,11%
L21	9-10 cm	Appropriate	0%
L22	9-10 cm	Appropriate	0%
B10	9-10 cm	Appropriate	0%
B11	7 cm	-2 cm	-22,22%
B12	7 cm	-2 cm	-22,22%
L23	8 cm	-1 cm	-11,11%
L24	9-10 cm	Appropriate	0%
L25	9-10 cm	Appropriate	0%
L26	9-10 cm	Appropriate	0%
L27	9-10 cm	Appropriate	0%
L28	8 cm	-1 cm	-11,11%
L29	9-10 cm	Appropriate	0%
L30	9-10 cm	Appropriate	0%
The average value of error			-8%

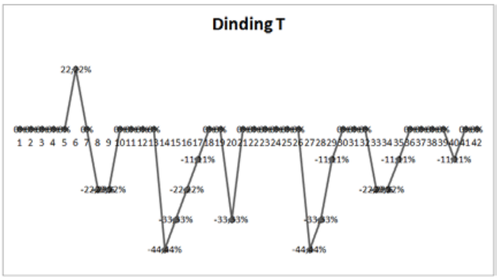

Figure 4. Graph of Error Robot Value on T-Shaped Wall T

Table 3. Test Result Artificial Intelligence Robot movement on Wall U

Robot Position	Distance of Robot	Compatibility with set point	Error Value
L1	9-10 cm	Appropriate	0%
L2	9-10 cm	Appropriate	0%
L3	9-10 cm	Appropriate	0%
L4	9-10 cm	Appropriate	0%
L5	9-10 cm	Appropriate	0%
L6	9-10 cm	Appropriate	0%
B1	9-10 cm	fit	0%
B2	7 cm	-2 cm	-22,22%
B3	8 cm	-1 cm	-11,11%
L7	8 cm	-1 cm	-11,11%
L8	8 cm	-1 cm	-11,11%
L9	9-10 cm	Appropriate	0%
L10	9-10 cm	Appropriate	0%
B4	5 cm	-4 cm	-44,44%
L11	5 cm	-4 cm	-44,44%
L12	7 cm	-2 cm	-22,22%

L13	9-10 cm	Appropriate	0%
B5	7 cm	Appropriate	-22,22%
L14	8 cm	-1 cm	-11,11%
B6	7 cm	-2 cm	-22,22%
B7	8 cm	-1 cm	-11,11%
B8	7 cm	-2 cm	-22,22%
L15	8 cm	-1 cm	-11,11%
L16	9-10 cm	Appropriate	0%
L17	9-10 cm	Appropriate	0%
L18	9-10 cm	Appropriate	0%
L19	9-10 cm	Appropriate	0%
B9	8 cm	-1 cm	-11,11%
L20	9-10 cm	Appropriate	0%
L21	9-10 cm	Appropriate	0%
L22	9-10 cm	Appropriate	0%
L23	9-10 cm	Appropriate	0%
L24	9-10 cm	Appropriate	0%
L25	9-10 cm	Appropriate	0%
L26	9-10 cm	Appropriate	0%
B10	9-10 cm	Appropriate	0%
B11	9-10 cm	Appropriate	0%
The average value of error			-8%

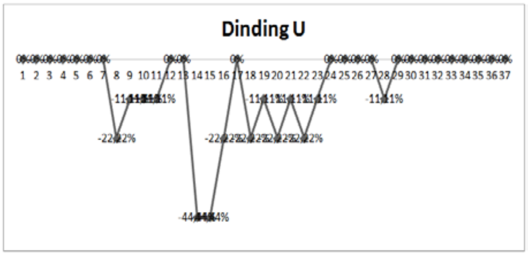

Figure 5. Graph of Error Robot Value on U-Shaped Wall

Table 4. Test results of Artificial Intelligence Robot movement on Square Wall

Robot Position	Distance of Robot	Compatibility with set point	Error Value
L1	9-10 cm	Sesuai	0%
L2	9-10 cm	Sesuai	0%
L3	11 cm	+2 cm	22,22%
L4	11 cm	+2 cm	22,22%
L5	9-10 cm	Sesuai	0%
L6	9-10 cm	Sesuai	0%
B1	9-10 cm	Sesuai	0%
B2	11 cm	+2 cm	22,22%
L7	9-10 cm	Sesuai	0%
L8	9-10 cm	Sesuai	0%
L9	9-10 cm	Sesuai	0%
L10	9-10 cm	Sesuai	0%
L11	6 cm	-3 cm	-33,33%

B3	9-10 cm	Appropriate	0%
B4	9-10 cm	Appropriate	0%
L12	9-10 cm	Appropriate	0%
L13	8 cm	-1 cm	-11,11%
L14	9-10 cm	Appropriate	0%
L15	9-10 cm	Appropriate	0%
L16	9-10 cm	Appropriate	0%
B5	9-10 cm	Appropriate	0%
L17	8 cm	-1 cm	-11,11%
L18	8 cm	-1 cm	-11,11%
L19	9-10 cm	Appropriate	0%
L20	9-10 cm	Appropriate	0%
L21	9-10 cm	Appropriate	0%
L22	9-10 cm	Appropriate	0%
L23	9-10 cm	Appropriate	0%
B6	9-10 cm	Appropriate	0%
B7	7 cm	-2 cm	-22,22%
The average value of error			-1%

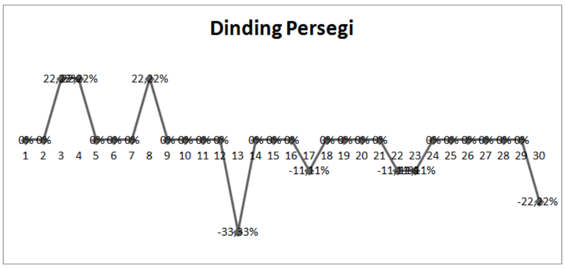

Figure 6. Graph of Error Robot Values on Square-shaped Walls

Robot Reaction When Given Disisturbance

Figure 9 shown a robot image when given interference. The result of the robot can run stable following the wall.

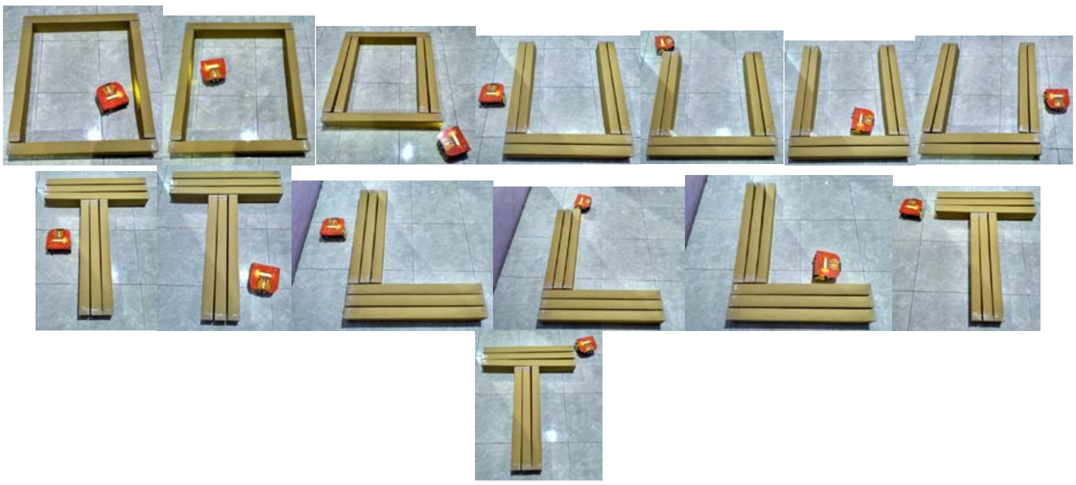

Figure 7. a robot image when given interference

5. Conclusion

Based on the results of research that has been done can be concluded that the Artificial Intelligence Robot can detect T-shaped wall produces an average error value of -8%. The U-shaped wall produces an average error value of -8%. On rectangular walls yield an average error value of -1%. So a better wall as a barrier wall is a square-shaped wall.

The robotic reaction when given a disorder of various patterns that is, the pattern of the square, the pattern of the letter U, the pattern of the letter T, and the pattern of the letter L can run balanced and not hit the wall.

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