BARRIER AVOIDANCE ROBOT BY FUZZY LOGIC

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ABSTRACT

Automated Guided Vehicles have many potential applications in manufacturing, medicine, space and defense. Barrier Avoidance Robot is primary used in embedded systems. The robot is using the fuzzy logic and applied in Arduino Uno microcontroller with ultrasonic sensors. The main scope of the system is to automatically changing the direction of robotic vehicle as required whenever any barrier comes on its ways. The aim of the system is to implement a fuzzy logic Barrier Avoidance Robot. It avoids any static barriers in front of the robot. The fuzzy logic controller uses the sensor data as inputs and drives the motor used in the robot for avoiding the barrier. This system uses three ultrasonic sensors and one output. Sensor detects the presence of any obstacle and sends the signal to microcontroller which changes the direction of the robot. It uses fuzzy logic controller to impart smooth movement of robot while it tries to avoid barrier. The eleven rules of fuzzy set are applied by testing 53 rules set. This system girts with three ultrasonic (HC-SR04) sensors to measure the distance from the barrier.

CHAPTER 1

INTRODUCTION

Introduce the design of an autonomous Barrier Avoiding Robot cars using ultrasonic sensors. The fuzzy logic system has been used for an effect means in unknown and complicated industrial surroundings. Environment improvements of mobile robot have attracted the attention of researchers in the areas of the branch of science and technology concerned with the design, use of engines, machines, and structures, computer science, and others. The barrier avoidance distance can be measured [25]. It has proposed another new rule table that is induced from the consideration of the distance to barrier and the angle between the sensor and the target. A new activity has been proposed to design a fuzzy controller to improve the competent of mobile robot to react to dynamic surrounding. The ultrasonic sensor retrieves data from environment area through mounted three ultrasonic sensors robot on the robot.

This system is designed to construct a robotic vehicle to avoid barriers using three ultrasonic sensors for its activity. A robot is an automated machine. Robotics is generally physical machines (motors)and a combination of computational intelligence. Computer intelligence contains programmed instructions. The system recommends an intelligent robot that guides itself whenever it encounters a barrier [20]. The Barrier Avoidance Robot is built using an Arduino uno. An ultrasonic sensor is used to command the Arduino to detect any barrier in front of it.

In most studies, the fuzzy logic controller has three input sensors for the robot to detect and avoid barriers. Ultrasonic sensors are used for measure distances around robot from left barrier, right barrier, center barrier. Specific challenge of design an intelligent controller is in determining what information is needed. One option is to apply the theory of probability to a more realistic model. It still depends on the agent's access to information about the environment with a small amount of accuracy. In fact, it is a unique feature of the design since it enables replacement of existing component with more sophisticate. The design specification was to build a robot which following a line and avoid barrier [16]. The implementation of a fuzzy logic controller is proposed for barrier avoidance.

The generality of the accidents occurs on the way because of human intensive driving. The solution to this problem is the development of driverless devices. A driverless vehicle can sense its surroundings and move in a direction without human intervention [22]. It has capability to minimize damage due to driver demerit.

1.1. Objectives of the Thesis

- To study the implementing of the robot by using with the microcontroller
- To build a robot that can avoid barrier using fuzzy logic
- To guide a mobile robot for avoiding barrier ahead

1.2. Overview of the System

Barrier Avoidance Robot is an intelligence robot that can automatically detect and overcome barrier in its path. It has microcontroller and three ultrasonic sensors to process the information to detect barrier in its path. Barrier avoids is one of the most important aspects of mobile robotics. The overview of the system as shown in Figure 1.1. They are consisting of three portions.

- Sensors as input
- Controllers
  - Fuzzy Logic Controller
  - Microcontroller
- Actuators

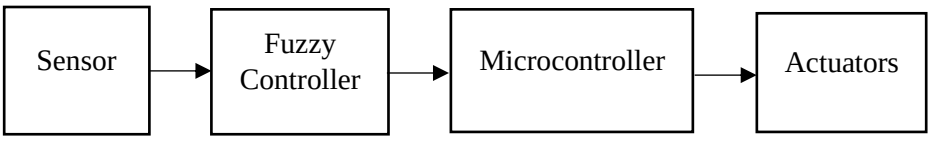


Figure 1.1 Overview of the Barrier Avoidance Robot

Sensors are quantifying distances mobile robot from facade barrier, left barrier, and right barrier. According to intelligence acquired by robot sensors relevant fuzzy control rules are activated. The outputs of activated fuzzy rules based are combined by fuzzy logic operations of the control and operation of a motor vehicle of the robot as shown in Figure 1.2.

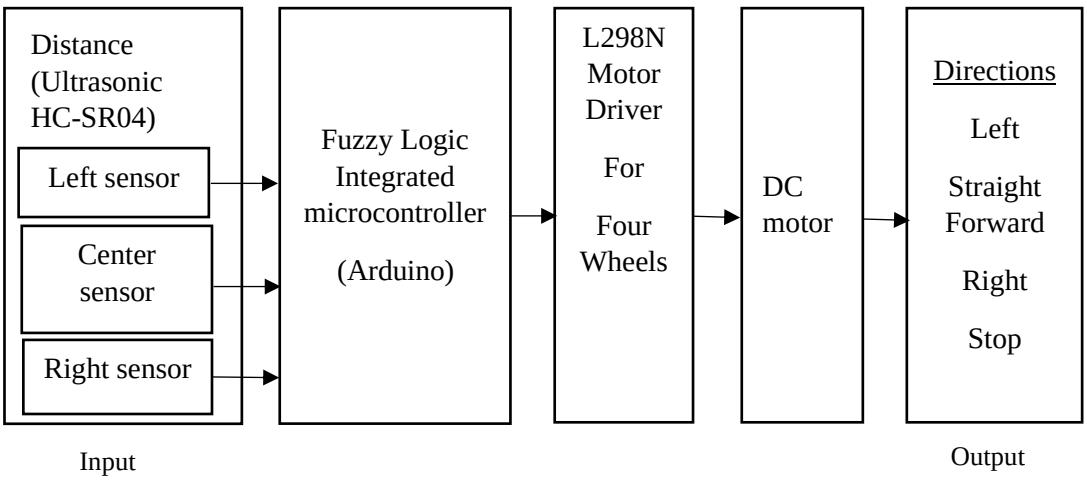


Figure 1.2 Overview of hardware setup for Barrier Avoidance Robot

1.3 Organization of the Thesis

This thesis is organized as five chapters. Chapter 1 introduces the basic information about the thesis and motivation, overview of thesis and objectives. Chapter 2 discusses the system components. It follows that the different types of sensors and also discuss the sensors that are used in the system. Chapter 3 describes the background theory of fuzzy logic techniques in microcontroller. In this chapter, the fuzzy logic algorithm and concept of fuzzy are also described. Chapter 4 explains the system design and its implementation. Chapter 5 concludes with the benefits of the system and further extensions of the thesis.

CHAPTER 2

SYSTEM COMPONENTS

An ultrasonic Sensor is used to calculate the distance around a robot from front barrier, left barrier and right barrier. According to the information received from the robotic sensors, the relevant fuzzy control rules are activated. The output of activated rules is combined by fuzzy logic operations to control velocities and steering angles of driving wheels of the robot.

2.1 Different Types of Sensors

A sensor is a machine that searches and reacts to certain types of input from the surroundings [14]. It can be translated into information that can be interpreted by humans or machines. The specific input could be motion pressure, temperature, gas or something of a good number of other environmental processes.

The output is generally a signal that is transformed to human-readable indicate transmitted electronically over a network or at the sensor location for further processing or reading. A sensor converts motivation like light and process of moving into electrical signals. These signals are passed an interface that change language them into a binary code and it is sent to a computer for processing. The following is a list of common sensor types used in various applications [23]. Different types of sensors are:

- Proximity
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure
- Light
- Touch
- Flow and Level
- Position
- Magnetic (Hall Effect Sensor)
- Microphone (Sound Sensor)
- PIR
- Strain and Weight

- Ultrasonic

There are many categories of sensors they are classify as Active and Passive. Active Sensors are those which demand a power signal or an external signal. Passive Sensors direct the output response without asking for an external power signal. Another type of classification is based on the means of production used in the sensor. The final classification of the detection sensors is Digital and Analog Sensors. Analog sensors detect the analog output, a continuous output signal associated with a measured number. Digital Sensors, in opposite to Analog Sensors, task with discrete or digital data. Data on digital sensors used for fluctuation and transmission is digital in nature.

2.1.1 Proximity Sensor

The proximity sensor is a sensor that can be emitted to nearby objects without physical contact as shown in Figure 2.1. The proximity sensor releases a beam of light from an electromagnetic field or light field, and often detects changes in the return signal or in the field. Not the same proximity sensor targets claim not the same sensors. Proximity sensors may have a high reliability and long functional life because of the want of mechanical parts and without physical contact between the sensed object and the sensor [14]. Proximity sensors are used to monitor the vibration between the shaft and its support bearing.

Figure 2.1 Proximity sensor (source: https://www.ato.com/proximity-sensor-capacitive-m30-2-wire-12v)

2.1.2 Accelerometer Sensor

The accelerometer sensor may be used to measure the accelerated upon the sensor as shown in Figure 2.2. An accelerometer is an electronic sensor that measures the speed of an object in space to determine the state of the object in space and to

monitor its motion. Acceleration, is the rate of change of an object's velocity, which is a vector quantity. There are two types of acceleration forces: dynamic and static. Static force is the force exerted on an object. Dynamic forces are the forces that move on an object at different speeds.

Figure 2.2 Accelerometer (source: https://opencircuit.shop/product/adxl345-3-axis-accelerometer-gy-291)

2.1.3 IR Sensor (Infrared Sensor)

Infrared (IR) Sensor Module is a distance proximity sensor "switch". When an object or barrier almost blocks the screen in front of two LEDs. It initiates an infrared transmitter-receiver module as shown in Figure 2.3. The clear LED is the IR transmitter while the black LED is the IR receiver. It uses the electromagnetism reflex principle where when the reflection surface (object) is closer, the recipient will accept stronger signal from transmitter due to shorter travel distance of reflected of wave. The IR Sensor Module includes a digit output main signal system. Digital Output is high or low, so this module may be used as a start button, though not as a distance meter [14]. It detects object or barrier within twenty centimeter in front of the transmitter-receiver IR LEDs.

Figure 2.3 IR sensor (source: https://sharvielectronics.com/product/ir-sensor-module/)

2.1.4 Pressure Sensor

A pressure sensor is a device that measures the pressure of a gas or liquid as shown in Figure 2.4. A pressure sensor usually acts as a transducer; it signals that the work is under pressure. For the objectives of this article, such a signal is electrical. Thousands of daily applications and pressure sensors are used to monitor and control. It can also be used to indirect measurement another variables like gas flow, water level, altitude_and_speed [14]. In other words, it is call pressure transducers, pressure indicators, pressure senders, piezometers, pressure transmitters and manometers, etc. There is also a type of pressure sensors designed to measure dynamically to catch very high-speed changes in pressure.

Figure 2.4 Pressure sensor (source: https://www.ato.com/digital-pressure-sensor)

2.1.5 Light Sensor

Light sensors are photoelectric engine that change illumination power produced to electrical power [14]. The light Sensor causes an output signal indicate the violence of illumination by measurement bright power that it is basically at a very narrow frequency range, called light. Light sensors are more popular known as photo sensors or photoelectric devices because the change light energy into electricity as shown in Figure 2.5.

Figure 2.5 Light sensor (source: https://www.intorobotics.com/common-budgeted-arduino-light-sensors/)

2.1.6 Level, Position and Magnetic Sensor

Level Sensor: Level and Flow switches for measuring dry materials or liquids, with current, millivolt or relay outputs. A level detector is a device for determining liquids or other substances, the level or number of fluids that flow in an open or closed system as shown in Figure 2.6.

Figure 2.6 Level sensor (source: https://cdn.sick.com/gb/en/fluid-sensors/level-sensors/lfv300/c/g149993)

Position Sensor: Position detectors are devices that determine its relative position measured from an established reference point or can detect the movement of an object as shown in Figure 2.7. This type of device can also be used to detect the absence of an object or its presence. Both off -the-shelf and custom position sensor solution is available featuring our main technologies, potentiometric, hall effect, magnet resistance, electrolytic.

Figure 2.7 Position sensor (source: https://www.dynapar.com/Knowledge/Position_Sensors/)

Magnetic Sensor: The hall detector uses a magnetic sensor to detect the presence and intensity of a region around a magnetic material. The output voltage of a magnetic sensor is directly proportional to the force of the field as shown in Figure 2.8. Magnetic sensors are used for positioning, current sensing applications, acceleration detection. Consumer goods are also often found in industrial application.

Figure 2.8 Magnetic sensor (source: https://sensormeasurement.com.au/sensor-products/magnetic-sensors-ex/)

2.1.7 Microphone, PIR Sensor, Strain and Weight Sensor

Microphone (Sound Sensor): The microphone sensor detects sound as shown in Figure 2.9. It gives a dimension of how loud is. There are a variety of these sensors. It has four points that needs to be connected Arduino board. Varieties of microphones use varying ways to fluctuate energy. All categories include a diaphragm, which is a thin section of material that it vibrates when shot by sound waves. Vibration of the diaphragm causes environmental part of the microphone to shake [15]. Conversion of these vibrations is delivered as a sound wave. The two most commonly used microphones are the variable condenser microphones and the dynamic.

Figure 2.9 Sound sensor (source: https://electropeak.com/sound-sensor-module)

PIR Sensor: PIR sensors are called Passive Infrared Detectors. This device can infrared that is produced by particles. PIR can detect the movement of an animal or a human within the required range determined by a separate sensor. PIR Sensor is an acronym for a passive infrared sensor used to document the need for human or particle movement within certain distance. This is called a motion sensor. IR sensors sense the motion of an object; It is always possible to know whether a person is moving within or outside the sensor distance. These are called PIR, Pyroelectric, Passive Infrared or IR motion sensors as shown in Figure 2.10.

Figure 2.10 PIR sensor (source: https://www.amazon.in/Generic-HC-SR501-Sensor-Pyroelectric-Infrared/dp/B00VNWWZM0)

Strain and Weight Sensor: A Strain gauge is a device that differentiates between force and electrical resistance. it converts tension, strength, weight, repression, etc., then a measurable change in endurance. A weight detector is a device that converts the quality signal into a measurable signal output as shown in Figure 2.11. When using the weight detector, we must first consider the actual working surrounding, it is very important for the right choice of the weight sensor.

Figure 2.11 Weight sensor(source:https://proto-pic.co.uk/product/load-cell-sensor-50kg/)

2.1.8 Ultrasonic Sensor (HC-SR04)

Ultrasonic sensor works by sending out a sound pulse at high frequencies that can be heard by humans. Then calculate the distance at the required time and wait for the sound to come back. They measure distance are easy to use and reliable and without damage. Ultrasonic sensor (HC-SR04) provides 2cm-400cm 0r 1" to 13 feet distance the action of measurement task carried out, the dimensional precise can reach to 3mm [15]. The modules include ultrasonics transmitters, receiver and control circuit as shown in Figure 2.12. The ultrasonic sensor acts as a microphone to send and receive the transducer sound. The transducer of the sensors, use a single transducer to receive the echo and to send a pulse.

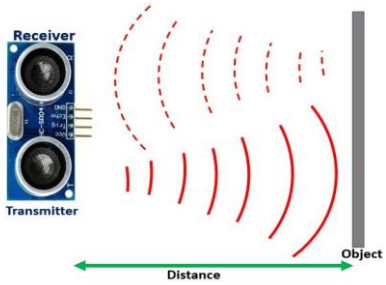


Figure 2.12 Ultrasonic Sensor (HC-SR04) working

(source: https://microcontrollerslab.com/hc-sr04-ultrasonic-esp32-tutorial/)

$$Distance = \frac{Time \times Speed\ of\ sound\ in\ air(\frac{343m}{s})}{2} \quad (2.1)$$

Ultrasound Technology: The transducer sensor is one of the best technologies used for sensing the block. The ultrasonic sensor module "HC-SR04" works on "Echo"

concept which is something you get when sound come back after reaches the surface [15]. The travelling time of acoustic waves is 343m/s. Practically the waves come back from the surface located four meters away in 15 ns. The sound wave not effective the humans. This sensor is widely used for distance measurement application. The ultrasonic sensors can be identified the barriers present in front of them. The transducer sensors generate sound waves with higher frequencies that humans cannot perceive, making them ideal for quiet environments. They do not use a lot of electricity, are relatively inexpensive, and are simple in design.

HC-SR04 Sensor Features:

- Operating voltage: +5V
- Accuracy: 3mm
- Theoretical Measuring Distance: 2cm to 450cm
- Practical Measuring Distance: 2cm to 100cm
- Measuring angle covered: < 15°
- Operating Current: < 15mA
- Operating Frequency:40Hz

Advantages of Ultrasonic Sensor: It has sensing capability to sense all types of products. This sensor is not affected due to rain, atmospheric cushion, snow etc. It may work in any bad conditions. It has higher sensing distance compare with to capacitive and inductive proximity sensor categories. In this system, the ultrasonic sensor in mainly use to detect the barrier and handle the directions (left, right, straight forward, stop).

2.2 Actuators

An actuator is a part of a machine that helps it to achieve physical activity by energy conversion, often hydraulic, electrical, or air, into mechanical force. The examples of actuators include:

- Electric motors: An electric motor is an electrical equipment that exchange electric power into industrial power. Electronic motors are a device component or a device that translates electrical energy into the process of moving, like those

found in an electric mixing machine used in food preparation for liquefying, or freezers, includes at least one device. Actuators are also used in electric cars.

- Stepper motors: This motor is known for acceptance digital pulses and converting them into mechanical activity. Stepper motors can be used in smart devices, robots, or it can be seen in automatic cutting tools. A stepper motor is a lacking a brush, electric motor that change digital into mechanical.
- Hydraulic cylinders: They are linear-movement machines that operate using a rod, pipe, and conduit. A large number of vehicles are in operation using hydraulic the process of moving like excavators, bulldozers, or backhoes.

2.2.1 DC motor

Direct current motor is a device that converts electrical power into mechanical power in the design of rotation. This motion is made by the physical manner of electromagnetisms. DC motors have inductors inside, which produce a region around a magnetic material used to generate movement. It is one of two basic types of motors; the other type is the alternating current or AC motor as shown in Figure 2.13. DC motor is controlled with voltages and it can be active ahead and rear according to the polarity of the voltage applied. A gear motor is a producing electricity motor type that is pattern to produce high torque while maintaining a low speed, motor output. The gear device can change the torque, speed, and direction. Two DC motor are used for forward and backward, one DC motor is used for turning left and another DC motor is used for turning right.

Figure 2.13 DC motor (source: https://ram-e-shop.com/product/ro-wheel-motor-dg01d/)

2.2.2 Pulse Width Modulation

There are several ways to supervise the speed of direct current motors but easy way is to use Pulse Width Modulation and one very simple. Digital signals have two signs: off or on, abbreviated as 0 or 1. Analog signals, can be half-way, on, off, two-thirds the way to on, and an infinite number of positions between 0 and 1 either 1 or descending down to zero. The two ways are handled very differently in electronics is very different, but very often must work together. An analog input into digital input for the embedded controller by using an analog-to-digital converter.

PWM is a way to control analog tools with a digital output. Another way to put it is that may output a signal from a digital device like an MCU to drive an analog device. It's one of the primaries means by which MCUs drive analog tools such as speakers, dimmable light, variable-speed motors, and actuators. The voltage is being applied and then removed a lot of times in between, but what you experience is an analog-like response. The motor does not stop immediately due to inertia, and so by the time you use the power again it has only slowed a bit.

Duration of time that a pulse is in a given situation (high/low) is the "width" of a wave. A machine driving by PWM end of action like the average of the pulses. The average voltage level can be a moving target or a steady voltage. The term duty cycle is used elsewhere in electronics, but in every duty-cycle is a comparison of "on" and "off." The motor to go faster, can drive the PWM output to a higher duty cycle. The higher the frequency, the higher the average voltage and the faster the motor, the more it runs. The duty cycle and multiply it by the high voltage level, will get the average voltage rating that the motor is seeing at that time**.**

$$Average\ Voltage = Duty\ Cycle\ \times High\ Voltage\ Level \tag{2.2}$$

2.2.3 Motor Driver

A DC motor driver circuits are current amplifiers. Motor driver are circuit used to run a motor. Motor drivers acts as an intermediary the motors and the control circuits. They act as a bridge between motor drive and the motor in the controller. Motor requires high current whereas the controller circuit jobs on low current. The function

of the circuit is to change 0 signal to 1 signal. Maximum current of microcontroller output is not enough to drive motor coil. The function of the motor drivers is to convert the motor that can drive the motor into a high current signal [24].

2.2.4 L298N Motor Driver

- The L298N H-bridge module can be used with motors that have a voltage between 5V and 35V DC with a peak current up to 2A.
- It is double H-bridge drive and its max power is 25W.
- L298N H-bridge motor board is typically used to control the speed and heading of motors.
- It can also be used to control brightness of certain lighting system like high-powered LED arrays. The L298N motor driver as shown in Figure 2.14.

Figure 2.14 L298N motor driver pinout (source: https://techmartgh.com/product/l298n-motor-driver/)

2.3 Summary

This chapter discuss the sensors that are used in Embedded System design. The ultrasonic sensor and microcontroller are mainly used in the Barrier Avoidance Robot. This L298N motor driver is used for controlling the direction that can turn exactly directions.

CHAPTER 3

FUZZY LOGIC TECHNIQUES IN CONTROLLERS

Fuzzy logic is a technique to represent and manipulate inaccurate information. Fuzzy logic is a general statement of criterion logic, in which a concept can possess a degree of truth anywhere between 0.0 and 1.0 [9]. The robot main control device is an only one microcontroller that controls all capabilities of the robot. A fuzzy logical structure is used to control the angular speed of left and right wheels.

3.1 Fuzzy Control

Fuzzy controllers are very simple. They include of an input step, a processing step, and an output step. The input step sensor to the appropriate membership functions and the values of truth. The processing step put into effect each appropriate rule and a result for each, then unites the results of the rules. Finally, the output step change religion the combined result back into a specific control output value. The most common form of membership functions is trapezoidal, triangular and bell curves are also used. The processing step is based on a concentration of fuzzy logic rules in the form of IF-THEN statements, where the IF portion is known as the "antecedent" and the THEN portion is called the "consequent"[16]. This fuzzy control systems have eleven of rules.

A fuzzy system is a control system based on mathematical system that analyzes analog input values in terms of logical variables that take on values between 0/1, in contrast to digital logic or classical, which does on discrete values of either 1 or 0. The Arduino Software (IDE) are called Arduino Integrated Development Environment. It is containing a text editor for a message area, writing code, a message area, a toolbar with buttons for common functions, menus and a text button. It connects to upload programs and communicate with them to the Arduino hardware. Programs written using Arduino Software is known as sketches**.**

The Arduino Integrated Development Environment can be extended through the use of Libraries, just like most programming platforms, to provide extra

functionality to sketch. Libraries are files written in C or C++ which provide your Arduino Software with extra functionality. The robot has four wheels powered and controlled using Pulse Width Modulator to control DC motors and provided for calmness of the mobile robot. Simulations are performed to approve probability and the quality of being efficient of proposed control technique using eFLL fuzzy library.

3.2 Fuzzy Logic Controller

Fuzzy Logic Controller is a method for determining an irregular. Intelligent fuzzy logic controller for intelligent robot enables the robot to avoid the barrier and improve target seeking ability. While moving towards the barrier avoidance way to go, the robot changes its direction. Three inputs of membership function in fuzzy logic controller are near, medium and far and using three distance ultrasonic sensor for distance from robot to left sensor, right sensor, center sensor the barrier. Fuzzy logic is a basic control system which trusts on the degrees of state of the input and the output take refuge in the state of the input and rate of change of this state. Fuzzy Logic is a problem-solving control system methodology. It incorporates a simple, rule-based IF A AND B THEN X approach to a solving control problem. The functions which take part in the rule-based system is called Membership Function. The values that are generated by Membership functions are called Linguistic Variables. It can be especially important when high precision or accuracy in a measurement is quite costly. Three main part processes Fuzzy Logic System design are

(1) Fuzzification Unit
(2) Fuzzy Inference Engine
(3) Defuzzification

This process is shown in Figure 3.1[4].

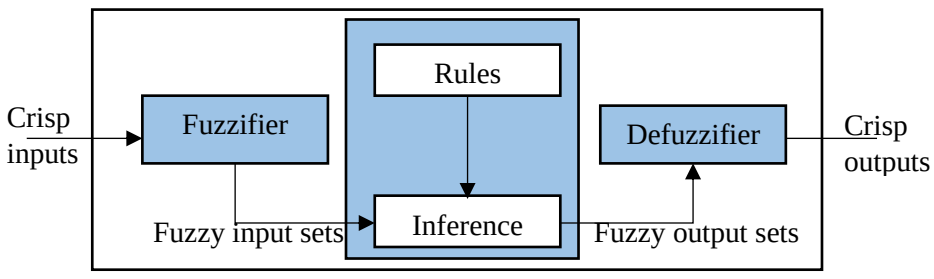


Figure 3.1 Fuzzy Logic System

3.2.1 Fuzzy Logic

Fuzzy Logic is an extension of traditional Boolean logic, using linguistic variables allows to express logical values between FALSE and TRUE, describing with greater efficiency the uncertainty principle in the real world.

3.2.2 Fuzzy System

Fuzzy Systems are practical applications that employ Fuzzy Logic in its decisions making on the basis of linguistic variables and terms, the robotics and the electronic engineering has a large utility room.

Fuzzy Inference Systems implement in Microcontroller: Fuzzy Inference Systems take inputs and process them based on the prespecified rules to produce the outputs. Both the inputs and outputs are really valued, whereas the inner parts processing is based on arithmetic and fuzzy rules.

Fuzzy Rule-Based System: Fuzzy rule-based systems are one of the most important areas of application of fuzzy sets and fuzzy logic [30]. The use of fuzzy statements, it is a key component of the rule allows capturing and handling the potential uncertainty of the represented knowledge. The analysis will begin by thinking the two main conceptual components of these systems, knowledge, and reasoning, and how they are represented. Then, a review of the main structure to fuzzy rule-based systems will be considered. Hierarchical fuzzy systems will also be analyzed. Once defined the structure, parts and approaches to those systems, the design question will be considered. Fuzzy Inference is the process of a mapping from input set to output set using fuzzy logic. The basic rules used in fuzzy logic are "if ... then ..." the basic rules are determined according to the desired output.

3.2.3 Embedded Fuzzy Logic Library (eFLL)

Embedded Fuzzy Logic Library is a standard library for microcontroller-based systems to implement easy and efficient fuzzy control systems [2]. The Embedded Fuzzy Logic Library is able to adapt to many different functions, lightweight and efficient option to job with fuzzy logic in embedded systems. This library provides

easy access to Arduino robot functions. This library is reasonable with all architectures [30].

3.2.4 Fuzzification Unit

Fuzzification is the process of converting a crisp set value to a fuzzy set value that is performed by the use of the information in the knowledge base. Fuzzification is the various types of curves can be seen in literature, Gaussian, triangular, and trapezoidal are the most used in the fuzzification process [29]. This operation translates accurate crisp input value into linguistic variables as shown in Figure 3.2 sensor detection. This system is calculated using the min-max method to fuzzy.

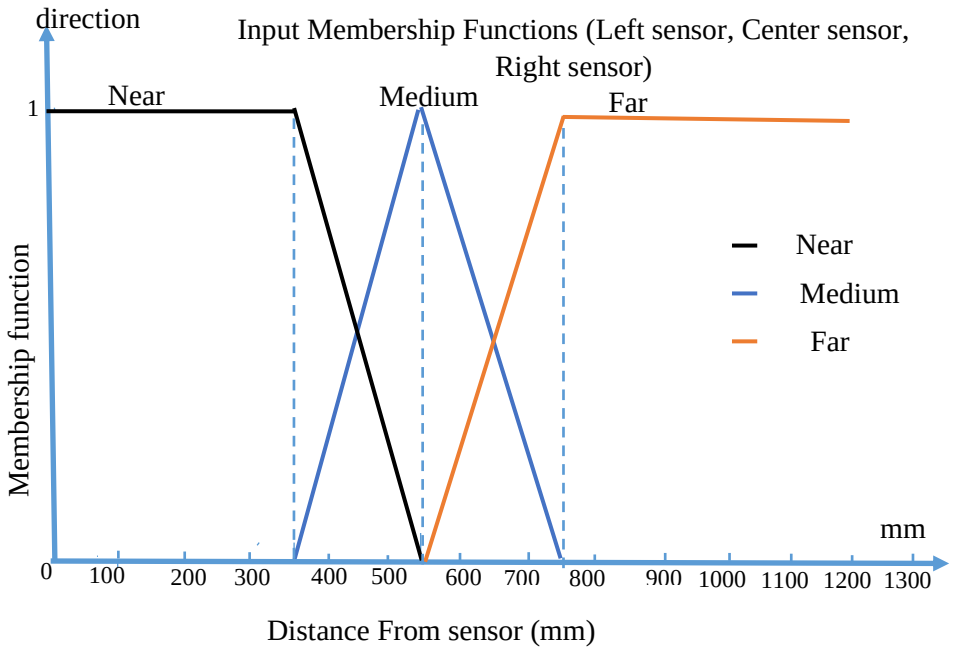


Figure 3.2 Sensor detection

3.2.5 Defuzzification Unit

Defuzzification is the process of inverse a fuzzified output into the value is either 0 or 1 with respect to a fuzzy set. The defuzzied value in FLC (Fuzzy Logic Controller) represents the action to be taken in controlling the process. Mathematically, the process of defuzzification is also called rounding it off [26]. Defuzzification is the process of converting the degrees of membership of output linguistic variables within their linguistic terms into crisp numerical values as shown in Figure 3.3. There are several different ways of defuzzification available, including the following:

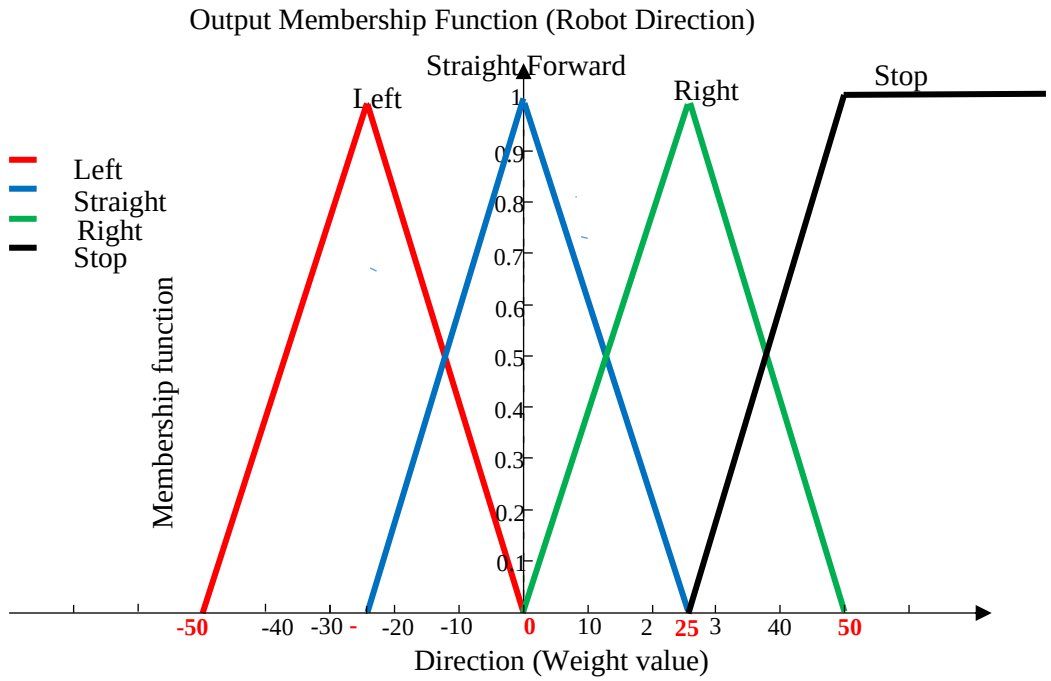


Figure 3.3 Robot direction

Different Defuzzification Methods: The following defuzzification methods are known to calculate crisp output [11].

1. Center of Sums Method (COS)
2. Center of gravity (COG) / Centroid of Area (COA) Method
3. Center of Area / Bisector of Area Method (BOA)
4. Weighted Average Method
5. Maxima Methods

Maxima Method (Height Method): This method is based on Max-membership principle [11] and defined as follows:

$$\mu_C(x^*) \geq \mu_C(x) \text{ for all } x \in X \qquad (3.1)$$

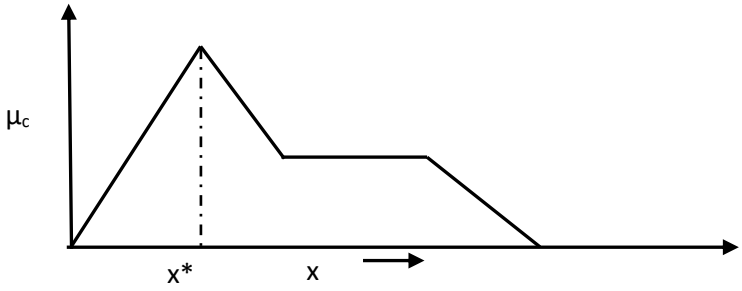


Figure 3.4 Height method sample

x* is the height of the output fuzzy set C. This method is applicable when height is unique as shown in Figure 3.4, Figure 3.5, Figure 3.6 and Figure 3.7.

Type of Maxima Methods (Height Method) are

- First of Maxima Method (FOM)
- Last of Maxima Method (LOM)
- Mean of Maxima Method (MOM)

First of Maxima Method (FOM):

$$x^* = \min\{\frac{x}{C(x)} = max_w C\{W\}\} \quad (3.2)$$

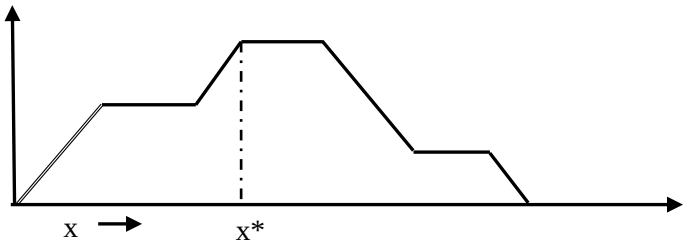


Figure 3.5 First of maxima method sample

Last of Maxima Method (LOM):

$$x^* = \min\{\frac{x}{C(x)} = max_w C\{W\}\} \quad (3.3)$$

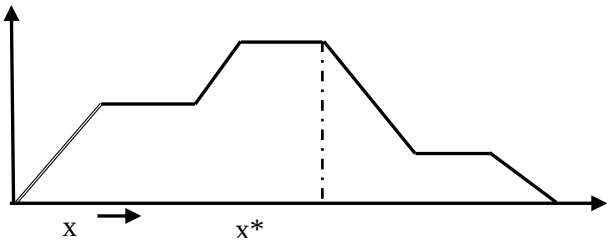


Figure 3.6 Last of maxima method sample

Mean of Maxima Method: MoM is also synonymous to middle of maxima. MoM is also general method of Height.

$$x* = \frac{\sum_{xi \epsilon M}(xi)}{|M|} \quad (3.4)$$

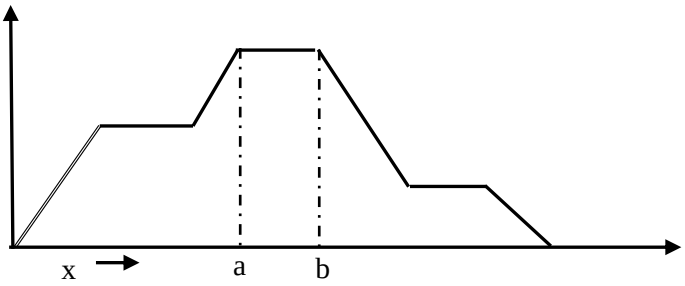


Figure 3.7 Mean of maxima method sample

This system uses the First of Maxima Method (FOM) in the maxima-method.

3.3 Microcontroller

A microcontroller is a compact integrated circuit designed to administer a unique operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip as shown in Figure 3.8. Sometimes referred to as microcontroller unit (MCU) or an embedded controller, microcontrollers are found in robots, vehicles, medical devices, office machines, home appliances, vending machines, and mobile radio transceivers, among other devices [7].

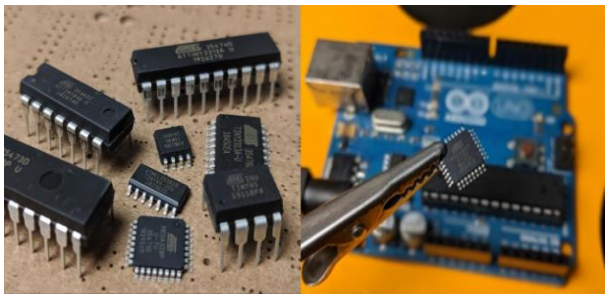


Figure 3.8 Difference types of microcontrollers

(source: https://maker.pro/custom/tutorial/attiny-microcontrollers-a-low-cost-arduino-alternative)

They are essentially simple miniature personal computers (PCs) designed to control small features of a larger component, without a complex front-end operating system (OS) [19]. Microcontroller is a microprocessor based electronic device that can be deployed for real-time applications and can be programmed [7].

A microcontroller is embedded within a system to control a few functions in a device. It does this by interpreting data it receives from its I/O peripherals using its central processor [5]. The impermanent information that the microcontroller accepts is stored in its data memory, where the processor accesses it and uses instructions stored in its program memory to decipher and apply the incoming data. It then uses its I/O peripherals to communicate and provision the appropriate action. A microcontroller's processor will vary by application. Options section from the simple 4-bit, 8-bit or 16-bit processors to more complex 32-bit or 64-bit processors. Microcontrollers can use volatile memory types such as random-access memory (RAM) and non-volatile memory types [19]. This includes flash memory, electrically erasable programmable read-only memory (EEPROM), and erasable programmable read-only memory (EPROM).

3.3.1 Components in Microcontrollers

Flash Memory: Flash Memory is a special type of unstable memory that, unlike RAM, save its data for an expand term, when the computer's power is close, memory will maintain its contents.

EEPROM: EEPROM is like Flash Memory, being a non-volatile memory and retaining its data even after shutdown. The difference is that, while EEPROM can re-write any specific, byte Flash Memory re-writes a "block" of bytes at any time.

I/O Ports: I/O ports are what the microcontroller uses to connect to real-world applications. Inputs receive changes in the real-world, from push buttons, to motion sensing, to temperature sensing, and much more. The input then goes to central processing unit (main processor) and give a decision what to do with that information. When it's time to do a sure command based on a sure value from the input, it sends a signal to the output ports, where it can range from a simple LED light going off, to running a motor for a sure part, to many more [7].

3.3.2 Arduino UNO Microcontroller Board

Arduino board is an open-source electronics platform use to make software and hardware. It consists of instructions microcontroller and Arduino software or Integrated

Development Environment (IDE), based on processing. Arduino 1.8.3 version is used for hardware configuration and the programming language.

The code is written in Arduino (IDE) using C language, it is upload to Arduino (IDE) and result output is obtain on serial monitor. The platform of an Arduino has become students or very famed with designer just starting out with electronics, and for an extremely good cause. Arduino board is basically a single-board microcontroller with a microprocessor and input and output points. They get interfaced with any other devices such as blue tooth, during implementation.

The Arduino Uno is a single-board microcontroller based on the ATmega328. It has 20 digital input and output pins (of which 6 can be used as analog inputs and 6 can be used as PWM outputs), a reset button, a USB connection, an in-circuit system programming (ICSP) header, a power jack and a 16 MHz resonator. Arduino UNO board is shown in Figure 3.9.

Figure 3.9 Arduino UNO Board (source: https://moonpreneur.com/tech-corner/problems-with-arduino-uno-on-macos-solutions/)

Arduino is an open-source electric platform based on straightforward and simple to use software and hardware. To do so you use the Arduino Software (IDE), and the Arduino programming language (based on Wiring), based on Processing. A worldwide community of makers - professionals, artists hobbyists, programmers, and students - has gathered around this open-source platform, their contributions have added up to an impossible to believe amount of able to be reached knowledge that can be of great help to novices and experts alike.

As soon as it arrived a vaster community, the Arduino board started changing to make suitable to new needs and challenges, differentiating its offer from simple 8-

bit boards to products for IoT applications, wearable, 3D printing, and embedded environments [17]. The software, too, is open-source, and it is growing through the contributions of users worldwide as shown in Figure 3.10.

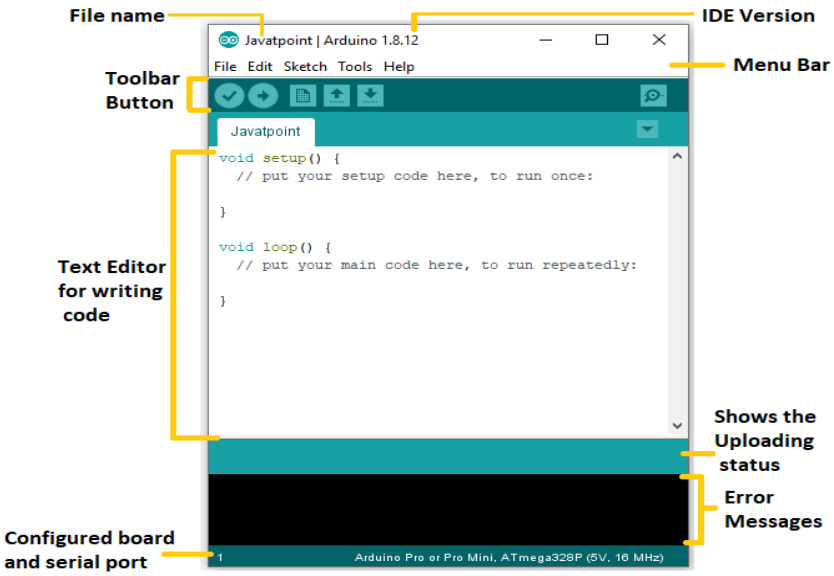


Figure 3.10 Arduino Integrated Development Environment (source: https://www.javatpoint.com/arduino-ide)

Arduino board has been used for thousands of different applications and different research. Arduino software is very simple and easy-to-use for begin leaner, yet flexible sufficient for users. It runs windows, Linux and Mac. The Arduino Board runs Linux, Mac and window. The Arduino board also makes simpler the working process of microcontroller, but it gives some advantages the other systems for the first beginners, teachers, students. Arduino is an open-source electronics platform based on straightforward and simple to use hardware and software.

CHAPTER 4

SYSTEM DESIGN AND IMPLEMENTATION

The robot uses an ultrasonic sensor to detect the nearest level 35, intermediate 36 to 75, above 75 is considered the farthest distance. The robot uses an ultrasonic sensor to detect if there is a barrier in the path, and it combines the fuzzy controller and microcontroller to determine which direction to go and changes direction from the DC motor. When the robot detects a barrier in its path, it stops, turns a few centimeters back, look left and right, and then turns to the direction indicated by the extra space in front of it.

4.1 Design of the System

The system flow is shown in Figure 4.1. In this system, four main portions are involved:

1. Input sensor
2. Fuzzy controller
3. Microcontroller
4. Direction of the output

First, it uses a sensor for input and sends the resulting data to a fuzzy controller. Then, the detectable inputs are converted to crisp values, which are checked using a fuzzy rule-based system and the result is converted back to defuzzified. After that, the output is fed back into the microcontroller as input. Finally, the output is displayed as the orientation of the machine.

Hardware components included in this system are:

(1) Arduino UNO R3
(2) L298N motor driver
(3) 4× 6V DC motors for 4 wheels
(4) 3 Ultrasonic sensors
(5) 3× 4V Lithium-Ion Battery model: 18650
(6) 1 battery holder
(7) Car Chassis
(8) Jumper wires

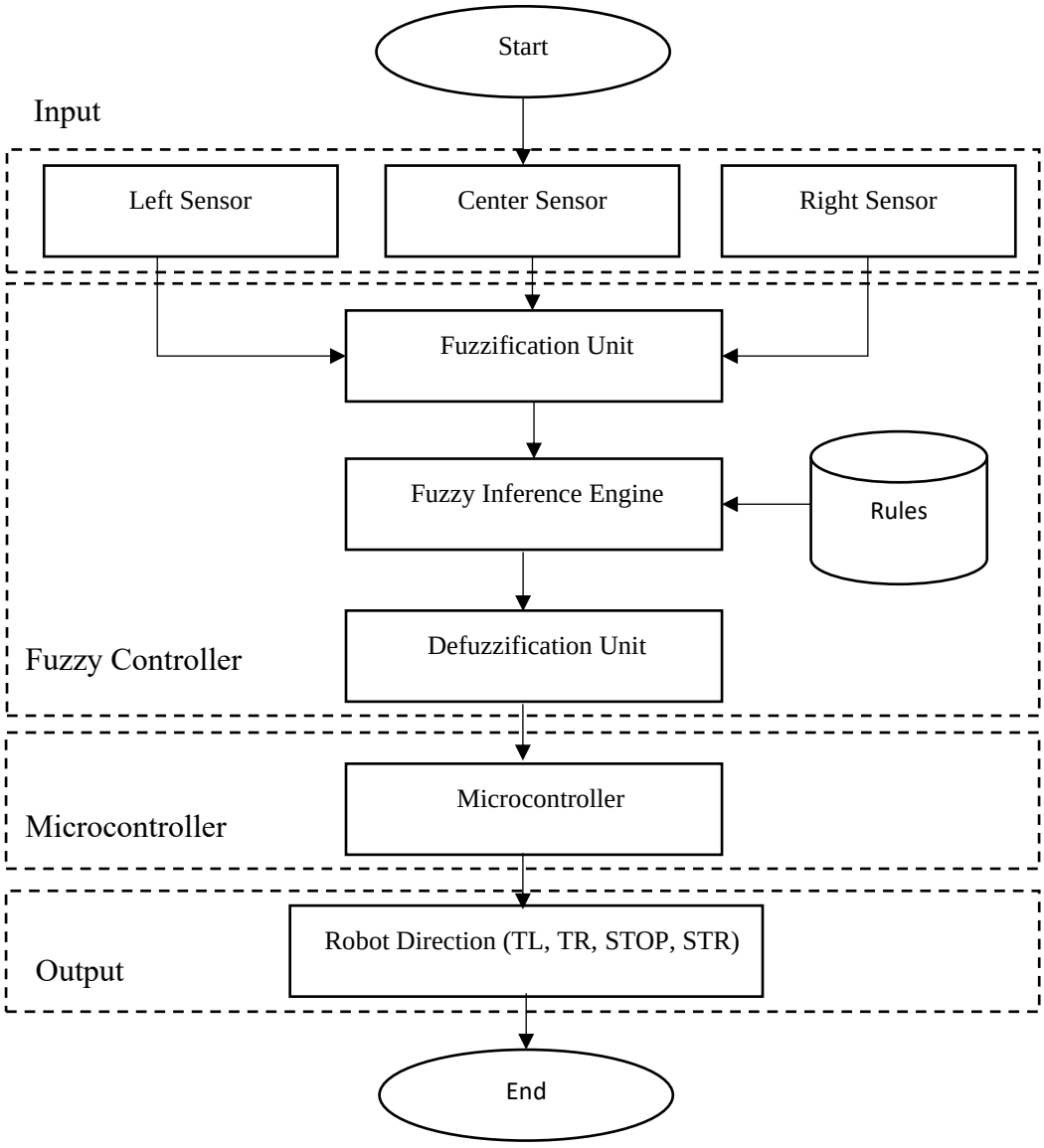


Figure 4.1 Proposed system design

4.1.1 Working Principle of the System

Depending on the condition of the mobile robot is able to choose the true path. A determination makes process of barrier avoiding the outside limit of an object area detection occurs as a result of a sudden impulse and without premeditation [20].

Step1. Start

Step2. Is any barrier?

(a) If yes, move robot backward and go away step 3.

(b) No, robot straight forward.

Step3. Range measurement to move right or left.

IF left distance > right distance

(a) Yes, move left

(b) No, move right

Step4. Continuous step 2.

Step5. If power down (or) barrier is in all direction go to step 6.

Step6. Stop

4.2 System Implementation

There are two parts in system implementation. These are software implementation and hardware platform.

4.2.1 Software Implementation

In this proposed system, the software is developed by using C++ language and eFLL fuzzy library. There are three ultrasonic sensors, so based on 27 inputs, starting from a possible fuzzy rule 53-point situation, the experimental result is obtained as shown in Figure 4.2. This error occurs because the memory storage on the Arduino UNO board is full. The test result with Figure 4.2 to 4.6 is the result error.

Test started with rule 53 as shown in Figure 4.2. The output result error can no longer be displayed.

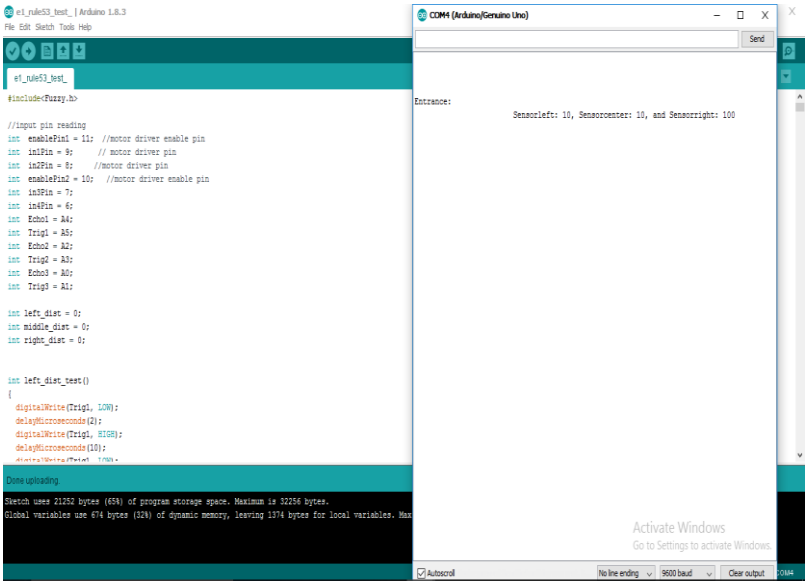


Figure 4.2 Test result with 53 rules

Then, the tested with rule 36 using fuzzy rule-based system is compared with random input and output result as shown in Figure 4.3. When input random value, **all result errors output** shown in 0.00.

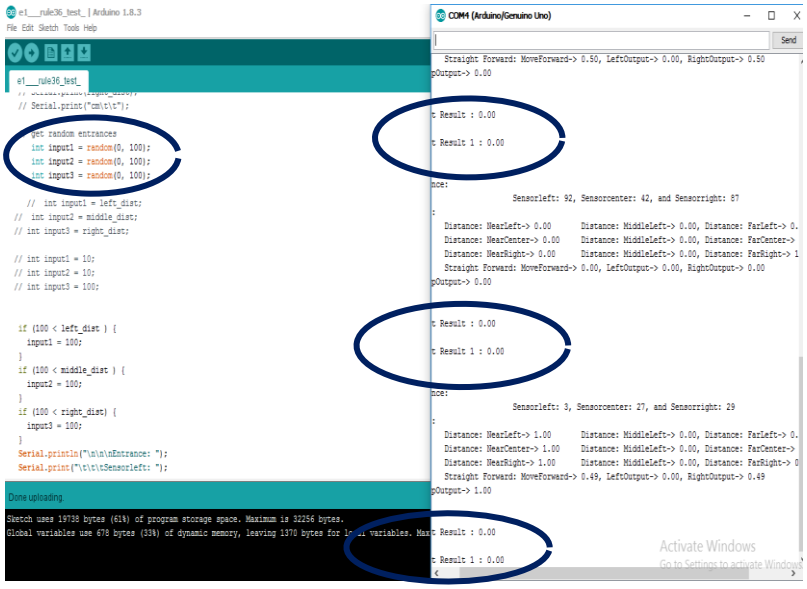


Figure 4.3 Test result with 36 rules

Next, it is tested it by adding rule 27 and then testing it several time step by step as shown in Figure 4.4. When three input random value, all **result output error** shows 0.00.

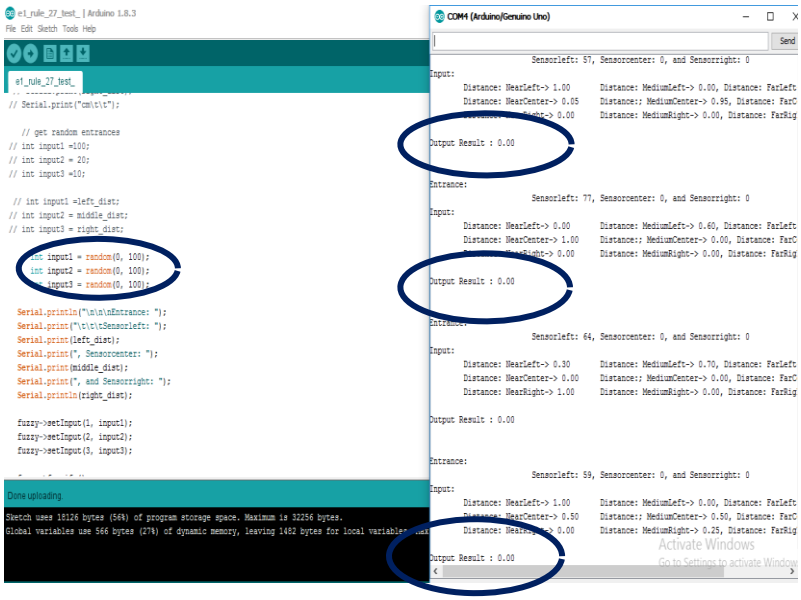


Figure 4.4 Test result with 27 rules

The 14 rule-based is reduced and tested several step by step as shown in Figure 4.5. When three input random value, all **result output error** shows 0.00. The output result is not valid.

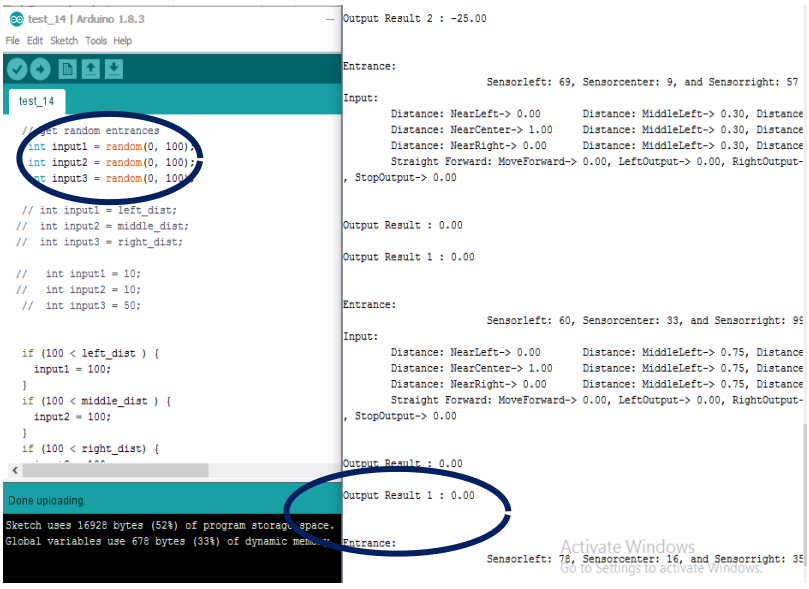


Figure 4.5 Test result with 14 rules

Then, the 13 rule-based is reduced and tested as shown in Figure 4.6. The output result error can no longer be displayed.

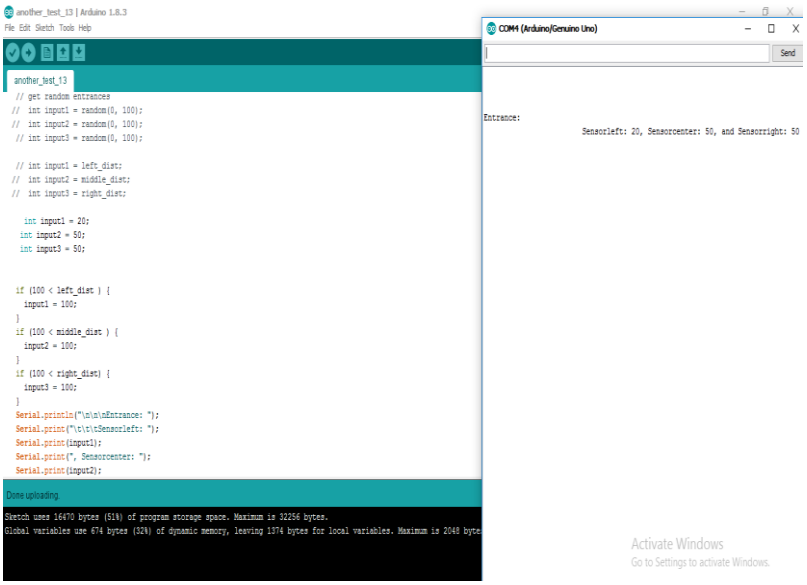
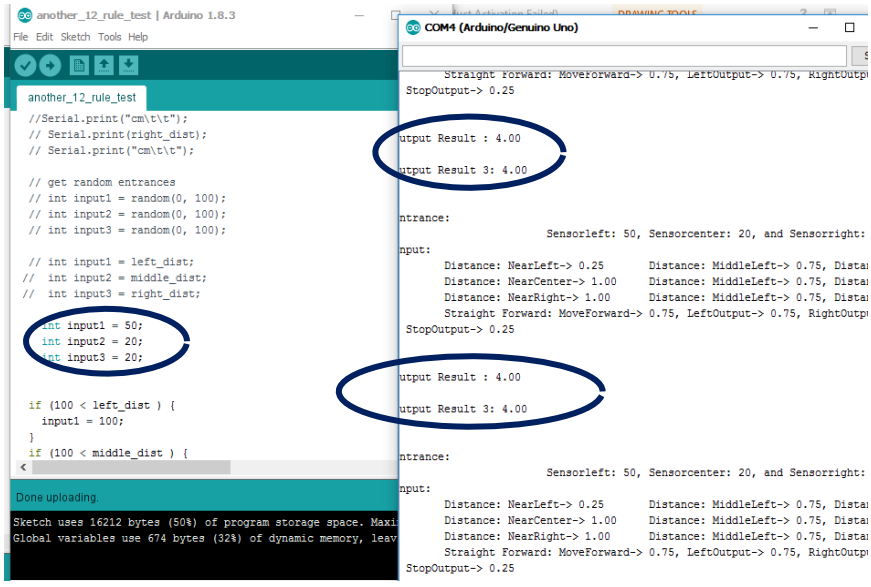


Figure 4.6 Test result with 13 rules

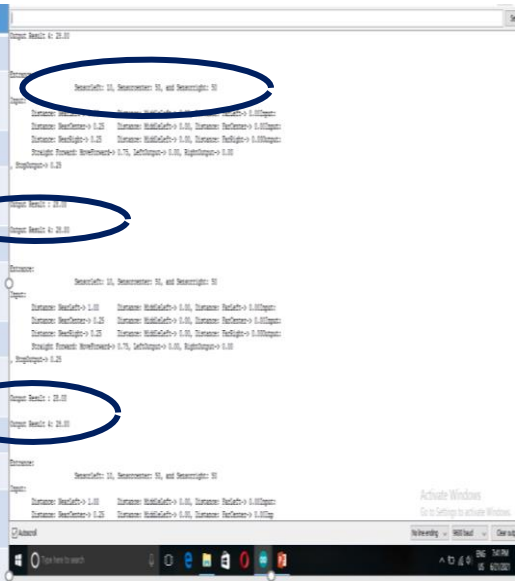
Then, the 12 rule-based is reduced and tested. The experiment with 12 fuzzy rule bases is done, but the output result is not valid as illustrated in Figure 4.7.



(a)input 1= 50, input 2= 20, input 3= 20, real output left direction between -35 and -25

After trying several times by adding 12 rules, the input and output did not match.

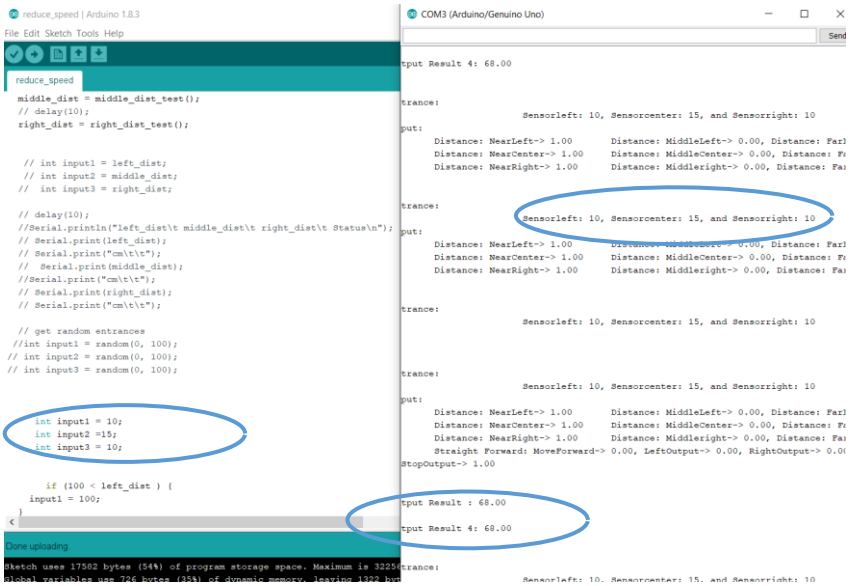
no	left	center	right	direction
1	near	near	near	stop
2#	near	medium	medium	Straight forward
3	near	far	far	right
4	near	far	far	Straight forward
5	medium	near	near	left
6	medium	medium	medium	Straight forward
7	medium	far	far	right
8	medium	far	far	Straight forward
9	far	near	near	left
10	far	medium	medium	left
11	far	far	far	Straight forward
12	near	medium	far	right



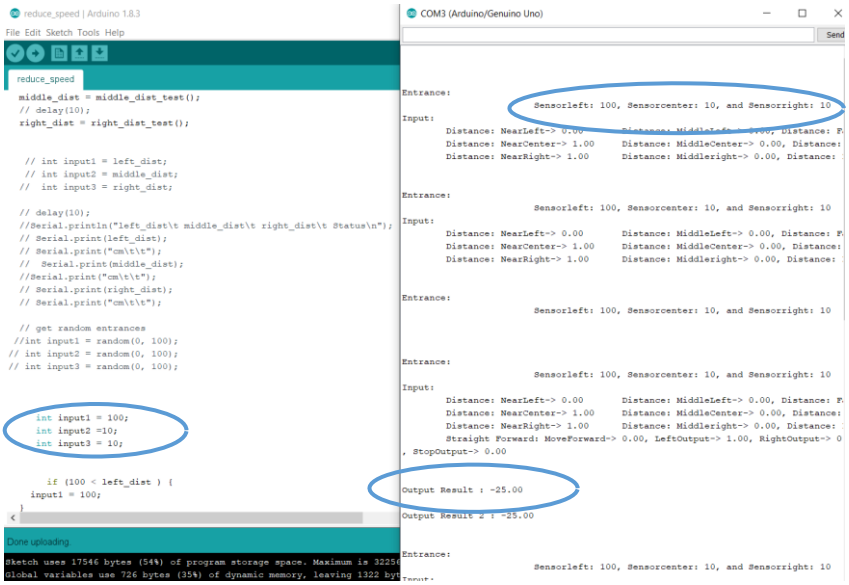
(b) input 1= 10, input 2= 50, input 3= 50, real output is 0.00 (straight forward)

Figure 4.7 Test result for rule 12

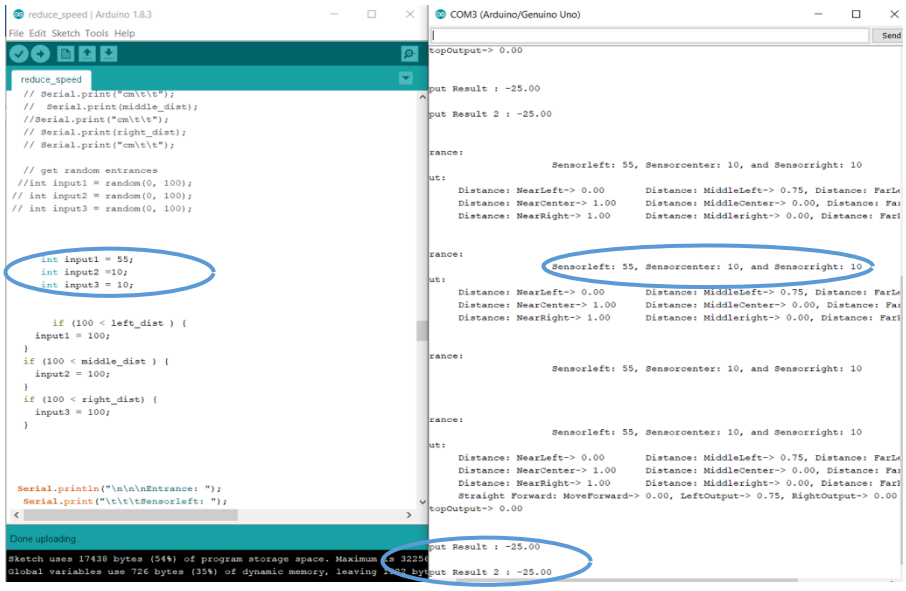
Then, the reduction and testing of the 11 rule-based are done the experiment with adding 11 fuzzy rule bases as illustrate in Figure 4.8. According to practical tests, the input and output results are correct.



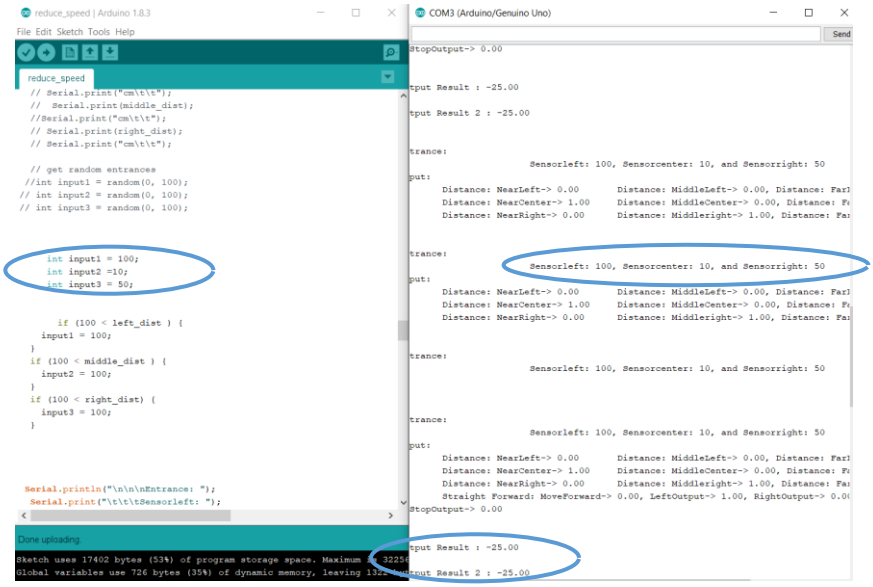
(a) input1= 10, input2= 15, input3= 10, real output result is stop (68)



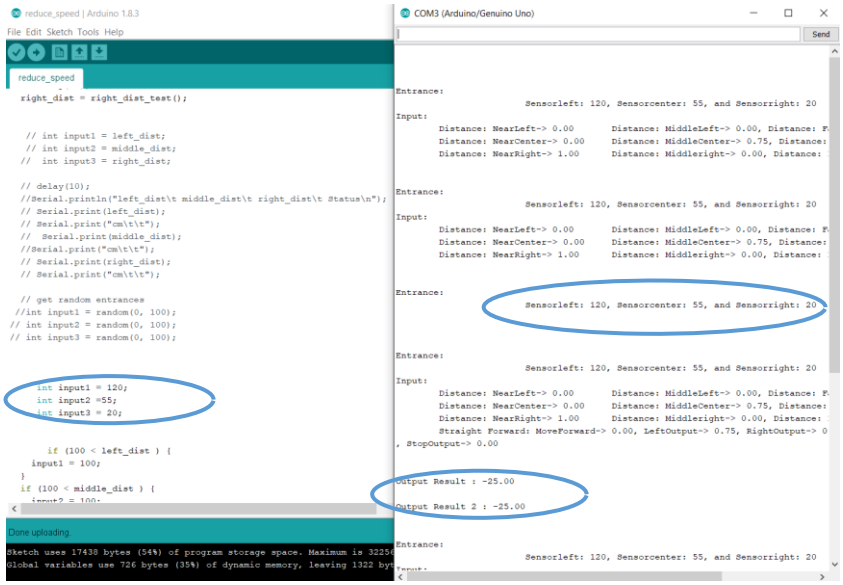
(b)input1= 100, input2= 10, input3= 10, real output result is left directiom (-25.00)



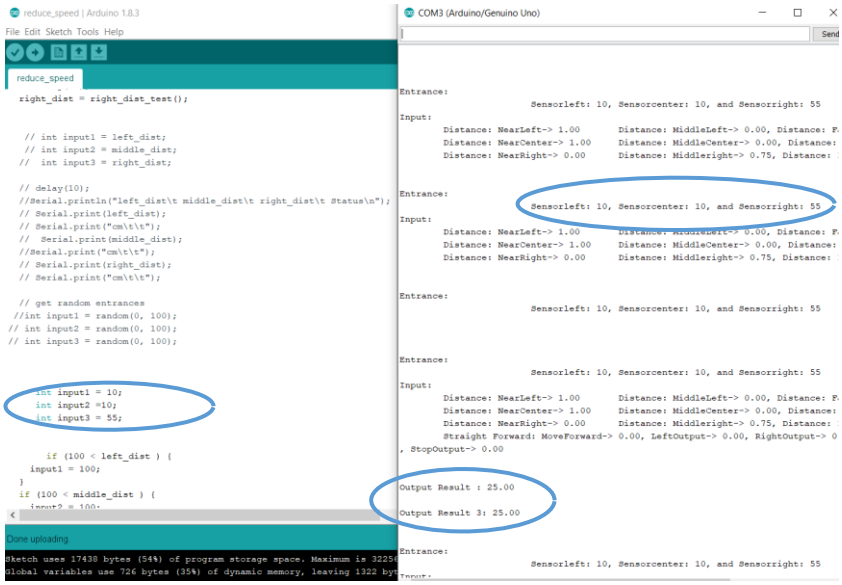
(c)input1= 55, input2=10, input3= 10, real output is -25.00 (left direction)



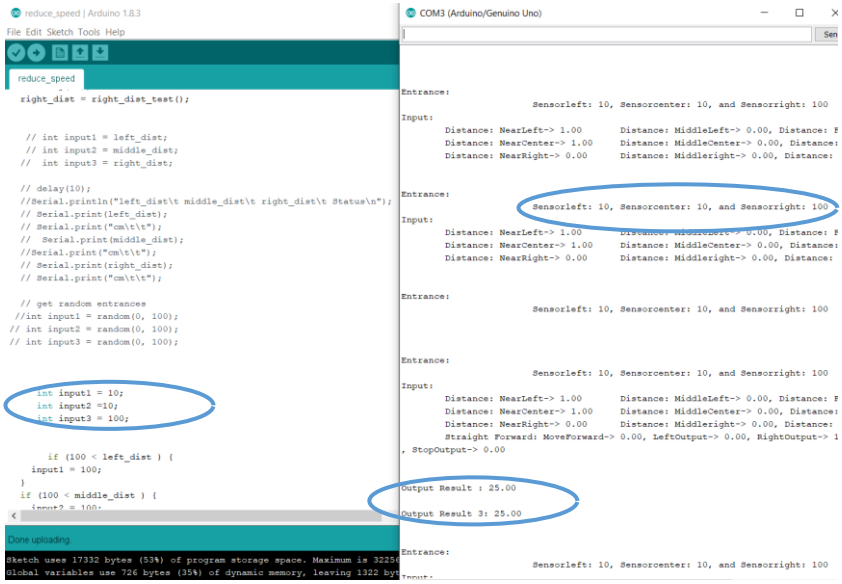
(d) input1=100, input2=10, input3=50, real result output is -25.00(left direction)



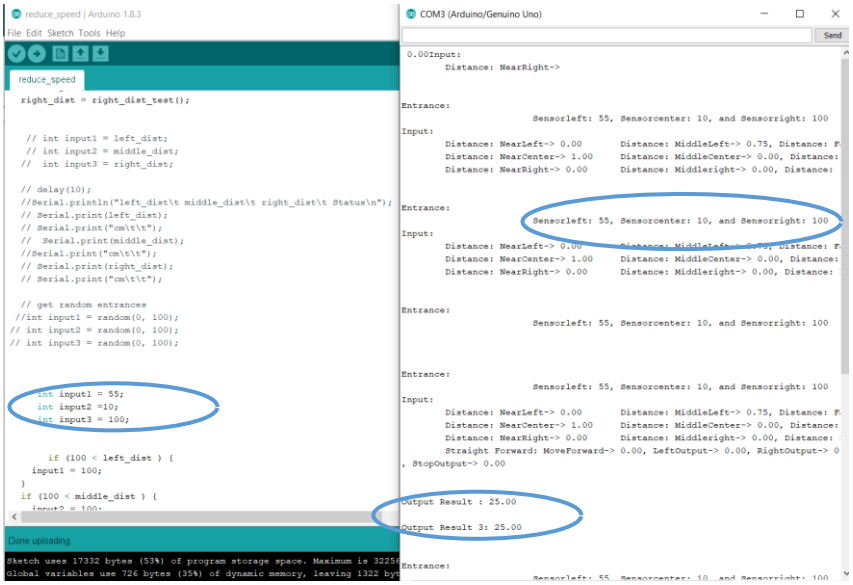
(e) input1=120, input2=55, input3=20, real result output is -25.00(Left direction)



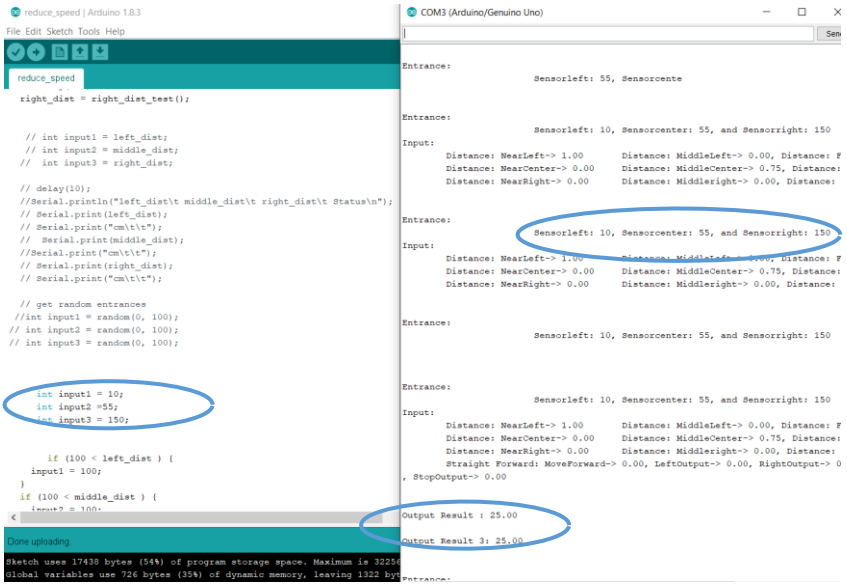
(f) input1=10, input2=10, input3=55, real result output is 25.00(right direction)



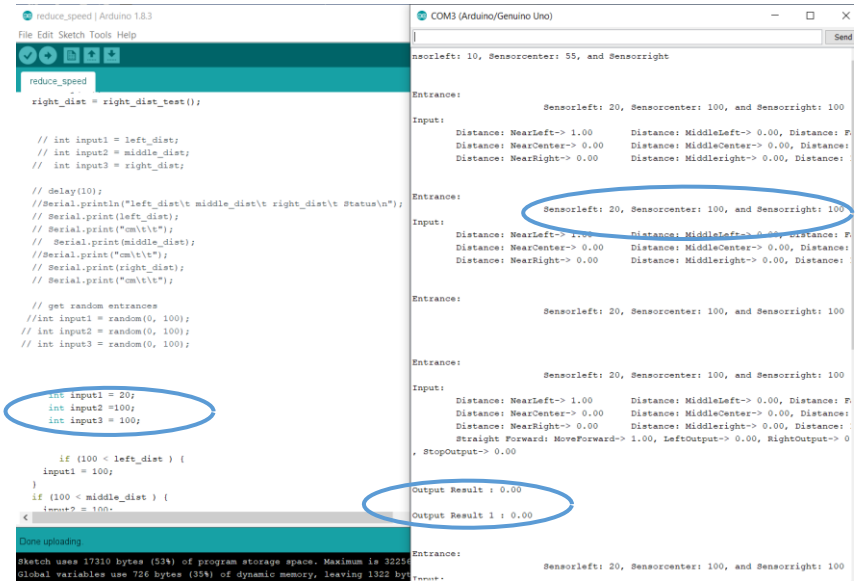
(g) input1=10, input2=10, input3=100, real result output is 25.00(right direction)



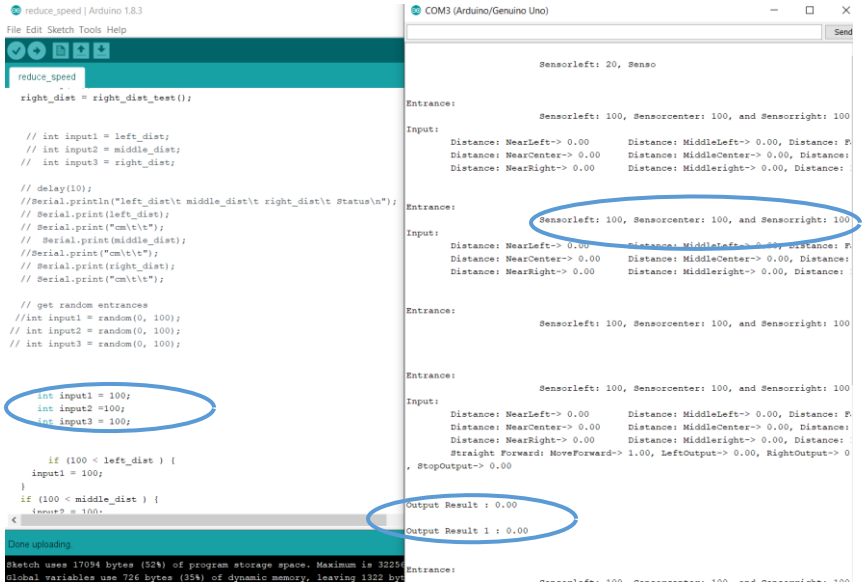
(h) input1=55, input2=10, input3=100, real result output is 25.00(right direction)



(i)input1=10, input2=55, input3=150, real result output is 25.00(right direction)



(j) input1=20, input2=100, input3=100, real result output is 0.00(straight forward direction)



(k) input1=100, input2=100, input3=100, real result output is 0.00(straight forward direction)

Figure 4.8 Test for rule 11

According to repeated tests, the best eleven rule is obtained as shown in Table 4.1 and calculation theory can be applied as illustrated in Table 4.2 and Table 4.3.

Table 4.1 Fuzzy rule based to the system

Rule	Left sensor	Center sensor	Right sensor	Direction of Robot Motion
1	Near	Near	Near	Stop
2	Far	Near	Near	Left
3	Medium	Near	Near	Left
4	Far	Near	Medium	Left
5	Far	Medium	Near	Left
6	Near	Near	Medium	Right
7	Near	Near	Far	Right
8	Medium	Near	Far	Right
9	Near	Medium	Far	Right
10	Near	Far	Far	Straight Forward
11	Far	Far	Far	Straight Forward

If Left sensor = 200mm, Near = 1, Medium = 0, Far = 0 as shown in Figure 4.9.

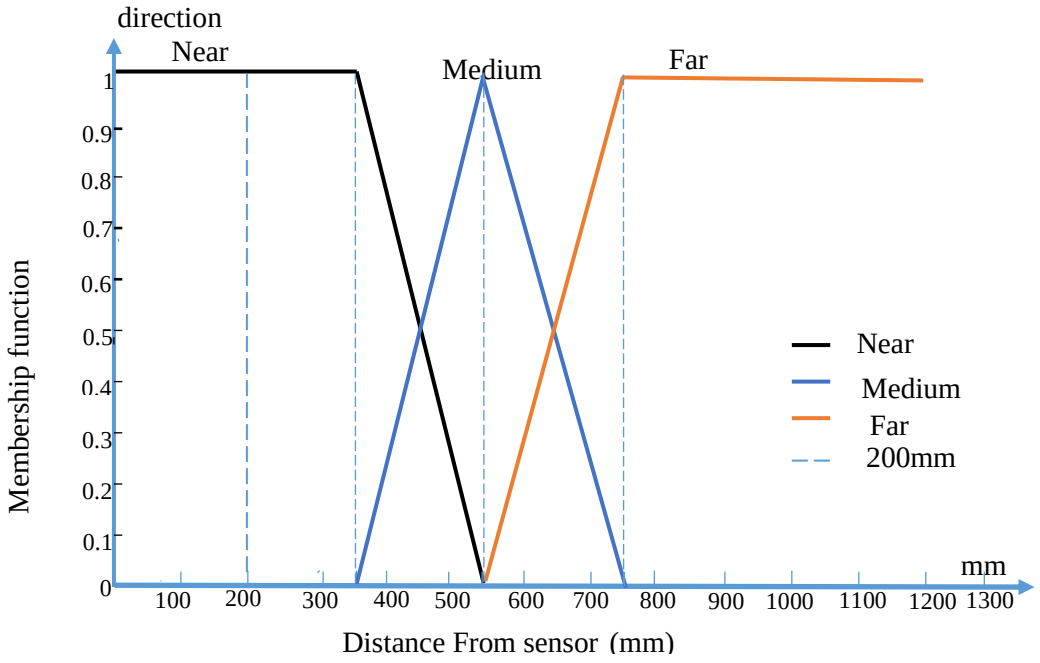


Figure 4.9 Membership function for left sensor

If Center sensor = 450mm, Near = 0.5, Medium =0.5, Far = 0 as shown in Figure 4.10.

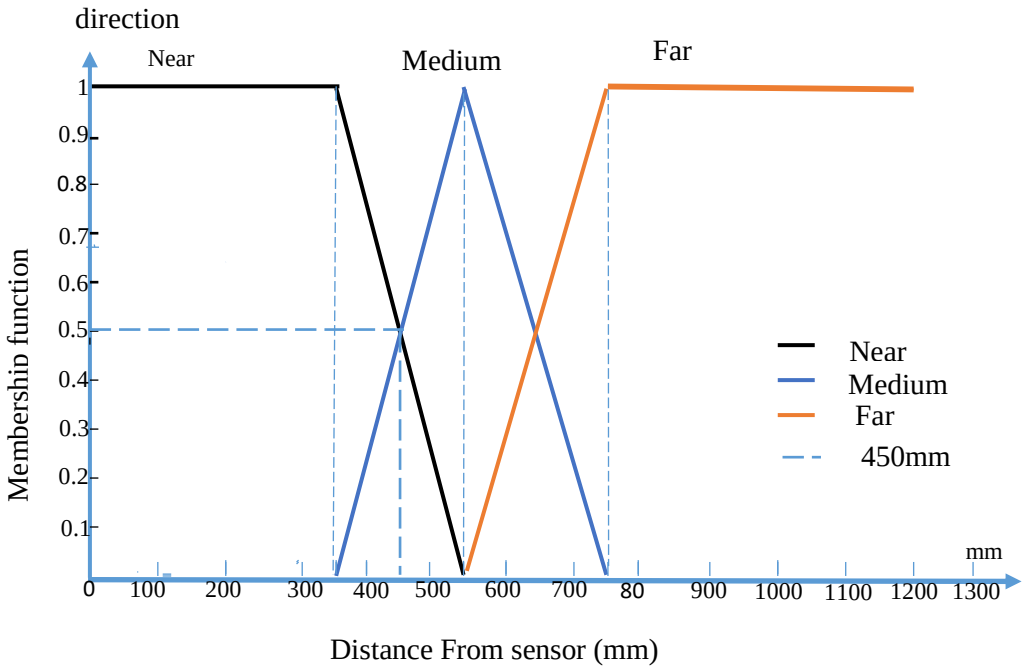


Figure 4.10 Membership function for center sensor

If Right Sensor = 550mm, Near = 0, Medium = 1, Far = 0 as shown in Figure 4.11.

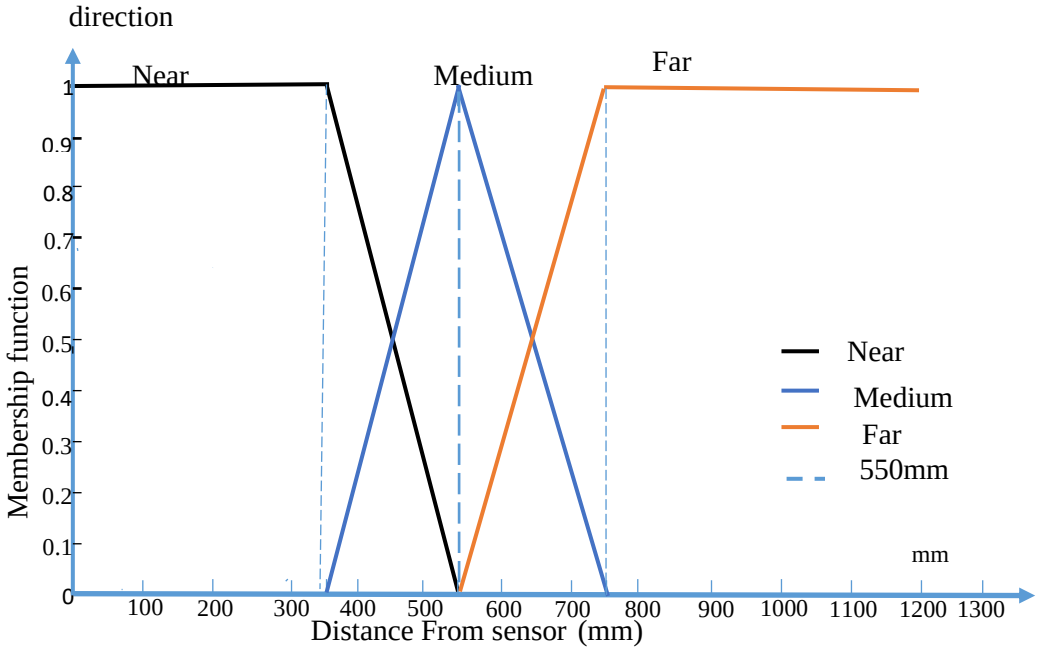


Figure 4.11 Membership function for right sensor

Left = 200mm, Near = 1, Medium = 0, Far = 0

Center = 450mm, Near = 0.5, Medium =0.5, Far = 0

Right = 550mm, Near = 0, Medium = 1, Far = 0

Using **min-max method** for fuzzification,

Table 4.2 Calculation of Fuzzified Values by min-max method

No	**Left**	**Center**	**Right**	**Robot Direction**
1	Near	Near	Near	Stop
	1	0.5	0	0.5
	Min(max(1(0.5,0)))			
	(1,0.5)			
2	Far	Near	Near	Left
	0	0.5	0	0
	Min(max(0(0.5,0)))			
	(0,0.5)			
3	Medium	Near	Near	Left
	0	0.5	0	0
	Min(max(0(0.5,0)))			
	(0,0.5)			
4	Far	Near	Medium	Left
	0	0.5	1	0
	Min(max(0(0.5,1)))			
	(0,1))			
5	Far	Medium	Near	Left
	0	0.5	0	0
	Min(max(0(0.5,0)))			
	(0,0.5)			
6	Near	Near	Medium	Right
	1	0.5	1	1
	Min(max(1(0.5,1)))			
	(1,1)			

7	Near	Near	Far	Right
	1	0.5	0	0.5
	Min(max(1(0.5,0)))			
	(1,0.5)			
8	Medium	Near	Far	Right
	0	0.5	0	0
	Min(max(0(0.5,0)))			
	(0,0.5)			
9	Near	Medium	Far	Right
	1	0.5	0	0.5
	Min(max(1(0.5,0)))			
	(1,0.5)			
10	Near	Far	Far	Straight Forward
	1	0	0	0
	Min(max(1(0,0)))			
	(1,0)			
11	Far	Far	Far	Straight Forward
	0	0	0	0
	Min(max(0(0,0)))			
	(0,0)			

Combined Rule Result:

Root-Sum Square Method:

For Defuzzification,

$$\text{Output} = \sqrt{(\sum_i rule^2)} \quad (4.1)$$

Straight Forward $= \sqrt{0^2 + 0^2} = 0$

Left $= \sqrt{0^2 + 0^2 + 0^2 + 0^2} = 0$

Right $= \sqrt{1^2 + 0.5^2 + 0^2 + 0.5^2} = 1.22 = 1$

Stop $= \sqrt{0.5^2} = 0.5$

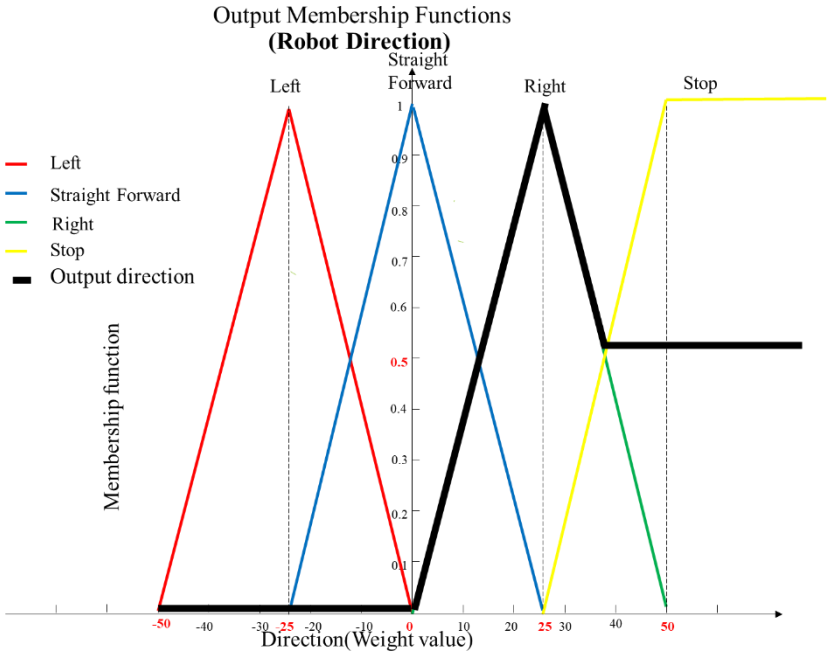


Figure 4.12 Direction of the robot

By using **Maxima method**:

The First of Maxima Method (FOM), the output direction of the robot is **Right** as shown in Figure 4.12.

One more test, If Left = 750mm, Near = 0, Medium =0, Far = 1 as shown in Figure 4.13.

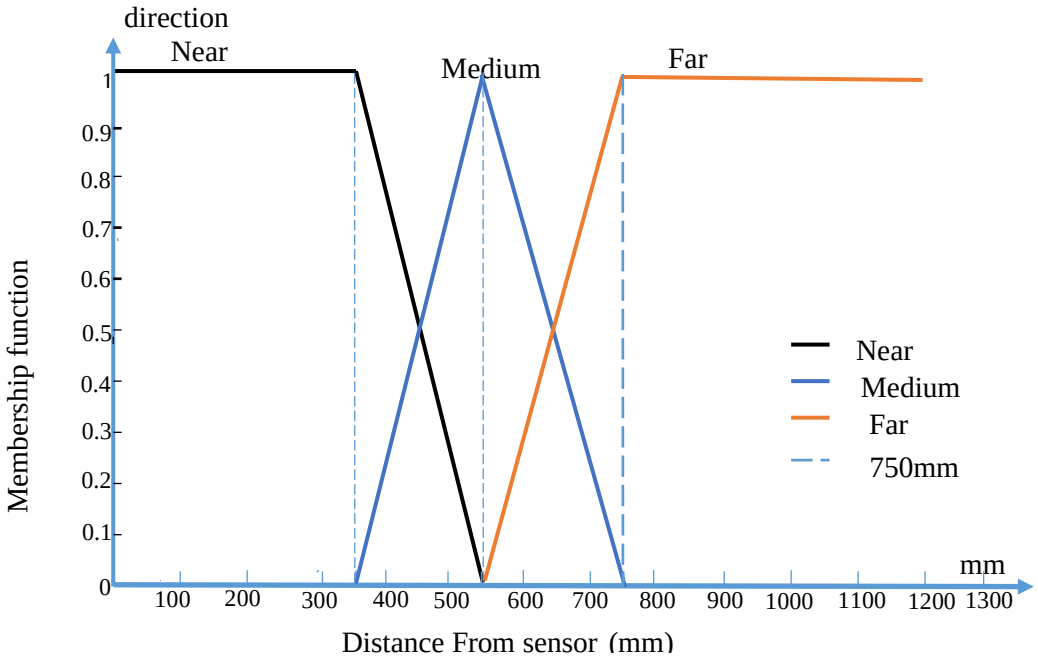


Figure 4.13 Membership function for left sensor

Center=550mm, Near =0, Medium =1, Far =0 as shown in Figure 4.14.

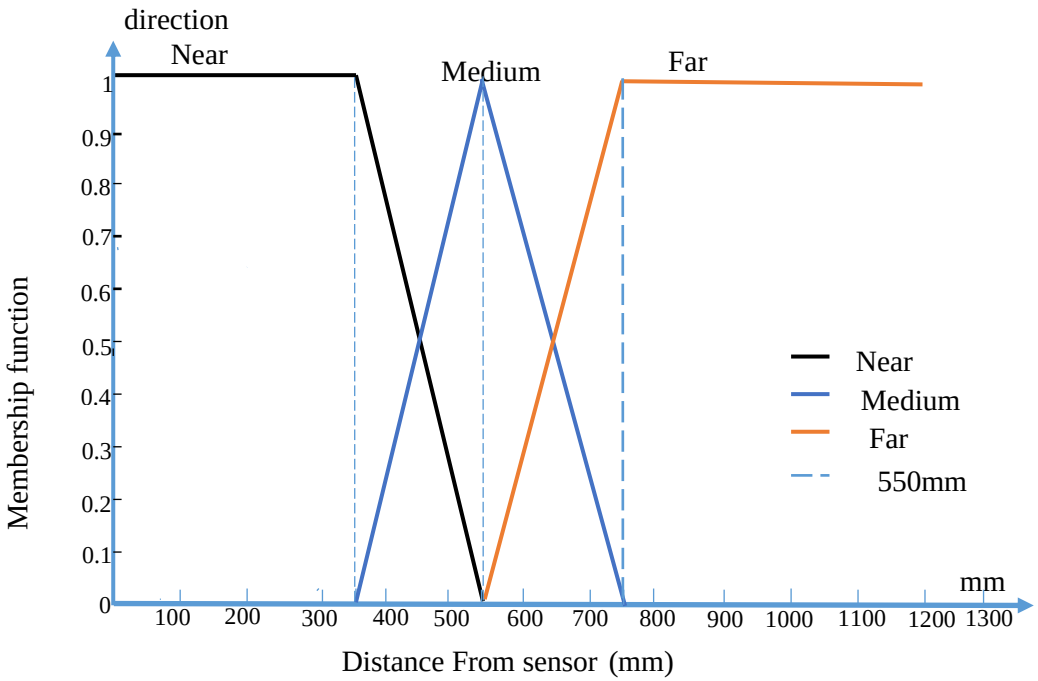


Figure 4.14 Membership function for center sensor

Right =450mm, Near =0.5, Medium =0.5, Far =0 as shown in Figure 4.15.

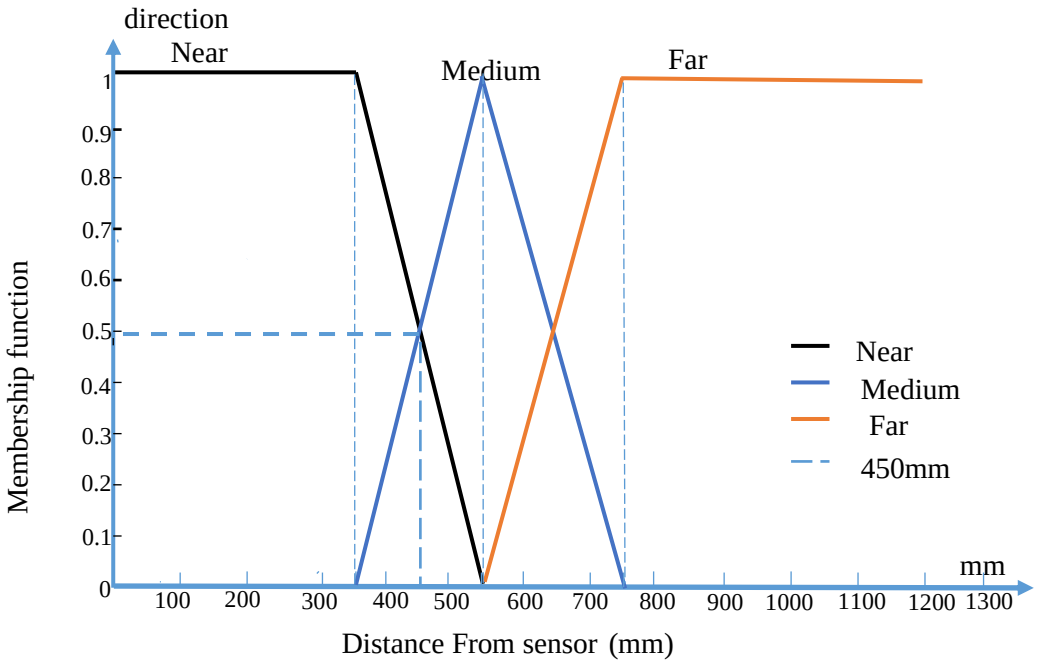


Figure 4.15 Membership function for right sensor

Left = 750mm, Near = 0, Medium =0, Far = 1

Center=550mm, Near =0, Medium =1, Far =0

Right =450mm, Near =0.5, Medium =0.5, Far =0

Table 4.3 Calculation in the fuzzified value by min-max method

No	Left	Center	Right	Robot Direction
1	Near	Near	Near	Stop
	0	0	0.5	0
	Min(max(0(0,0.5)))			
	(0,0.5)			
2	Far	Near	Near	Left
	1	0	0.5	0.5
	Min(max(1(0,0.5)))			
	(1,0.5)			
3	Medium	Near	Near	Left
	0	0	0.5	0
	Min(max(0(0,0.5)))			
	(0,0.5)			
4	Far	Near	Medium	Left
	1	0	0.5	0.5
	Min(max(1(0,0.5)))			
	(1,0.5)			
5	Far	Medium	Near	Left
	1	1	0.5	1
	Min(max(1(1,0.5)))			
	(1,1)			
6	Near	Near	Medium	Right
	0	0	0.5	0
	Min(max(0(0,0.5)))			
	(0,0.5)			
7	Near	Near	Far	Right
	0	0	0	0

	Min(max(0(0,0)))			
	(0,0)			
8	Medium	Near	Far	Right
	0	0	0	0
	Min(max(0(0,0)))			
	(0,0)			
9	Near	Medium	Far	Right
	0	1	0	0
	Min(max(0(1,0)))			
	(0,1)			
10	Near	Far	Far	Straight Forward
	0	0	0	0
	Min(max0(0,0)))			
	(0,0)			
11	Far	Far	Far	Straight Forward
	1	0	0	0
	Min(max(1(0,0)))			
	(1,0)			

For Defuzzification,

Combined Rule Result:

Root-Sum Square Method:

$$\text{Output} = \sqrt{(\sum_i rule^2)}$$

Left $=\sqrt{0.5^2 + 0^2 + 0.5^2 + 1^2} = 1.22 = 1$

Right $= \sqrt{0^2 + 0^2 + 0^2 + 0^2 = 0}$

Straight Forward $=\sqrt{0^2 + 0^2} = 0$

Stop $= \sqrt{0^2} = 0$

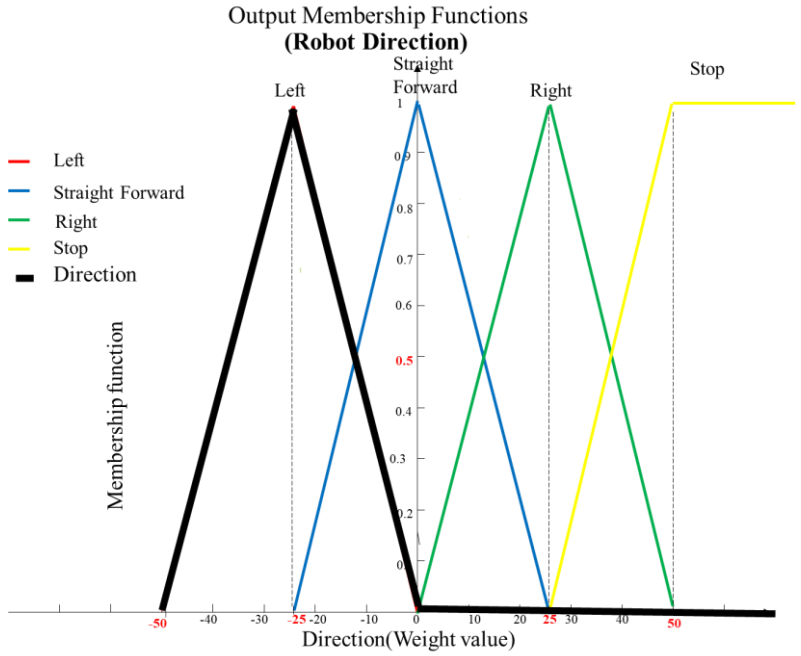


Figure 4.16 Robot direction

By using **Maxima method**:

The First of Maxima Method (FOM), the output direction of the robot is **Left** as illustrated in Figure 4.16.

4.2.2 Hardware Platform

The structure of this robot consists of an Arduino UNO connected with four DC motors with matching wheels, motor driver H-Bridge L298N, three ultrasonic sensors (HC-SR04). There are three ultrasonic sensors used in the circuit mounted in front of the robot. The three ultrasonic sensors mounted on the front is connected to Pin A0, Pin A1, Pin A2, Pin A3, Pin A4, Pin A5, Ground, 5V of the Arduino UNO board. There are four DC motors used for making mobile robot car. DC motor is interfaced between Pin 6, Pin 8, Pin 9, Pin 10 and Pin 11 of the L298N motor driver IC. The out 1 and out 2 pin motor drivers for DC motor as illustrated in Figure 4.17.

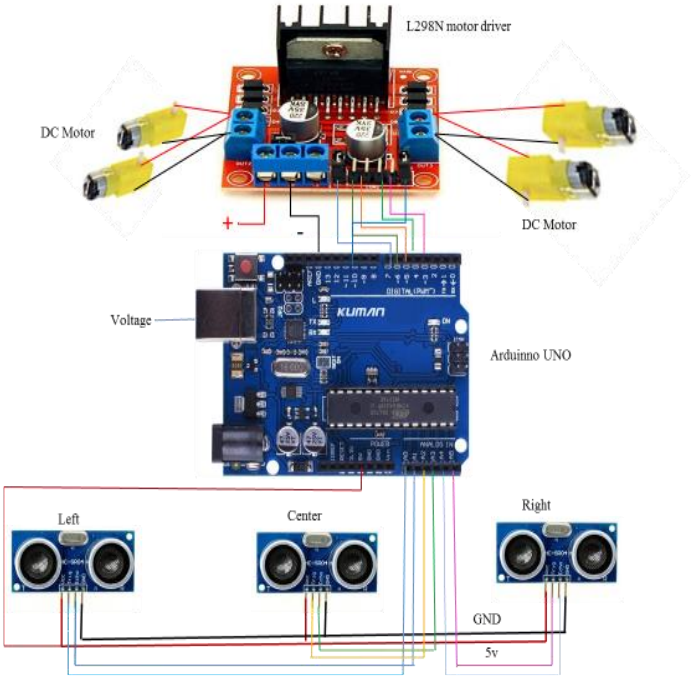


Figure 4.17(a) Schematic diagram of Barrier Avoidance Robot

Barrier Avoiding Robot was constructed, designed and programmed which can be probably used for educational and research objectives as shown in Figure 4.17 (b).

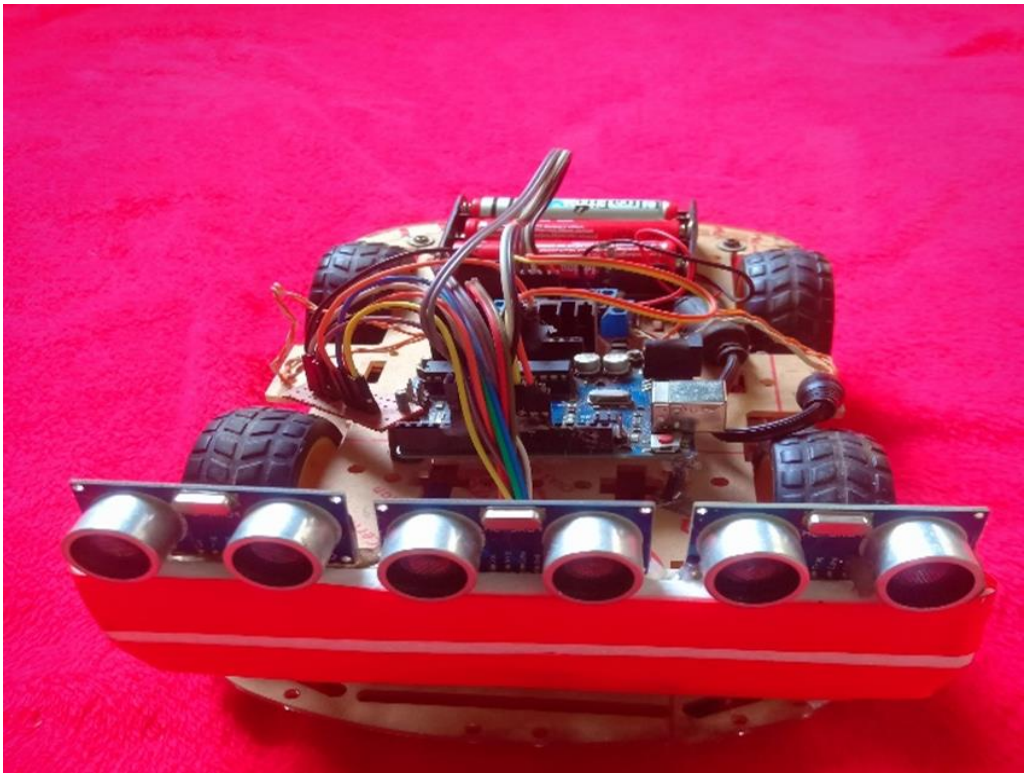


Figure 4.17(b) Prototype design of the robot

CHAPTER 5
CONCLUSION

This system has accomplished a purpose of integrity completion a fuzzy control system scheme for adjust the heading and mobile robot speed. Algorithm of Fuzzy Logic for barrier avoidance were implemented in the mobile robot. Testing results with many conditions of barrier display the ability of mobile robot to avoid it and have directed a good performance. The structured fuzzy controller is implemented in a barrier avoidance robot. This system has successful completion of a fuzzy control scheme for adjusting the heading and speed of mobile robot. In conclusion, barrier avoidance is widely researched and applied around the world, and it is believed that in the future most robots should be able to avoid barriers.

5.1. Benefits

Each time the robot detects a barrier, it automatically shifts its position to the left or right and follows the path in the absence of human guidance. The programming of the microcontroller is easy to use. It can avoid accidents. It is a low-cost circuit.

5.2. Application Area

Barrier avoiding robots can be used in almost all mobile robot navigation systems. It can be used as a part of a robot. It can be used for household chores such as automatic vacuuming. This system is used to avoid collisions. The design developed for use in risky area. Barrier avoidance is one of the best applications to prevent many accidents and deaths.

5.3. Limitation

This system uses an Arduino Board based on the fuzzy rule. Arduino board memory is limited, will not work if it exceeds the specified limit. There is no limit in the fuzzy library. But Arduino has a limited memory, and it is the same to the process. A lot of rules can be applied with Arduino Mega. The eleven rules are sufficient for this system and have better accuracy. This is a really useful fuzzy library. The robot

can only avoid barriers according to the 11 rules used in this system. The remaining barrier cannot be avoided.

5.4. Future Work of the System

This robot is able to produce the basic moving activities using four gear DC motors. They have created a robot with an excellent intelligence that can easily sense barriers and activate the signal from the sensor so that it can completely avoid barriers in its path. The future work of the system includes improving robot design so that in this system a sensor will also be added to the back of the robot to sense the rear, which will turn around and avoid barriers.

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