

# Low Cost Serving Robot Using Fuzzy Logic Technique

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**Abstract**— A food and beverages serving robot using fuzzy logic technique is presented in this paper. The utilisation of fuzzy logic technique's objective is to improve the performances and behaviors of these service robot in performing a line following technique to go to a group of workers in a targeted cubical office. A PIC16F877A is used as a controller and RF 315MHz transmitter and receiver are used to communicate between the user and the controller. The program was created by using the MPLAB IDE software. By using an optimal setting of Pulse Width Modulation (PWM), the performances of the robot were analyzed by recording the time and speed taken by the robot to complete the task with and without the utilisation of fuzzy logic. Both of the data is compared and discussed. The results shows that the line follower robot can reach the destination with minimum of time and smoothly with the fuzzy logic approach.

**Keywords**— Service Robot, Fuzzy Logic, PIC16F877A, DC Motor, PWM

## I. INTRODUCTION

Nowadays, as we can see majority of human tasks are being replaced by robot. There are two types of robot i.e. industrial robot and service robot. One of the service robot that has been developed nowadays is a robot that can serve food and drinks. ServerBot is one of the robots that serve food and drinks [1]. ServerBot has the ability to move efficiently in between rooms in a house while carrying a payload. For The Dalu Robot, it is a robot that follows a fixed route that can serve of up to 100 diners [2]. The 21 tables are set up in a circular pattern and diners are served in rotation, upon completion the robot will return to the kitchen to refill their carts. Another example of robot that serves food and drinks is CAFERO [3], the robot will take orders via a touch screen and fills them up with the help of a human operator and send it to the customers. Another example is Chassis, which is a mobile robotic beverage delivery system [4]. It uses a remote control to allow an operator to drive Chassis. For RoboButler, it is a robot that can perform delivery tasks in a quick and safe manner [5]. Based on these examples, we can see that many types and functions that have been developed to build a robot that serves drinks and food that requires a high cost for development and maintenance. In this paper, a line follower robot had been used to serve food and drinks to a group of workers in a cubical office by using a fuzzy logic approach. In order to build a low cost robot, the utilisation of line following

technique was applied to this robot. When the worker pushed the button, the input will be transmitted to the receiver of the RF module and the output will be sent to the microcontroller to move the robot towards the target. The utilisation of fuzzy logic technique was applied to the line following system so that the movement of the robot will become smoother and the time to deliver the food and beverage will be reduced.

## II. SCOPE OF WORK

The scope of this project is to develop a low cost serving robot in a cubical office. The fuzzy logic technique will be used in the line following system of the robot. The test environment parameters are 3m in length, 1.5m in width and consists of 4 cubicles (Figure 1). The input sent by the user will be transmitted by using the RF transmitter module 315MHz and will be received by using the RF receiver module 315MHz. The receiver module will be attached to the robot so that the data can be sent to the controller. The selected controller is PIC16F877A that uses MPLAB.IDE as a software to program the robot. The robot will move clockwise before and after delivering the food and beverages which means the robot cannot make a reverse movement.

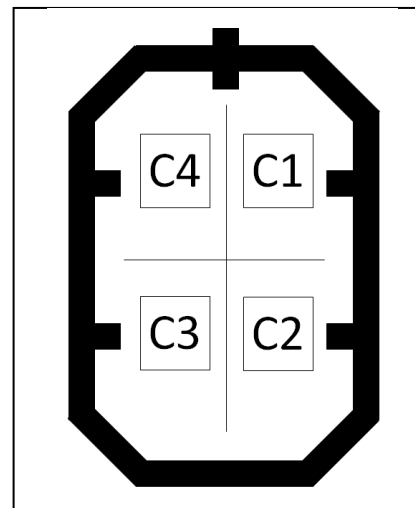


Figure 1. Test environment

III. METHODOLOGY

This research was divided into 3 parts which are mechanical, electrical and software developments.

A. Mechanical Development

The robot base was built with a plastic material with an estimated width of 30mm. The advantages of using plastic material were the weight of the robot can be reduced and the material is cheap. The width was important so that the base is stiff and difficult to bent. A small ball bearing with a plastic casing was used as a balance wheel. It was light and gave a small amount of friction between the surface. The arrangement of wheels was sufficient to ensure static stability with easy turning. The total weight of robot was 0.9 kilogram.

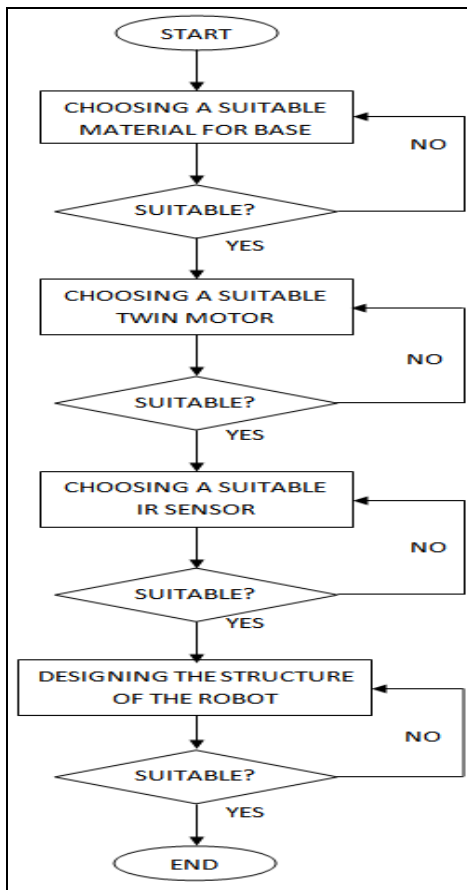


Figure 2. The flow chart of a hardware development

B. Electrical Development

Figure 3 shows the schematic diagram for a robot controller circuit and the circuit was interfaced with a motor driver to control the robot movements and with the RF Receiver so that user could communicate with the robot wirelessly.

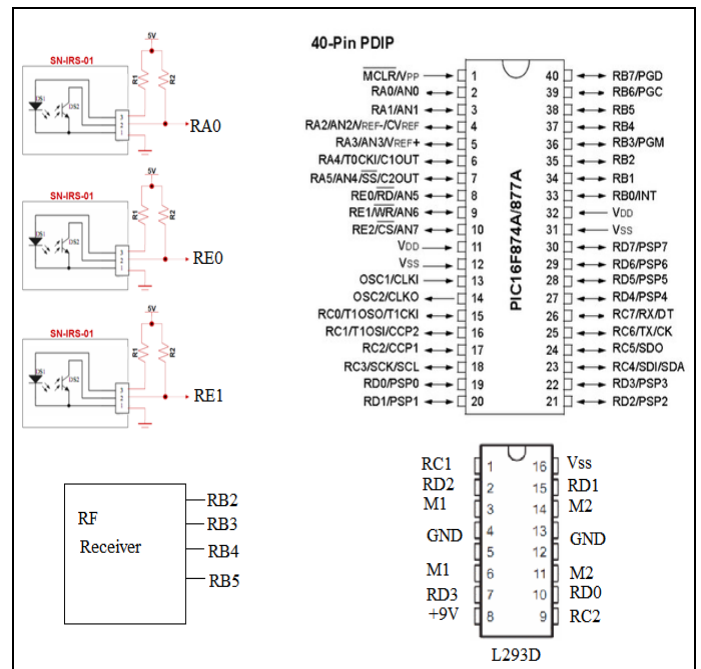


Figure 3. The schematic diagram of a complete controller circuit

The RF 315MHz Transmitter and Receiver were used to transmit input from the user and send it to the receiver that was connected to the microcontroller. Four switches i.e. SW1,SW2,SW3 and SW4 were connected to the RF Transmitter. SW1 was attached to the cubic 1(C1), SW2 was attached to cubic 2(C2), SW3 was attached to the cubic 3(C3) and SW4 was attached to cubic 4(C4). When the controller received the data from the receiver, the robot will start to move by following the black line by using the 2 IR sensors that have been attached under the robot and will stop at the targeted cubic by using another IR sensor. The sensors used a reflective type of optical sensor to detect the line and it will project a light and detect its reflection off an object [6]. The output sensor was connected to the ADC input of PIC 16F877A which converts the input to a digital value. The value will then be compared so that the controller knows whether the sensor sensed black or white color. This technique is also known as ADC as comparator.

Motor driver was used to control the direction and the speed of a motor. There are two sources of power on the motor driver which provides the power for the DC motor (Vs) to the motor driver (Vss). The motor driver used in this paper was L293D [7], and it can control a 2 DC motor separately.

PWM method was used to control the speed [8]. PWM is a commonly used technique to control power to inertial electrical devices. The main advantage of PWM was that the power loss in the switching devices was very low. When a switch is turned off there is practically no current, and when it is turned on, there is almost no voltage drop across the switch.

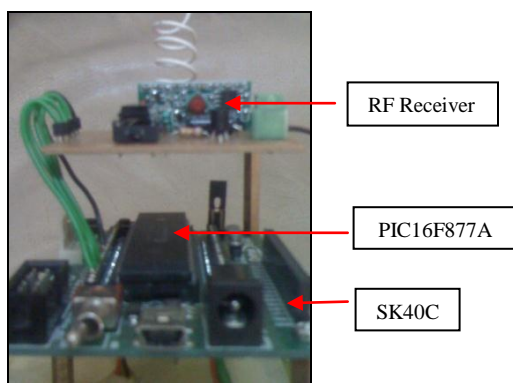


Figure 4. Controller circuit

C. Software Development

The four switches of the microcontroller cannot be push together so that no conflict for the robot to go to the target location (Figure 5). When the robot reached the located cubical, it will move back to the start point if there is no input from other users. If other users push the switch, the robot will go to that location instead of going back to the starting point.

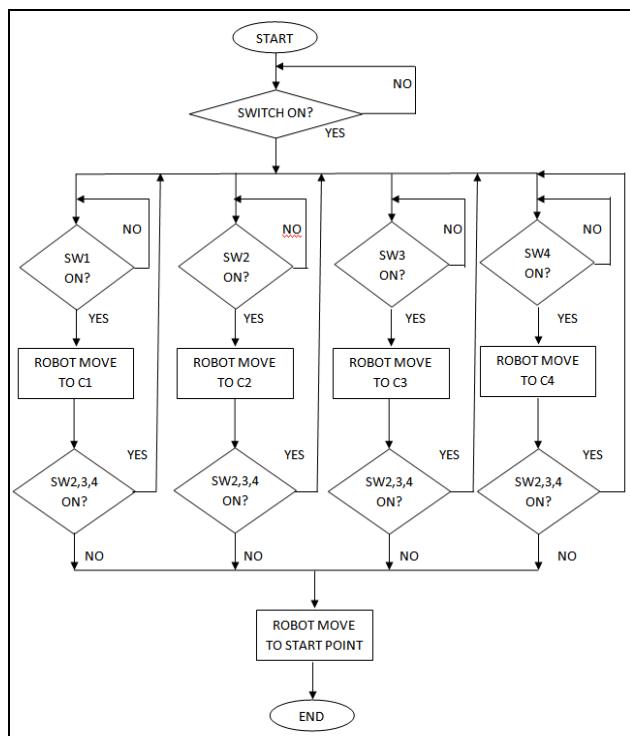


Figure 5. Flow chart of microcontroller function

In this paper, the author used the fuzzy logic approach on the movement of the robot following the black line. Fuzzy logic is a form of many-valued logic or probabilistic logic; it deals with reasoning that is approximate rather than fixed and exact[9]. Figure 6 shows the block diagram of the line following robot system. Left and right IR sensors detect the

line under the robot and feed the received signal to the microcontroller system. The microcontroller implements the fuzzy logic rules and sends the signals to the left and right motors.

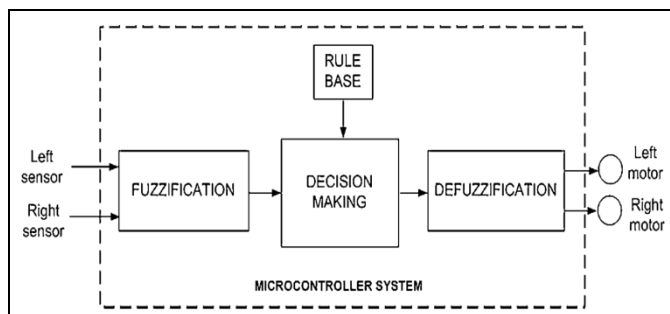


Figure 6. Block diagram of the system

In binary logic, the output of the sensor will be '0' if it detects black color, voltage 3.5V and above and '1' if it detects white color, voltage 3.5V and below. By using fuzzy the technique, the logic can be added so that the movement of the robot will become smoother. The fuzzy logic rules used in this paper are shown below:

*if sensor = 0, voltage range  $\geq 3.5V$*

*if sensor = 1, voltage range 1.5V to 3.5V*

*if sensor = 2, voltage range  $\leq 1.5V$*

The design for the line following robot system by using the fuzzy logic approach are shown below :

**IF input1 AND input2 THEN output**

IF *sensor\_left=2 AND sensor\_right=2* THEN *forward*

IF *sensor\_left=2 AND sensor\_right=0* THEN *turn\_right*

IF *sensor\_left=1 AND sensor\_right=0* THEN *slow\_right*

IF *sensor\_left=0 AND sensor\_right=2* THEN *turn\_left*

IF *sensor\_left=0 AND sensor\_right=1* THEN *slow\_left*

IF *sensor\_left=0 AND sensor\_right=0* THEN *stop*

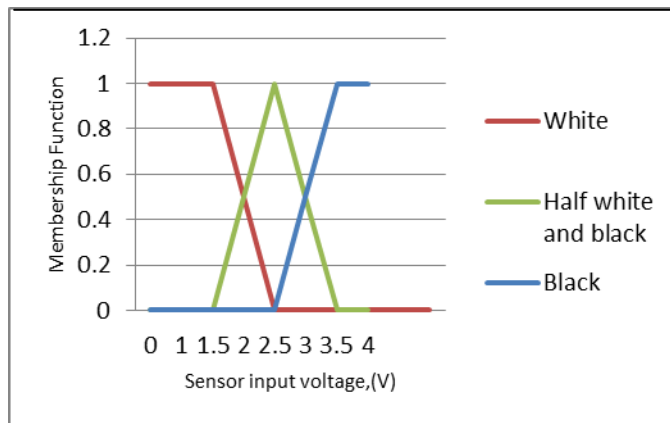


Figure 7. Membership function INPUT for line follower

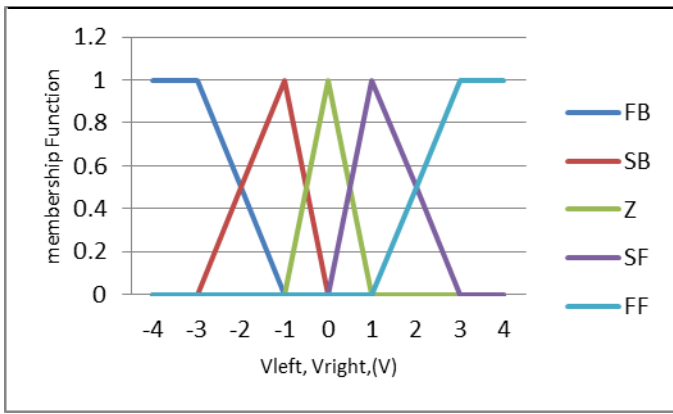


Figure 8. OUTPUT membership function for line follower

TABLE I. FUZZY RULES FOR LINE FOLLOWER ROBOT

No	Sensor Left	Sensor Right	Vleft	Vright
1	W	W	FF	FF
2	W	B	FF	SB
3	B	W	SB	FF
4	HWB	B	SF	Z
5	B	HWB	Z	SF
6	B	B	Z	Z

W = White                      B = Black                      HWB = Half White Black  
 FF = Fast Forward            SF = Slow Forward            Z = Stop  
 FB = Fast Backward        SB = Slow Backward

IV. RESULTS AND DISCUSSION

In order to measure the robot performances, the robot had been tested with two conditions and the results were compared. The first condition tested was without using the fuzzy logic approach and the second condition tested was with the fuzzy logic technique. The data obtained for both tests is as shown in Tables II and III.

TABLE II. THE RESULTS OF ROBOT PERFORMANCES WITHOUT FUZZY LOGIC TECHNIQUE

Sequence	Distance ,(m)	Time, (s)	Speed, (m/s)	Robot Movement
Start→C1	1.5	10.0	0.15	Smooth
Start→C2	3.0	19.0	0.16	Not Smooth
Start→C3	6.0	32.0	0.19	Not Smooth
Start→C4	7.5	43.0	0.17	Not Smooth
Start→End	9.0	48.0	0.19	Not Smooth
C1→C2	1.5	6.0	0.25	Smooth
C2→C3	3.0	15.0	0.20	Not Smooth
C3→C4	1.5	7.0	0.21	Smooth
C4→C1	3.0	17.0	0.18	Not Smooth

TABLE II. THE RESULTS OF ROBOT PERFORMANCES WITH FUZZY LOGIC TECHNIQUE

Sequence	Distance, (m)	Time, (s)	Speed, (m/s)	Robot Movement
Start→C1	1.5	6.0	0.25	Smooth
Start→C2	3.0	12.0	0.25	Smooth
Start→C3	6.0	20.0	0.30	Smooth
Start→C4	7.5	28.0	0.27	Not Smooth
Start→End	9.0	32.0	0.28	Not Smooth
C1→C2	1.5	3.0	0.50	Smooth
C2→C3	3.0	8.0	0.38	Smooth
C3→C4	1.5	4.0	0.38	Smooth
C4→C1	3.0	9.0	0.33	Smooth

Figure 9 showed that the performances of the robot that used fuzzy logic approach were higher than the performances of the robot that did not use the fuzzy logic approach.



Figure 9. The comparison with and without fuzzy logic technique

From Table II, the time for the robot to complete one round is 48seconds, it show that the average speed of the robot is 0.19m/s. This data show that the robot unable to follow the path smoothly and keep swaying all the line making the time to reach the point increase. By using the fuzzy logic approach, it was proved that the robot can follow the line smoothly thus reducing the time taken to reach the point. The large differences in duration for both conditions showed that the fuzzy logic technique was more suitable with higher accuracy than without fuzzy logic.

Table IV shows the speed and time taken for the robot to move in one complete circle with a different duty cycle using fuzzy logic. A motor supply of 9V was used for this setting.

TABLE IV. THE DATA OF ROBOT'S SPEEDS BY USING A DIFFERENT DUTY CYCLE

Duty cycle,%	Distance,(m)	Time,(s)	Speed,(m/s)
40	9.0	50.0	0.18
45	9.0	46.0	0.20
50	9.0	38.0	0.24
55	9.0	32.0	0.28
60	9.0	-	-
70	9.0	-	-

Table IV shows that the best setting for duty cycle that can be used is 55%. When the duty cycle increased to 60%, the robot was not able to follow the line because the speed of the motor was too fast, thus this made response of the robot slow. By using a low duty cycle, the robot was able to follow the line but the speed of the robot was slow thus the time taken for the robot to complete task increased. In PIC16F877A, the PR2 register determined the period of the PWM. The formula to get the value of PR2 is given by;

$$PWM\ period = (PR2 + 1) \times 4 \times T_{osc} (Timer2\ prescaler) \quad (1)$$

$$PWM\ frequency = \frac{1}{period} \quad (2)$$

The CCPR1L and CCPR2L registers set the duty cycle. The duty cycle is calculated with equation below;

$$Duty\ cycle = \frac{CCPRxL}{PR2} \quad (3)$$

The suitable frequency that has been determined for an optimum performance of the motor was 5 kHz.

#### V. CONCLUSION AND RECOMMENDATIONS

It can be concluded that the fuzzy logic approach is more efficient than a binary logic in a line following system. The utilisation of the fuzzy logic technique had improved the performances of the robot in following the black line. In order to further enhance the accuracy and efficiency of the robot performances, it is recommended to increase the logic rules and since the test environment was small, it is recommended to increase the channels used for the RF module so that more cubical can be added. It is also recommended to use a high torque motor so that the robot can move smoothly while carrying a heavy load. This model of robot can also be used in other work system, it can be used in a library to collect books and send it to a certain location. It can also be used in a hospital to help doctors to carry things to a target location.

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