Path Planning Navigation of Mobile Robot With Obstacles Avoidance Using Fuzzy Logic Controller

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1 author:

Dr. Anish Pandey
KIIT University

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Anish Pandey, Rakesh Kumar Sonkar, Krishna Kant Pandey, D. R. Parhi
Mechanical Engineering Department, National Institute of Technology
Rourkela-769008, Odisha, India
anish06353@gmail.com, rakeshsonkar45@yahoo.in,
kknitrkl@yahoo.in, dayalparhi@yahoo.com

***Abstract*—Autonomous mobile robots are used in several application areas including manufacturing, mining, military, and transportation, search and protect missions, etc. For the navigation system it is necessary to locate the position of the mobile robot in surrounding environment. For avoiding obstacles efficiently and to reach the target under many different shapes of obstacle in environment, a fuzzy logic controller has been designed to improve the movement of mobile robot according to obstacles positions by defining or establishing input variables, output variables, fuzzy logic membership functions, fuzzy logic rule base 'If-Then' fuzzy inference system rules and defuzzification method. Then it has to plan a path towards desired goal. The navigation system of a mobile robot has to identify all potential obstacles in order to search for a collision free path. Obstacles avoidance and destination point can be achieved by changing the direction angle of the mobile robot. To make the mobile robot move in its environment, the basic path planning strategies have been used. While the mobile robot is navigating in its workspace environment, it avoids obstacles and look for the target. In this paper the simulation of path planning technique for an autonomous mobile robot is presented. The figure shows simulation of the mobile robot with four obstacles.**

***Index Terms*—Autonomous mobile robot, Fuzzy logic, Obstacles, Collision avoidance, Path planning.**

I. INTRODUCTION

In this paper a fuzzy logic method is developed for solving the motion planning problem of mobile robot in the presence of different shapes of static obstacles to find out collision free path. The application of different mixed soft computing techniques like artificial potential field (APF) methods, vector field histogram (VFH) methods, neural network (NN) methods, fuzzy logic methods, genetic algorithm (GA) methods and behaviour-based methods are applied by various researchers to overcome the problem present in real world scenarios. The membership functions and set of rules of a fuzzy logic controller (FLC) is used by mobile robot to navigate in presence of static obstacles. The objective of this review paper is to navigate an autonomous mobile robot using a fuzzy logic controller [1]. In order to navigate, the mobile robot has to obtain information about its surrounding environment. For the velocity case, the robot velocity varies on how away obstacle are detect from its current position. If obstacles are detected near to the robot, a low velocity command will be send by the FIS. Using this approach to direct the robot moves safely reaches its destination point [2]. The fuzzy variables such as membership functions limit and rules of the involved FIS must be tuned respected to the knowledge base informations i.e. predicted data samples [4]. The robot behaviours are two types: global (e.g. - path tracking and goal seeking) and local (e.g. – obstacle avoidance, wall following and door crossing etc.). The global behaviour uses network of cameras. The local behaviour is basically sensor based navigation. The mobile robot navigation in uncertain environments using fuzzy logic control system design consist of a heading angle (turning angle) between a robot and the specified destination and the distance calculation between the mobile robot and the obstacles to left, front and right locations. The fuzzy rule sets will allow us to control and navigate to select different behaviours of an autonomous mobile robot in different condition of any environments. The problem of driving a mobile robot to a reach the goal in known or partially known environment is formulated as a fuzzy logic problem in which sensor informations is used to control the heading angle and speed (or velocity) decisions while the mobile robot is moving [5]. The other real-world mobile robot path planning problems which needs to find a collision free path from its starting point to its destination point. In order to be able to find that path, the robot needs to run a suitable path planning algorithm, to calculate the distance of path between any two points has been asked by Mohammad et al. [6].

This paper presents the simulation and design of mobile robot for obstacle avoidance in an environment about which no a priori knowledge is available and which consists of static obstacles. The Fuzzy Inference System (FIS), performed by the mobile robot reasoning system, can be defined as a relationship between the inputs and outputs variables. The input is multi variable, with each variable parallel to a particular input data mode, e.g. front obstacle distance, right obstacle distance, and left obstacle distance. Similarly, the output is multi variable, with each variable parallel to a particular type of output, which is speed of the left and right motor wheels of mobile robot.

Motion planning is an essential requirement in the field of mobile robotics. Meaning of motion planning is to find a suitable collision-free path for a mobile robot move from starting to its destination in an environment consisting of number of obstacles. A fuzzy logic based obstacle avoidance and navigation scheme has been used here for path planning of mobile robot with destination in presence of obstacles. The design method consists of two platforms. In the first platform the structure of a Takagi –Sugeno (TS) type model Fuzzy Inference System (FIS) is established. In the second platform the heading angles is controlled or changing its angle by mathematically formulations. The using FIS the predicted user defined membership functions are developed and used to navigate and control the mobile robot. FIS has been used with 3 types of input variables, 2 types of output variables and 3 membership functions for each. The mobile robot has been used of ultrasonic sensors for measuring the distances (range from 1cm to 4m) of obstacles (front, left and right) around it and an infrared sensor (range from 20cm to 150cm) is used for find out the bearing of destination.

Many researchers have adopted fuzzy logic method in mobile robot navigation. In this paper navigation of mobile robot presence of static obstacles in known or partially known environments using Fuzzy Inference System (FIS) is discussed. For hurdle avoidance purposes of mobile robot, which has a large amount of uncertainty and incomplete or the absence of prior knowledge of environment, fuzzy controller is much more suitable.

VII. Mobile Robot Wheel Arrangement

The mobile robot used here imagined being a rear wheel drive having two rear wheels with two motors and one front castor wheel. The mobile robot configuration has two rears independent driving wheels arranged parallel to each other is shown in Fig. 1. Their speed can be controlled separately. To start navigation in known or partially environments the mobile robot must have capable to sense the real-world, by using fuzzy logic and sensors interpreting the information to understand the environments surrounding it, particularly the situations in ahead of it.

$$\theta=\tan^{-1}\left\{\frac{T_y - Y_{n+1}}{T_x - X_{n+1}}\right\}$$

Where n = 0, 1, 2, 4, 5, 6 ………..….n.

X_n is the current position of the mobile robot in X axis, and X_{n+1} is the updated position in Eq. (1). Y_n is the current position of the mobile robot in Y axis, and Y_{n+1} is the updated position in Eq. (2). θ is mobile robot heading angle and heading angle (or turning angle either left or right or straight) varies (or updated) according to reach the destination point in Eq. (3). T_x and T_y is the destination (or target) in X and Y axis respectively.

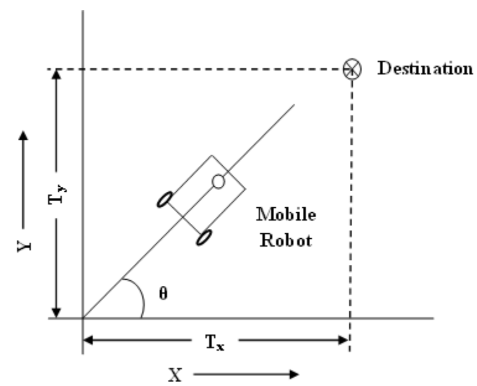

Fig. 1. Mobile robot wheel arrangement

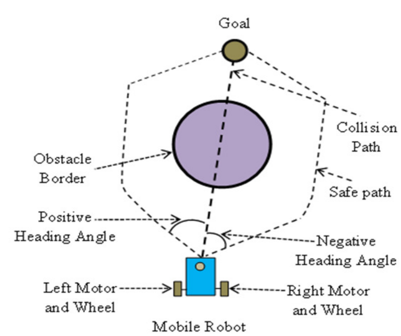

Fig. 2. Mobile robot avoiding obstacle

II. Obstacle Avoidance Strategy

Obstacle avoidance is the mainly requirement for any mobile robot. Once the distance and direction of the obstacles are known, a collision free path can be projected. Diagram description of obstacle avoidance problem for the wheeled mobile robot moving to reach goal is shown in Fig. 2. When the robot tracking moving to reach destination in a known and partially known environment, the robot is expected to make appropriate responses according to surrounding information detected by its sensors autonomously, and obtain collision-free path. To maximize the safe navigation, search the collision free path and moving behaviour will be active when there are not any obstacles detected. Fuzzy logic control technique is utilized in this paper to accomplish reactive obstacle avoidance, which has the advantage of rapid response and can make the robot react to unknown environment effectively and in real-time has been asked by Limin et al. [7].

Fuzzy controller is used for both navigation and obstacle avoidance has been developed. In order to steer controlled mobile robot, a fuzzy technique has been applied. This rule would be applied when the robot found an obstacle near on its. In that situation the robot would turn on its left or right. Similar rules would be defined to solve other situations. However, the result of these rules would not be the velocities applied to the robot motors, but a set of degrees of membership.

III. Fuzzy Logic Technique

We consider our Fuzzy Inference System (FIS) as shown in Fig. 3. Out of three inputs are the distance information from the front, left and right obstacles present in mobile robot environment. As output we obtain left motor speed and right motor speed. Our aim is to design a fuzzy controller to guide the mobile robot safely in known or partially known environment from its starting point to destination point. Fuzzy models will be implemented to control the movements of the robot according to position of obstacles. The robot will have to take action such as controlling of wheel motors speed up or down, turn left or right etc. These actions are taken by determining or controlling the values of variables like velocity, steering angle etc. These variables are all output variables [2]. The FIS will generate mobile robot speed and heading angle change corresponding to different conditions. The FIS is activated when the robot sensor detects any obstacle(s). Fuzzy control systems are easy and cheap implement. De-fuzzification is done by using centroid method. The centroid de-fuzzification scheme is used to produce a single numerical output from resulting output fuzzy set. A fuzzy rule-base is used to determine the speeds of both wheels. The fuzzy input variables are the distance between the obstacles from the mobile robot. FIS are typically designed to consider one single destination. When the robot detects obstacles, it makes suitable reactive obstacle avoidance via changing its moving direction and reducing moving velocity. For navigation purpose the input to all the FIS is front obstacle distance, left obstacle distance, and right obstacle distance considered. The output from FIS is left motor speed and right motor speed of mobile robot is in use. The fuzzy rules and its rule viewer are shown in Fig. 4 help the mobile robot to avoid obstacles and find destination. The mobile robot considered for analysis is three wheels having one front castor wheel and two rear wheels. The speeds of rear wheels are depend on two separate motors. In this paper the three types of membership functions are used. First for the three input variables front obstacle distance, left obstacle distance, and right obstacle distance respectively can be divided into a range of three triangular membership functions are ‘close’, ‘medium’, and ‘far’, are shown in Fig. 5, 6, and 7 respectively. Second for the two output variables right motor speed (R.M.S) and left motor speed (L.M.S.) respectively can be divided into a range of three triangular membership functions are ‘fast’, ‘medium’, and ‘low’, are shown in Fig. 8, and 9 respectively for navigation of mobile robot. The control variables of the robot are the Left Motor Speed (L.M.S.), and Right Motor Speed (L.M.S.) shown in Fig. 10, and 11 respectively and the change the heading angle.

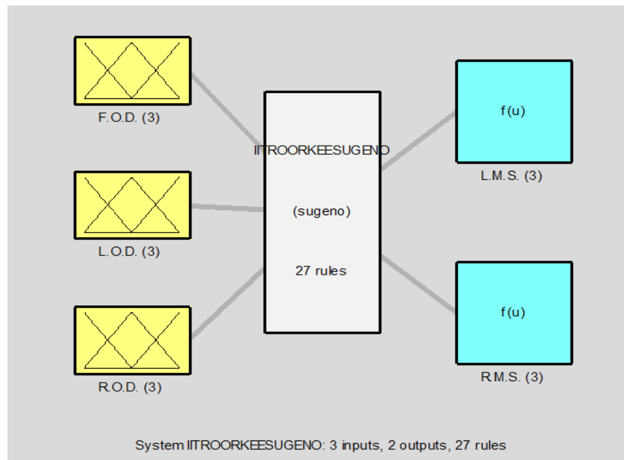

Fig. 3. Fuzzy Inference System (FIS) Sugeno-Type

A. Fuzzy control rules for mobile robot navigation:

Refer to Table 1

If (F.O.D. is close and L.O.D. is close and R.O.D. is close) then (L.M.S. is low and R.M.S. is fast)

If (F.O.D. is close and L.O.D. is close and R.O.D. is medium) then (L.M.S. is medium and R.M.S. is low)

If (F.O.D. is close and L.O.D. is close and R.O.D. is far) then (L.M.S. is fast and R.M.S. is low)

If (F.O.D. is far and L.O.D. is medium and R.O.D. is medium) then (L.M.S. is fast and R.M.S. is fast)

Using the knowledge base we develop the “If - Then” fuzzy control rules as described in Table 1 (speed change) for the fuzzy outputs [3]. Fuzzy systems have the ability to handle uncertain and imprecise information acquired from sensors using linguistic rules. Fuzzy logic controller (FLC) or FIS has been widely used for mobile robot navigation.

Fig. 4. Rule viewer of Fuzzy Inference System (FIS)

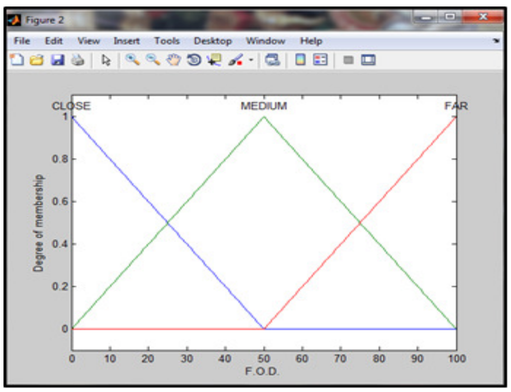

Fig. 5. Fuzzy membership function for input variable Front Obstacle Distance

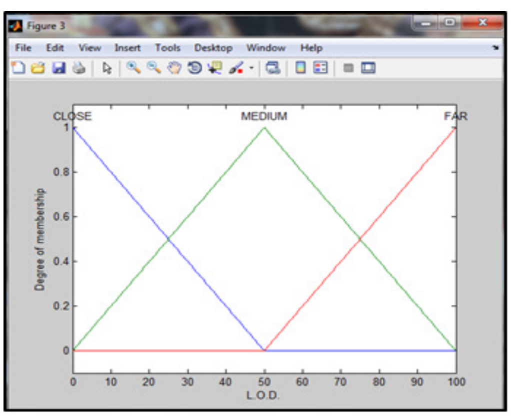

Fig. 6. Fuzzy membership function for input variable Left Obstacle Distance

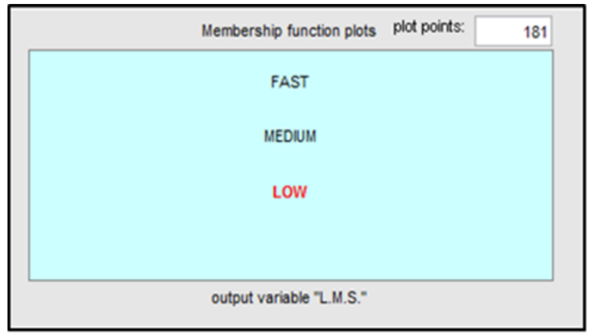

Fig. 7. Fuzzy membership function for input variable Right Obstacle Distance

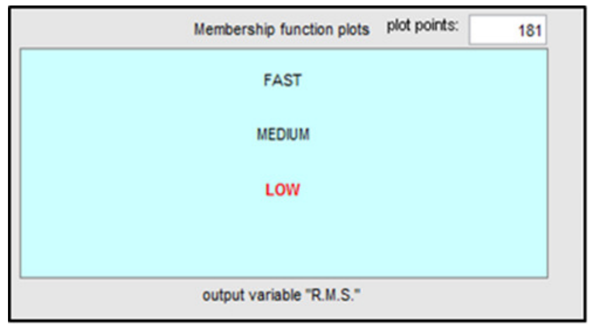

Fig. 8. Fuzzy membership function Sugeno-Type for output variable Left Motor Speed

Fig. 9. Fuzzy membership function Sugeno-Type for output variable Right Motor Speed

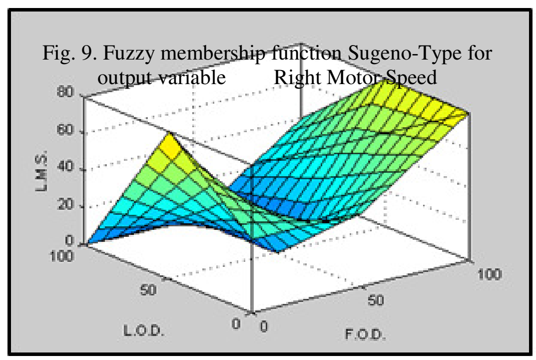

Fig. 10. Left Motor Speed (L.M.S.) control surface

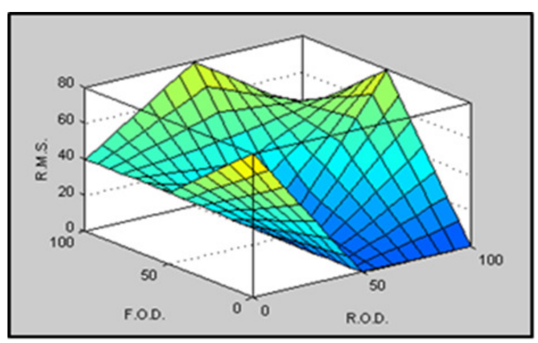

Fig. 11. Right Motor Speed (R.M.S.) control surface

TABLE I. FUZZY CONTROL RULES FOR MOBILE ROBOT NAVIGATION USING THREE-MEMBERSHIP FUNCTIONS.

Fuzzy Rule No.	Front Obstacle Distance	Left Obstacle Distance	Right Obstacle Distance	Left Motor Speed	Right Motor Speed
1.	Close	Close	Close	Low	Fast
2.	Close	Close	Medium	Medium	Low
3.	Close	Close	Far	Fast	Low
4.	Close	Medium	Far	Medium	Low
5.	Close	Far	Medium	Low	Fast
6.	Close	Far	Far	Fast	Low
7.	Close	Medium	Medium	Fast	Low
8.	Close	Medium	Close	Low	Fast
9.	Close	Far	Close	Low	Medium
10.	Medium	Medium	Medium	Low	Low
11.	Medium	Medium	Close	Low	Medium
12.	Medium	Medium	Far	Medium	Fast
13.	Medium	Far	Far	Fast	Medium
14.	Medium	Close	Close	Low	Low
15.	Medium	Far	Close	Medium	Fast
16.	Medium	Close	Far	Medium	Low
17.	Medium	Close	Medium	Medium	Low
18.	Medium	Far	Medium	Low	Medium
19.	Far	Far	Far	Fast	Fast
20.	Far	Far	Close	Medium	Fast
21.	Far	Far	Medium	Medium	Fast
22.	Far	Medium	Medium	Fast	Fast
23.	Far	Close	Close	Medium	Medium
24.	Far	Medium	Close	Low	Medium
25.	Far	Close	Medium	Fast	Medium
26.	Far	Medium	Far	Fast	Medium
27.	Far	Close	Far	Fast	Medium

IV. RESULTS

Simulation is performed using MATLAB Fuzzy Logic Toolbox and programming. Fig. 12, 13, and 14 are shows simulation and experimental results of the movement of a robot as it navigation from start point to destination point through various static obstacles in different positions. The environment information acquired by the robot with the help of sensors (measure obstacle distances) is the inputs to the FIS which control the speed of the motor (wheel speeds) of a robot as it two outputs (left motor speed and right motor speed). The FIS continuously collect the input sensor information and gives an output data until the mobile robot reaches its destination. Thus the obstacles are detected the speed of the mobile robot is reduced and hence it tends to move to left or right directions. A rule base of FIS is established by the operator according to predict prior knowledge. The basic objective of the robot is to achieve $3^3 = 27$ possible rules (3 membership functions for each inputs) when both the destination point and obstacles are far from the robot then the robot moves straight with fast speed. However if the destination point and obstacles are near to the robot then the robot takes appropriate action by turning its heading angle and moving at low speed for obtain collision free path. Fuzzy logic control method is developed to move the robot to reach collision free path while obstacles is presence in environment. Simulations developed on different obstacles with various shapes and sizes are conducted and the effectiveness of proposed method is verified. In simulation the robot is successful reach the destination without any collisions.

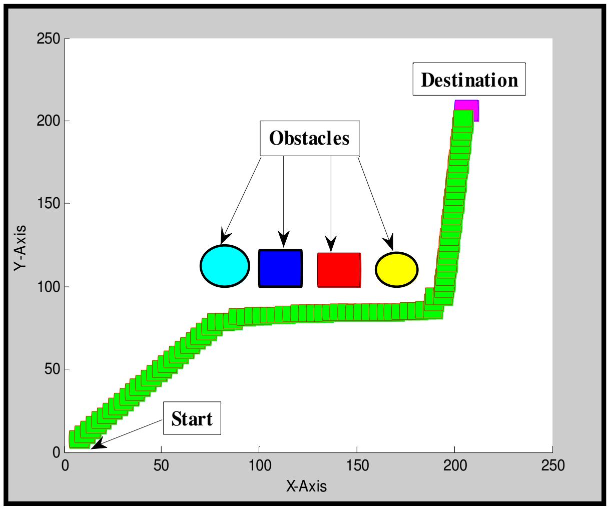

Fig. 12. Navigation path for obstacles avoidance of mobile robot using fuzzy controller

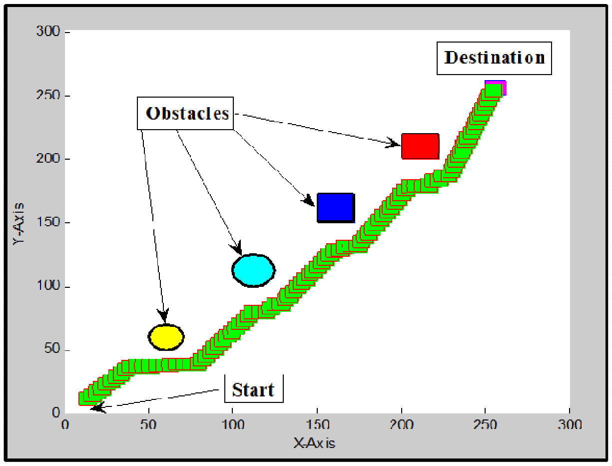

Fig. 13. Navigation path for obstacles avoidance of mobile robot using fuzzy controller

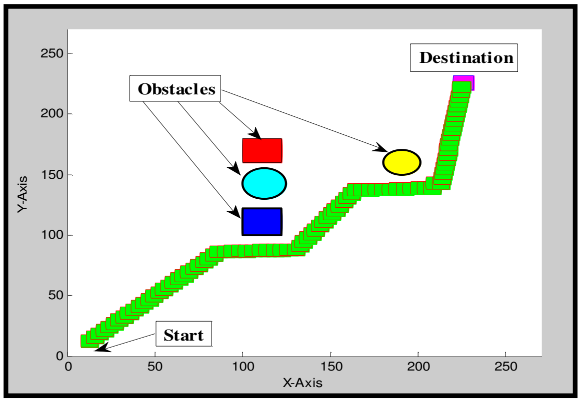

Fig. 14. Navigation path for obstacles avoidance of mobile robot using fuzzy controller

V. Conclusion And Future Scope

The simulation using MATLAB in different environment shows better performance to avoid obstacle present on the robot path. Fuzzy logic is a suitable technique to apply to path planning strategies defined by means of rules. The mobile robot navigation method described in this paper can be implemented for obstacle avoidance in environments consisting of static as well as dynamic obstacles for multiple robots and also for moving or changing destination point. Fuzzy Inference System is utilized in order to control the navigation behaviour of a mobile robot. The success of the robot navigation depends upon the accuracy of complete measurements of positions (mobile robot, obstacles and destination point), velocities (or speeds of mobile robot) and its rate of change of heading angle (of a mobile robot). The simulation result shows that the proposed method enables the mobile robot to safely reach the destination (or goal) without colliding. In future, the existing method can be enhanced by optimizing with the help of optimization algorithms.

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