Design and Implementation of a Line Follower Robot Based on Fuzzy Logic controller by Using Microcontroller

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Abstract

Robot is widely used to help human to do something, especially for difficult or danger ous tasks. The robot requires, some techniques, sensors and controller have been. In this research robot movement is guided by. Fuzzy logic control as intelligent control applied to govern the robot follow line. Infrared sensors are used to sense line as the input variable for the controller. Based on these signals, the controller control the turning angle of forward movement thus making robot move forward and turning at the same time. A fuzzy logic control was selected for its robustness and flexibility.

Key wordds:Robot , Micro controller , Fuzzy controller

تصميم و تنفيذ الروبوت متتبع الخط بالاعتماد على مسيطر المنطق المضبب باستخدام المسيطر الدقيق

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المستخلص

استخدم الروبوت على نطاق واسع لمساعدة الإنسان على فعل الاشياء، وخاصة بالنسبة للمهمات الصعبة أو الخطرة، الروبوت يتطلب بعض التقنيات ، وأجهزة للاستشعار و تطبيق المتحكم .تم في هذا البحث تطبيق المنطق الضبابي للتحكم الذكي في الروبوت متتبع الخط . واستخدمت أجهزة استشعار بالأشعة تحت الحمراء للاستشعار كمدخلات لوحدة التحكم .وبناء على هذه الإشارات، وحدة التحكم و السيطرة عملت على تحويل زاوية الحركة إلى الأمام وبالتالي جعل الروبوت يتحرك إلى الأمام، و تحويل الاتجاه في الوقت نفسه. وقد تم اختيار المنطق الضبابي لمتانة ومرونة عملة.

1. Introduction

A mobile robot is an intelligent mobile machine capable of autonomous operations in its environment. It must be able to do sensing (perceiving its environment),thinking (planning and reasoning), and acting (moving and manipulating) [1].

The mobile Line Follower Robot (LFR) is a type of mobile robot with only one specific task which is to follow the line made with black tape over the white background or vise verse[2]. The LFR perhaps is one of the most popular robot because it could be used as a teaching tool in industrial areas to implement the industrial standard control system such as the PID (Proportional Integral Deferential) or FLC (Fuzzy Logic Controller) control system on this robot[3]. Any controller design for any system needs some knowledge about the system. Usually this involves a mathematical description of the relation among inputs to the process, its state variables, and its output. This description is called the model of the system. The model can be represented as a set of transfer functions for time invariant linear systems or other relationships for non-linear or variant systems. Modeling complex systems can be a very difficult task. In a complex system such as a multiple input and multiple output system, inaccurate models can lead to unstable systems, or unsuitable system performance. Fuzzy Logic Control (FLC) is an effective alternative approach for systems which are difficult to model. The FLC uses the qualitative aspects of the human decision process to construct the control algorithm. This can lead to a robust controller design. The modeling of a mobile robot is a very complex task and a direct application of FLC can be found in this area.

2. Literature review

Deepak Punetha group describes the techniques for analyzing, designing, controlling and improving the health care management system. A line following robot carrying medicine has been designed for providing the medicine to the patient whenever they need it.[4]

Ramshetty K Sure and Savita Patil introduce a Robot having the ability to choose a desired line among multiple coloured lines. Every line has different colors as their identities. The robot can differentiate among various colours and choose a desired one to find its target. From the android mobile, instructions are given to the robot that senses a line and endeavours itself accordingly towards the desired target by correcting the wrong moves using a simple feedback mechanism but yet very effective closed loop system.[5]

Yousef Moh. Abueejela Mosbah presented the modeling and development of an autonomous wall following robot which use fuzzy logic as controller. In his method, the sensor reading of distance different at front and rear makes the angular velocity of left and right wheel will be different thus making a turning movement.[6]

Md Zabiuddin and Pushpalatha R. Proposed a line tracking robot based RF technology that helps in transferring the path drawn on the computer screen for the movement of Robot. The window to draw the line on computer screen is developed using C# language. From the computer, the path is transmitted and sensed by microcontroller. [7]

Thoa T. Mac group proposed MIMO fuzzy control applied to track different desired trajectories. Secondly, the controller performs on robot for navigation purpose to avoid obstacles and reach the defined target. The proposed MIMO fuzzy controller was investigated based on several conducted MATLAB simulation scenarios for mobile robot.[8]

3. STRUCTURE OF FUZZY LOGIC CONTROLLER

Fuzzy logic has rapidly become one of the most successful of today's technologies for developing sophisticated control systems. With its aid, complex requirements may be implemented in amazingly simple, easily maintained, and inexpensive controllers [9]. Fuzzy control uses only a small portion of the fuzzy mathematics that is available, this portion is also mathematically quite simple and conceptually easy to understand. In this chapter, we introduce some essential concepts, terminology, and arithmetic of fuzzy sets and fuzzy logic. The fuzzy controller,
(as explained in Fig. 1), have four main components:

- The Rule-Base holds the knowledge, in the form of a set of rules, of how best to control the system.
- The Inference Mechanism evaluates which control rules are relevant at the current time and then decides what the input to the plant should be.
- The Fuzzification Interface simply modifies the inputs so that they can be interpreted and compared to the rules in the rule-base. And
- The Defuzzification Interface converts the conclusions reached by the inference mechanism into the inputs of the plant [10], [11].

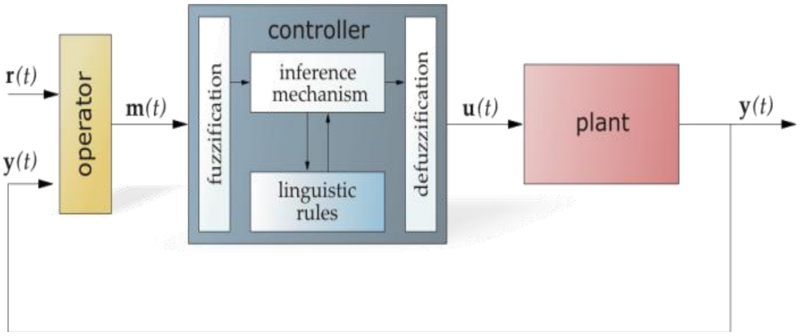


Fig.1: **Internal structure of a fuzzy controller.**

3. Hardware

General block diagram of the mobile robot system is given in Figure 2. The mobile robot system can be separated into three main parts as presented in Figure 2. These parts are vehicle motion system, vision system and control center. The vehicle motion system is a three-wheeled robot vehicle mechanism; in which the motion is enabled by the two back wheels where the front wheel can easily move with its steering. The vision system is based on the principle of infrared sensors, a microcontroller is termed as the control center.

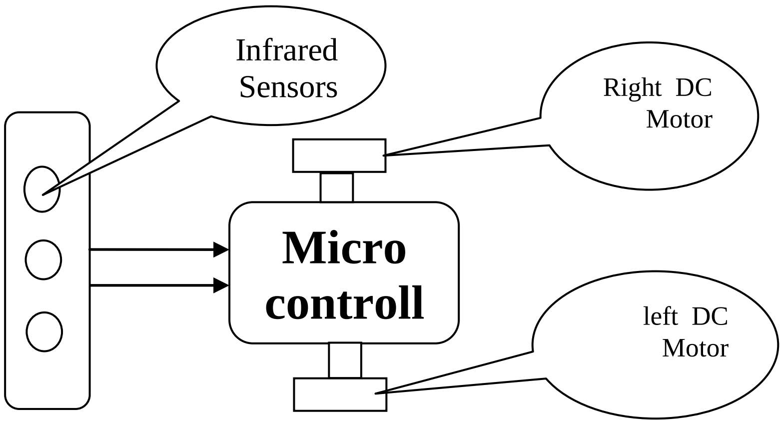
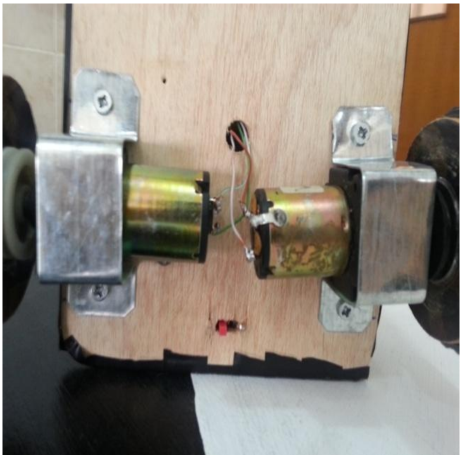


Fig.2: General block diagram of the designed mobile robot.

3.1 Motion System

In this paper the mobile robot consists of two back wheels controlled via two DC motors used for controlling the direction of motion and one front wheel which is floating without controlling, as shown in figures 3, 4, and 5.



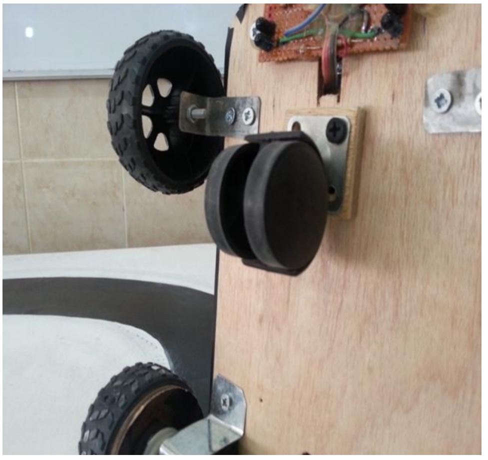


fig.3: back wheels controlled ig. 4: the front wheel without controlling
via two DC motors

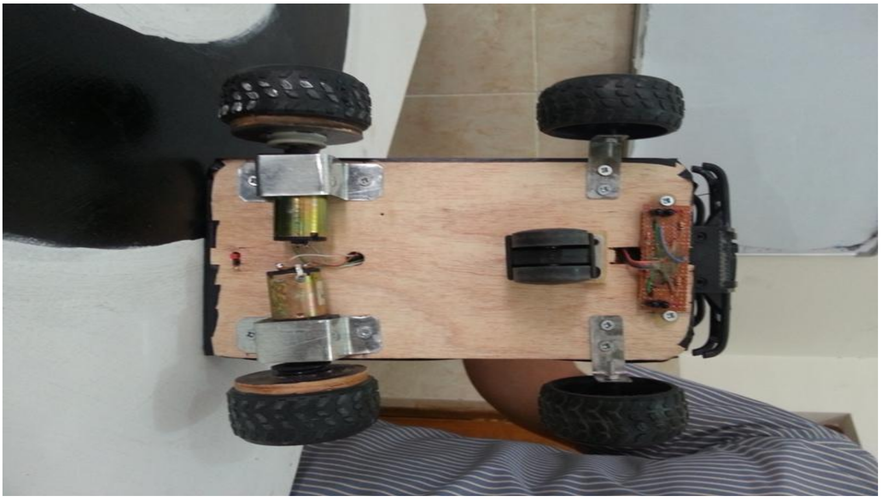


Fig.5: The motion system of the line follower robot

3.2 Vision System

In this paper the vision system consist of two infrared sensors, left and right,used for detection of black line on weight surface. The resistance of the sensor decreases when IR light falls on it. A good sensor will have near zero resistance in the presence of light and a very large resistance in absence of light. We have used this property of the sensor to form a potential divider. The potential at point ‘2’ is:

Rsensor / (Rsensor + R1).

Again, a good sensor circuit should give maximum change in potential at point ‘2’ for no-light and bright-light conditions. To get a good voltage swing , the value of R1 must be carefully chosen. If **R_{sensor} = a when no light falls on it and R_{sensor} = b when light falls on it**. The difference in the two potentials is:

Actual Voltage Swing =Vcc * { a/(a+R1) - b/(b+R1) } .(1)

Relative voltage swing = Actual Voltage Swing / Vcc .(2)

Relative voltage swing = Vcc *{a/(a+R1)- b/(b+R1)}/Vcc .(3)

Relative voltage swing = a/(a+R1) - b/(b+R1) ….(4)

The circuit diagram of the is shown in figure 6, and 7.

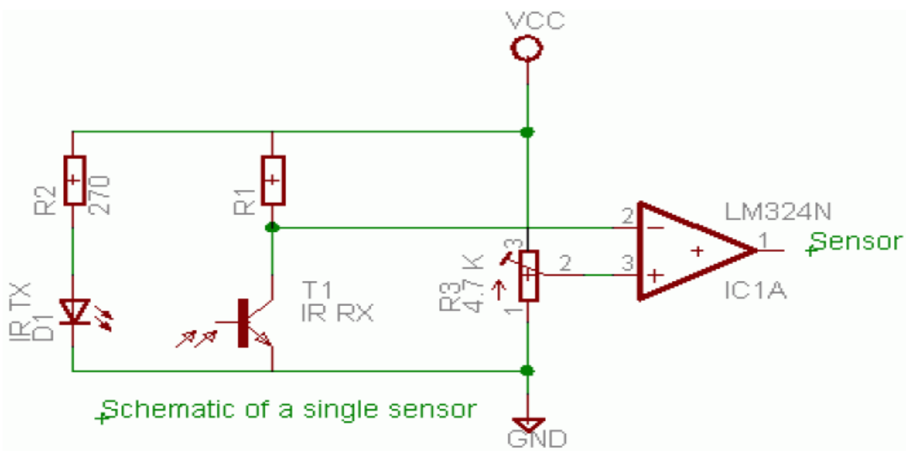


Fig.6: circuit diagram of single infrared sensor

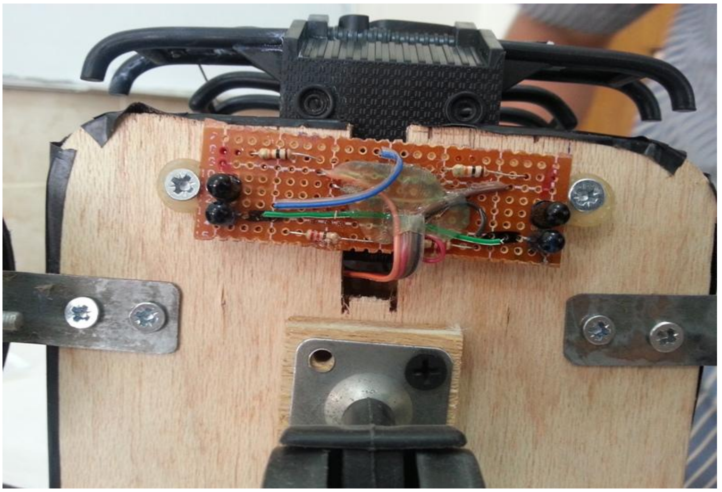


Fig.7: array IR sensors of the mobile robot

3.3 Control System

A microcontroller (PIC16F877A) unit is placed on the robot for the purpose of controlling the movement. This microcontroller reads signals from sensors then controls the motion via DC motors by using motor driver (L293D).

The L293D Motor Driver has 4 inputs to control the motion of the motors and to enable inputs which are used for switching the motors on and off as shown in figure 8 [12].

4. Fuzzy Control of the Line Following Robot

Figure 9 shows the block diagram of the line following robot system developed. Left and right infrared reflectors detect the line under the robot and feed the received signals to the microcontroller system. The microcontroller implements the fuzzy logic control algorithm and sends drive control signals to the left and right motors so that the robot is kept on the line.

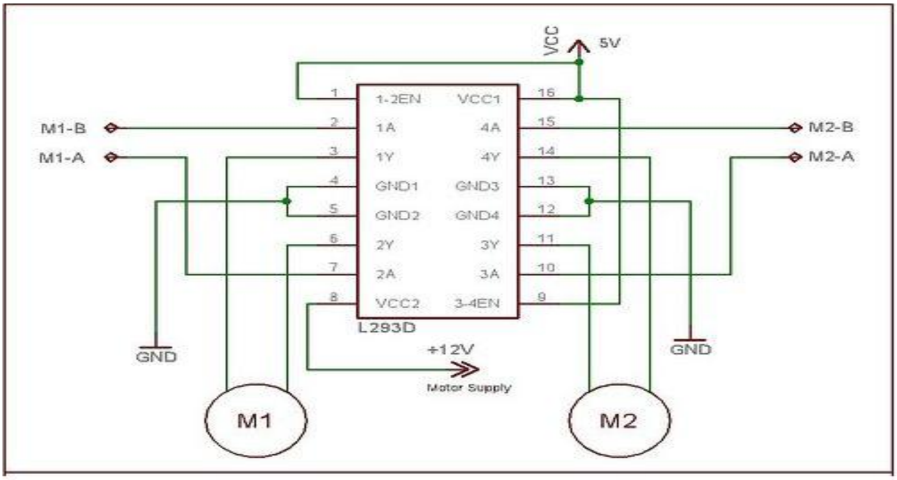


Fig.8: DC Motor controller using L293D

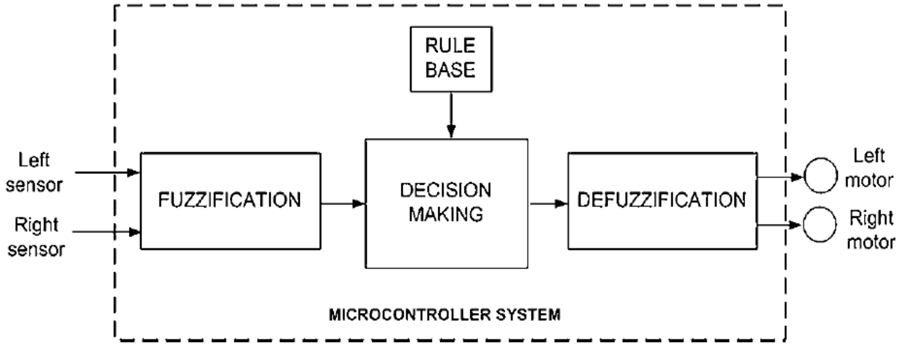


Fig.9: Block diagram of the system

A simplified circuit diagram of the system is given in Figure 10, showing the microcontroller, the infrared reflectors, and the motor drive circuitry. The left and right reflectors are connected to port pins RA0 and RA1 of the microcontroller, respectively. The motors are controlled using a L293D-type H-bridge motor driver IC which controls the direction of each motor.

4.1 Fuzzification

Fuzzification is the process of mapping crisp inputs to fuzzy membership functions. In fuzzy logic, it is important to distinguish not only which membership
functions a variable belongs to, but also the relative degree to which it is a member. Left and right sensors are used to detect a line position under the robot. Sensor become inputs to the fuzzy controller. The membership functions of error(e) and change in error (Δe) are shown in figure 11. Sensors membership functions are defined as Left (L), Zero (Z) and Right (R) with triangle shape for centre and trapezoidal shape for left and right. The range of inputs is defined as -1 cm to +1 cm.

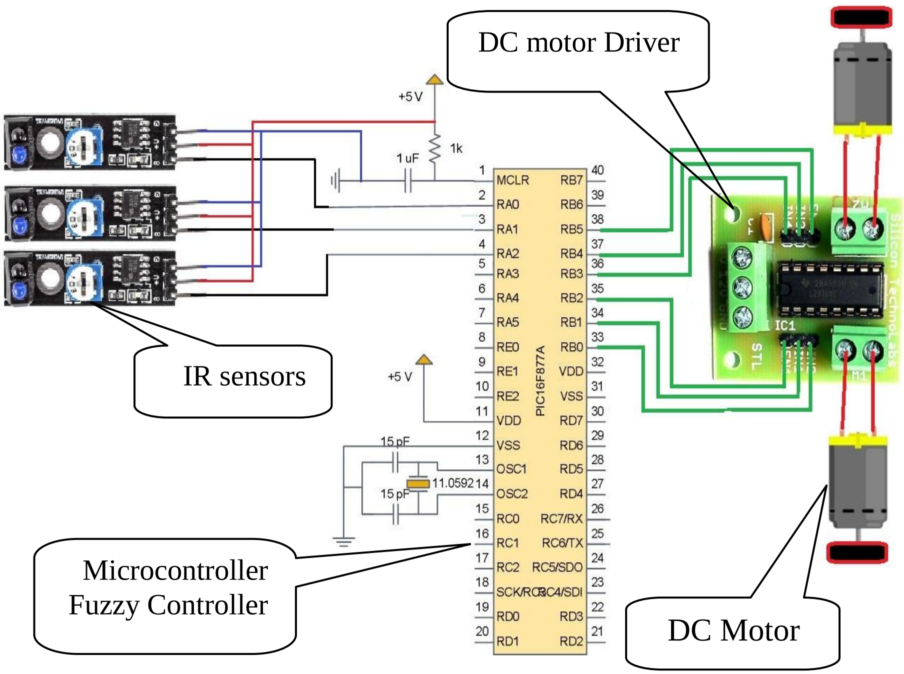


Fig.10: Circuit diagram of the system

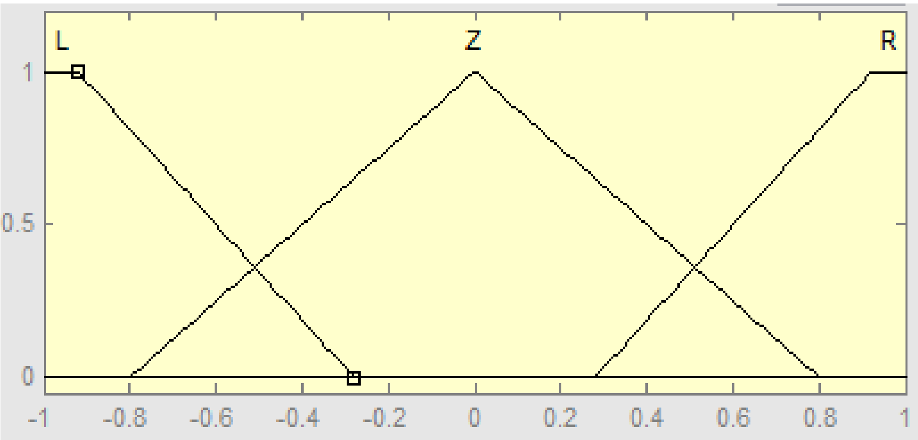


Fig.11: membership functions of e and Δe

The membership functions of the output which control the DC motors is shown in figure 12. membership functions are defined as Left (L), Forward (F) and Right (R) with triangle shape for centre and trapezoidal shape for left and right.

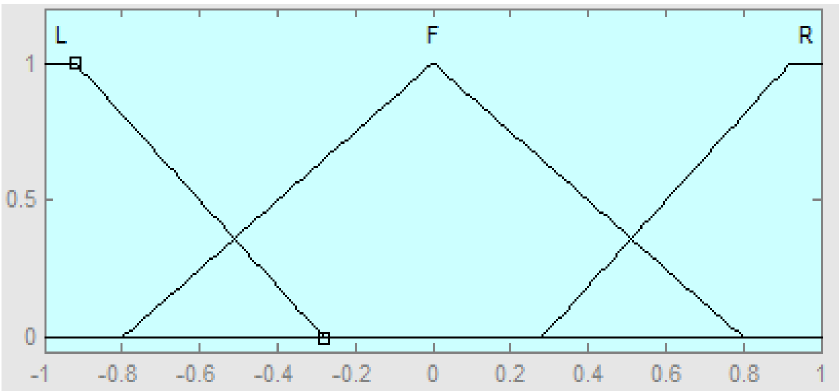


Fig.12: membership functions of the fuzzy output

4.2 Inference Rule Definition

After defining the membership functions, we can generate the fuzzy rule definitions to relate the output actions of the controller to the observed sensor inputs. The rule definition is usually in the form of IF_THEN statements, but the rules can also be shown in the table format as shown in table1.

Table.1: Fuzzy logic rules for the line following robot

e / Δe	L	Z	R
L	**F**	**L**	
Z	**R**	**F**	**L**
R		**R**	**F**

The rules viewer is shown in figure 13 where the possible output is simulated based on inputs value.

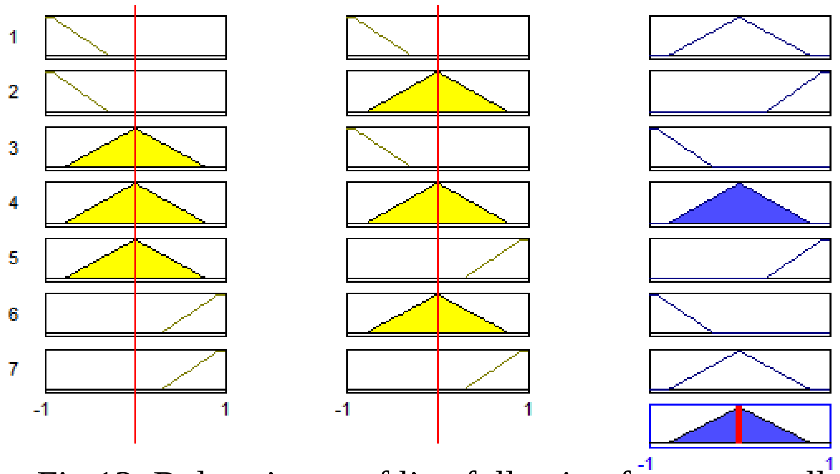


Fig.13: Rules viewer of line following fuzzy controller

The rules surface viewer is shown in figure 14.

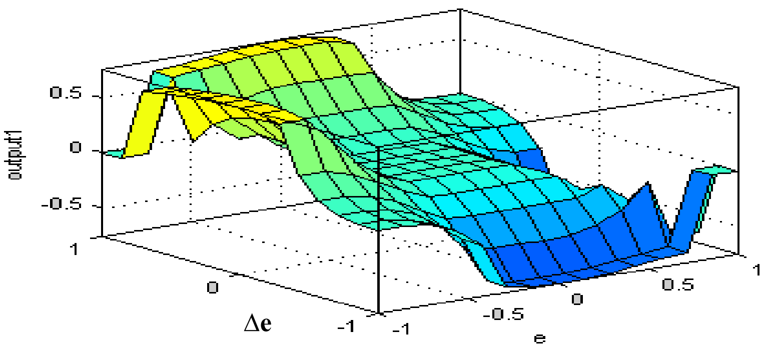


Fig.14: Rule surface for the fuzzy controller

4.3 Defuzzification

The resulting fuzzy set must be converted to a number that can be sent to the process as a control signal in this process. The resulting fuzzy set is thus defuzzified into a crisp control signal. The strategy adopted here is the height defuzzification method because of its simplicity and fast calculation. It uses the individual scaled control outputs, and builds the weighted sum of the peak values, as it is clear from Equation 6 [13][14].

$$y = C_F \frac{\sum_{i=1}^{L} \mu(y_i) y_i}{\sum_{i=1}^{L} \mu(y_i)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where support value at which the membership function reaches the maximum valued is the scaling factor defined for the output universe of discourse; designates the number of rules used [15][16].

5. THE SOFTWARE

The software is based on the mikroC language, which is a cut-down microcontroller version of the standard C language. Using a high-level language makes it easy to develop programs and concentrate on the algorithm rather than the actual coding task. The program initially reads the two infrared sensors then controls the DC motors. The prototype of implemented line follower robot is shown in figure 15.

Fig.15: prototype of a line follower robot based fuzzy logic controller

6. CONCLUSIONS

The aim of this research is to design and implement a line follower robot which can be used for many applications. The line follower robot has been designed and implemented successfully based on fuzzy logic controller where the fuzzy controller implemented based micro controller PIC16f877A which reads signals via infrared sensors, the Micro C is the software used for programming microcontroller.The advantage of the proposed controllers is the simplicity and the efficiency for the robot control while other controllers such as PID in this system cannot obtain perfect controling because the parameters of the controller use the manual tuning. It can follow any curve and cycle; it has high sensitivity for selected path with high speed operation.

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