# Navigation system for an autonomous robot using fuzzy logic

**Vivek Yerubandi [*], Y.Mukunda Reddy [**], M.Vinod Kumar Reddy [**]**

[*] B.TECH,Vellore Of Institute Of Technology,Vellore
[**] M.TECH,Vellore Of Institute Of Technology,Vellore

***Abstract***- Navigation system for an autonomous robot is an area that is undergoing constant development. This paper describes anautonomous robot that is capable of navigating in a real time environment. This can be achieved by obtaining the information about robot's environment by using sensors and process it. For implementation of obstacle avoidance, Fuzzy Logic approach is used and is implemented using Arduino-Uno board on mobile robot platform with three sets of ultrasonic sensors mounted on it. The Fuzzy Logic approach allows us to use the ultrasonic or infrared sensors that allow fast and cost effective distance measurements with varying uncertainty.

***Index Terms***- Fuzzy Logic, Obstacle Avoidance, Ultrasonic Sensors.

## I. INTRODUCTION

Autonomous robot is a robot working in an unmapped environment. The main problem of this robot is navigation and obstacle avoidance. The aim of this project is to build an autonomous robot that is capable of avoiding the obstacles in its path.

This can be achieved by obtaining the information about robot's environment by using sensors and process it.For processing the information we can use either probability theory or fuzzy logic methodology. Probability theory relies mostly on precision. Achieving high levels of precision requires highly precise sensors which are expensive and also the number of computations and complexity of the system increases. Whereas fuzzy logic provides the tolerance for uncertainty in the data received.

## II. ROBOTPLATFORM

Hardware:

This is a microcontroller based mobile robot that contains Arduino development board fixed to the chassis and ultrasonic sensor modules mounted on the three sides of itfor understanding the robots environment. The hardware implementation of the robot is shown in figure 1. Here Ultrasonic sensor modules gather the data and send it to the microcontroller through Arduino, where the data is processed and accordingly the actuations are made using DC motors.

Software:

Arduino and Matlab are the software's that are used for performing obstacle avoidance using fuzzy logic technique. Here, Microcontroller is programmed using the Arduino software, where the program calculates the distance of the obstacle and sends the data through serial port to the Matlab. Matlab uses this data as inputs for performing fuzzy logic and the fuzzy outputs are again sent to the arduino board through serial port for performing corresponding actuations.

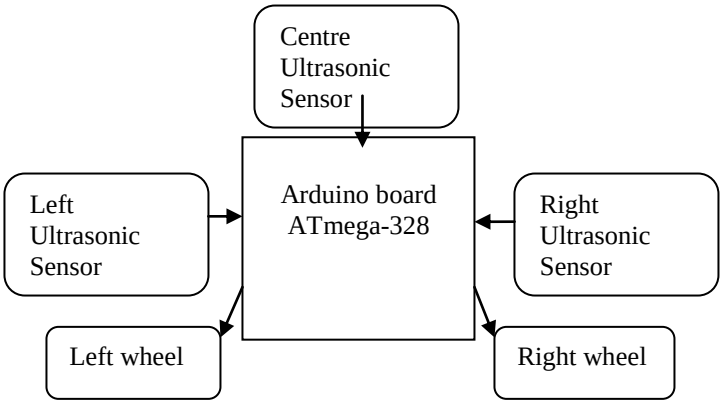



**Fig 1. Block diagram of hardware architecture**

## III. HARDWARE DEVELOPMENT AND IMPLEMENTATION

The proposed obstacle avoidance system uses fuzzy logic technique which makes it capable of reacting according to its environment. The system gathers the information from external world using Ultra-sonic sensors.

The information gathered by Ultrasonic sensors is used to calculate the distance of the obstacles. The microcontroller and Ultrasonic sensors that are used are described below.

Micro Controller:

The microcontroller board used for this system is Arduino Uno which is basedon ATmega328 microcontroller. Development board consists of fourteen digital I/O pins and six analog pins, with a flash memory of 32KB and EEPROM of 1KB operating at 16 MHz clock frequency.

Sensors:

Detection of obstacles is done by using ultrasonic sensor modules. The module used here is HC-SR04. It is a Ultrasonic proximity sensor which uses sonar to measure the distance to an object. It can sense distance from 2cm -450 cms with an accuracy of 0.3cm and sensing angle less than 15degrees.

Basic operating principle:

HC-SR04 has four pins - Vcc, GND, Trig, Echo. The module transmits a 40 KHz square wave signals when the pulses are given at Trig pin. When the signal is transmitted it sets the signal at echo – high. When an echo is received by receiver then the signal is set to low. The time duration of high signal is used to calculate the distance. No ranging data is provided by the module directly, it is calculated by the software using formula

Distance in cms = Duration of the high pulse in microseconds/29/2.

Since speed of sound = 29 microseconds/cm and signal travels out and back, so to calculate the distance we take half of the distance travelled.

For this system, three sets of Ultrasonic sensor modules are used for detecting the objects on the left, center and right of the robot.

## IV. FUZZY LOGIC

Once the ranging data is calculated it is sent to serial port. Matlab reads the data from the serial port and uses it as inputs to the fuzzy logic.

Fuzzy logic technique has three main sections. They are:

- Fuzzification of the ranging data
- Fuzzy Control Rules
- Defuzzification

All these are performed in Matlab with the help of a special toolbox called fuzzy toolbox provided by Matlab.

Fuzzification of the ranging data:

The ranging data acquired from the three ultrasonic sensors are sent through the serial port to the Matlab. In the Matlab a Fuzzy Inference System is created using fuzzy logic toolbox. A Mamdani system with three inputs and one output is chosen as shown in fig 2. The three inputs are the ranging data from the sensors. The membership functions are used for converting the discrete data into a fuzzy value between 0 and 1 and fuzzy output values into discrete values.

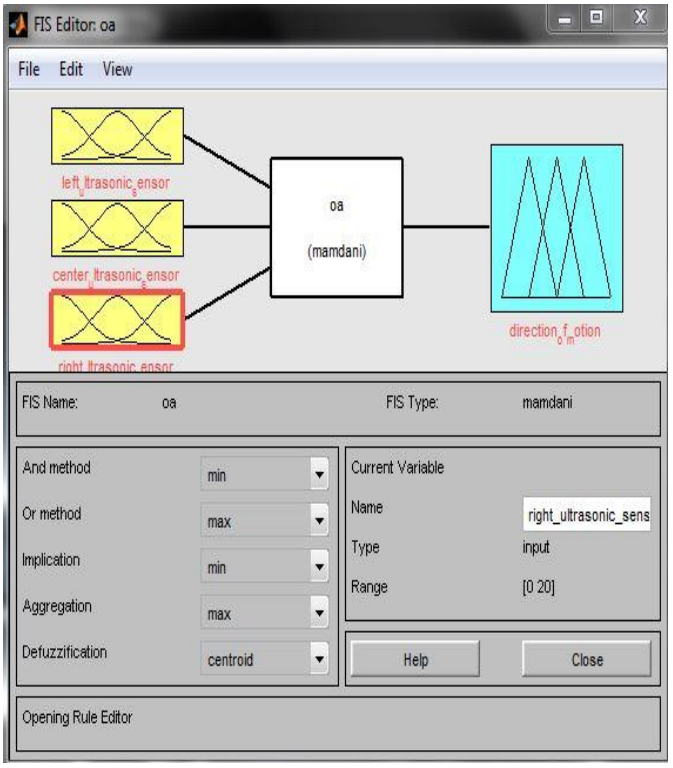
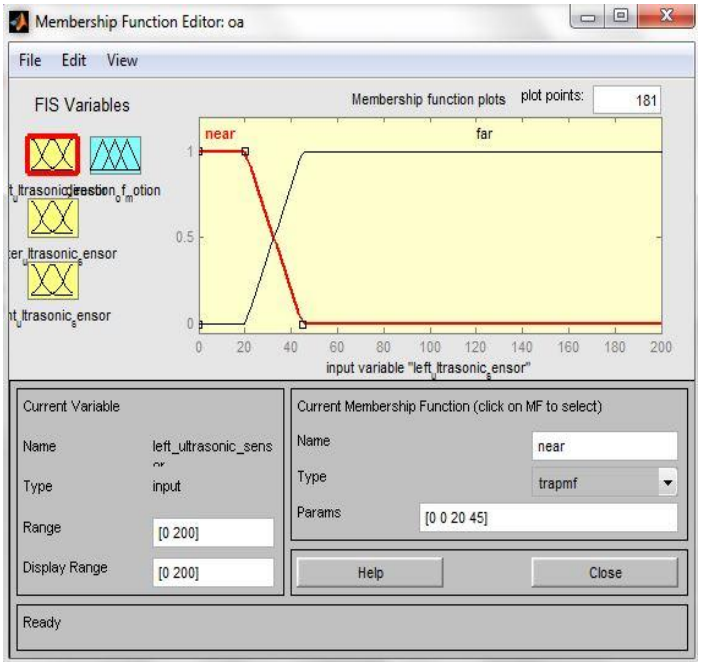
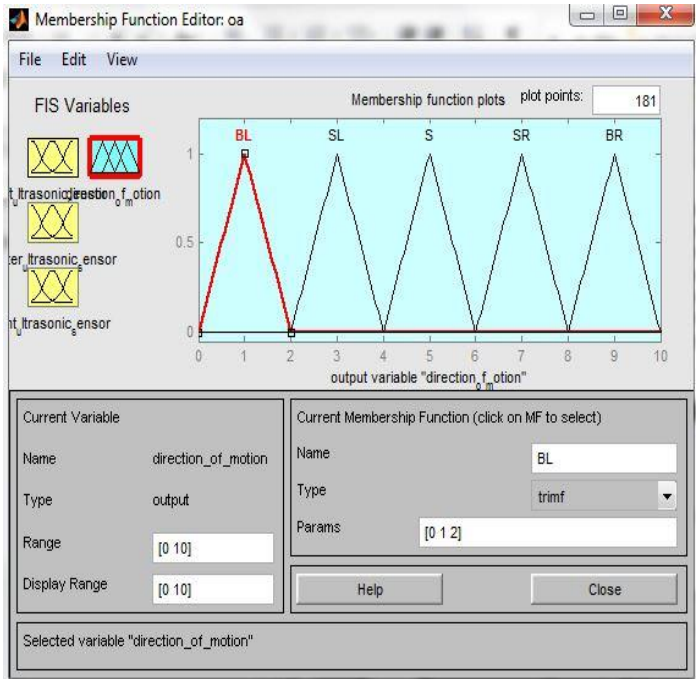



**Fig 2. FIS of obstacle avoidance system**

**In this application mainly trapezoidal and triangular membership functions are used for the inputs (distance) and for the output (direction of motion). The membership functions for different fuzzy sets of inputs and output can be seen in fig 3.**




**(a)**




**(b)**

**Fig 3. (a) Input Membership Functions (b) Output Membership Functions**

Fuzzy Control Rules:

In a fuzzy logic system, the rules define the output for any combinations of inputs.

Each input/output has different variables that are defined by the membership functions. For example, the distance input has either far or near, for direction of motion – Big Right (BR), Small Right (SR), Straight (S), Big Left (BL), Small Left (SL). The following Table 1 shows the rule base for this fuzzy controller.

| Rule | Left Sensor | Centre Sensor | Right Sensor | Direction of motion |
|---|---|---|---|---|
| 1 | Near | Near | Near | Big Right |
| 2 | Near | Near | Far | Small Right |
| 3 | Near | Far | Near | Straight |
| 4 | Near | Far | Far | Small Right |
| 5 | Far | Near | Near | Small Left |
| 6 | Far | Near | Far | Big Right |
| 7 | Far | Far | Near | Small Left |
| 8 | Far | Far | Far | Straight |

**Table 1: Rule base**

Defuzzification:

The fuzzy output is the union of all the rules that are defined. Defuzzification is the conversion of fuzzy output to the crisp output. For the present system, defuzzification is done using centroid method and is given as:

$$Z^* = \frac{\int \mu(z) z dz}{\int \mu(z) dz}$$

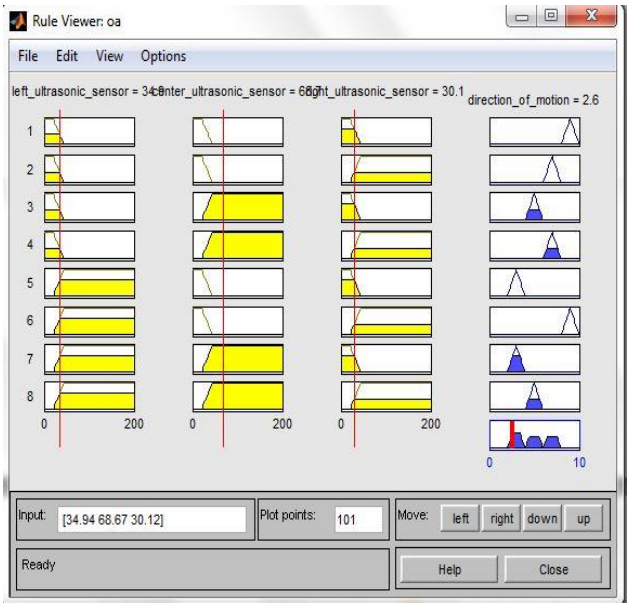



**Fig 4. Rule viewer**

Overall System functionality algorithm:

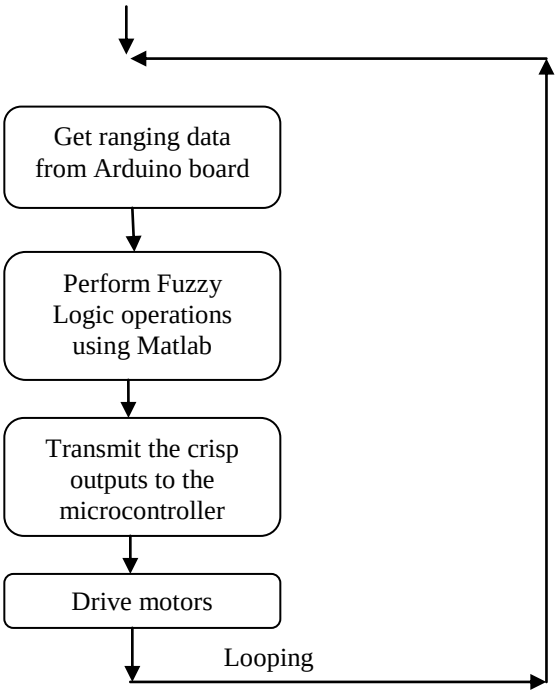



Fig 5. Algorithm for navigation of robot

## V. PRELIMINARY EXPERIMENTAL RESULTS

The mobile robot that is made using fuzzy logic technique is capable of avoiding the obstacles in its environment. Preliminary experiments are made using wired serial communication and the results obtained are seemed to be effective. However, sometimes Ultrasonic Sensors fail to detect the objects of particular geometries i.e, when the sonar beam hit a surface with oblique incidence, it would reflect away instead of going back as an echo and the obstacle is not detected.

## VI. CONCLUSION

In this paper, Fuzzy Logic technique is successfully employed for obstacle avoidance using Arduino development board. The Arduino platform seems to be an excellent platform for the implementation of this project.

## REFERENCES

[1] ShigangCui,XiongSu,LiZhao,ZhigangBing,Genghuang Yang, "Study on ultrasonic Obstacle Avoidance of Mobile Robot on Fuzzy Controller", IEEE Conference on computer application and system modeling,china,2010.

[2] S.Thongchai,S. Suksakulchai, D.M.Wilkes and N.Sarkar Sonar Behaviour-Based Fuzzy control for a Mobile Robot.Proceedings of the IEEE International Conference on Systems Man, and Cybernetics, 2000:435-440.

[3] Khatib, O.: Real time obstacle avoidance for manipulators and mobile robots. Int.J.Robotics Research 5(1), 90-98(1986).

[4] Hasan, K.M., Raza,A. Amar,M. "A Low cost microcontroller implementation of fuzzy logic bases hurdle avoidance controller for a mobile robot", Informatics,Electronics& vision,2013 International Conference.

[5] D R Parhi, M K Singh, S Bhowmik "Intelligent Controller for mobile robot: fuzzy logic approach," 12th International Conference of International Association for Computer method and advances in Geomechanics, Goa, India, October 2008.

## AUTHORS

**First Author** – Vivek Yerubandi, B.TECH,Vellore Of Institute Of Technology,Vellore
**Second Author** – Y.Mukunda Reddy, M.TECH,Vellore Of Institute Of Technology,Vellore
**Third Author** – M.Vinod Kumar Reddy, M.TECH,Vellore Of Institute Of Technology,Vellore