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MATLAB Simulation for Mobile Robot Navigation with Hurdles in Cluttered Environment Using Minimum Rule Based Fuzzy Logic Controller

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Abstract

In this paper concentrated on the design of a minimum rule based fuzzy-logic controller for robot navigation, and hurdles avoidance in cluttered environment, based on the Mamdani type fuzzy method. The controller has 3 inputs, and single output. This technique generates suitable heading angle maneuvers control of the autonomous vehicle which is used by the robot to reach its goal safely without any collision in cluttered environment. Simulation results show the method can be used for wheeled mobile robot moving on in cluttered environment with lot of hurdles. We present a path-planning system that can control and safely navigate robot motion in a static environment. The success of the mobile robot navigation control depends mostly on the accuracy of absolute measurements of its position, hurdle distances, goal distance, velocity, orientation, and its rate of change its heading angle. The whole navigation system has been tested in a simulation environment with satisfying results.

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Keywords: Mobile robot ; Fuzzy logic ; Hurdles avoidance ; Mamdani ; Cluttered environment.

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1. Introduction

In real-world problem for autonomous mobile robot navigation, it should be capable of sensing its environment, understanding the sensed information to receive the knowledge of its location and surrounding environment, planning a real-time path from a starting position to goal position with hurdle avoidance, and controlling the robot steering angle and its speed to reach the target. Fuzzy Logic is used in the design of possible solutions to perform local navigation, global navigation, path planning, steering control and speed control of a mobile robot. Fuzzy Logic (FL) and Artificial Neural Network (ANN) are used to assist autonomous mobile robot move, learn the environment and reach the desired target [1].

In this paper a Mamdani type Minimum Rule Based Fuzzy Logic Controller for mobile robot navigation path planning in cluttered environment has been designed. A fuzzy logic system is designed for mainly two basic reasons, first goal seeking, and second hurdles avoidance in cluttered environment. The inputs of the fuzzy controller are multivariable system, including the hurdle distances obtained from the front, left, and right sensors group the output is single heading angle which control the movement of mobile robot [2]. Navigation Simulations are carried out with mobile robot in various cluttered environments, e.g. environment with lot of hurdles. The robot can avoid complex hurdles and move for reach goal successfully [3].

Our aim is to design a fuzzy controller to guide the robot safely autonomous without any collision in cluttered environment from start point to goal point. The robot will have to take action such as changing its heading (steering) angle. These actions are taken by determining or controlling the values of variable heading angle is called output variable [4]. To calculate the value of output variable it is possible to determine the change of input variables such as the front, left, and right distance of the robot from hurdles. A fuzzy logic minimum rule based real-time navigation controller in cluttered environment is described below.

2. Design of Mamdani Type Minimum Rule Based Fuzzy Controller for Autonomous Navigation in Cluttered Environment

In this section, we present Mamdani fuzzy logic navigation with knowledge base minimum rules that drive the mobile robot from a known starting position to a user specified goal position, regardless of the known or unknown scenarios with hurdles in cluttered environments [5]. To avoid the hurdles, controller drives with user defined minimum rule based it functioning under Mamdani type fuzzy-logic controller shown in Fig. 1. The inputs of the fuzzy controller consist of hurdles which stand on the front, left, and right of a mobile robot, and each input variables has two membership functions (MF) close, and away are trapezoidal (trapmf) shaped membership function as shown in Fig. 2 (a), (b) and (c). The output of this system control the heading (steering) angle of a robot to avoid lot of hurdles and move to reach the goal, output variable has also two trapezoidal (trapmf) shaped membership function (MF) negative, and positive as shown in Fig. 3. The centroid or Centre of Gravity (COG) defuzzification method is used to generate a single numerical output value from the resulting output fuzzy set and output heading angle (H_A) control surface rule distribution as shown in Fig. 4. These rules establish the relation between front, left, and right hurdles, and heading angle in terms of linguistic term(s) or values [6]. In simulation environment the robot started with 3 inputs, and 2 trapezoidal membership with 8 ($2\times2\times2$) basic rules functions. The entire body of knowledge based rules, needed for mobile robot to navigate, is expressed in Table 1 containing 8 rules needed to navigate autonomously from a start to a goal, avoiding lot of hurdles in cluttered environment.

The hurdles distance (front, left, and right) is represented by linguistic fuzzy rule antecedent sets {CLOSE, AWAY}, with two trapezoidal type membership functions shown in Fig. 2 (a), (b), and (c). The hurdles avoidance in cluttered environment navigation fuzzy minimum rule example is discussed below in TABLE 2. The motion control variables of the mobile robot is heading (turning) angle. The robot heading (turning) angle is represented by linguistic fuzzy rule consequent sets {NEGATIVE, POSITIVE}, with two trapezoidal type membership functions shown in Fig. 3. Positive and negative mean that the robot turns to the left and right, respectively [7].

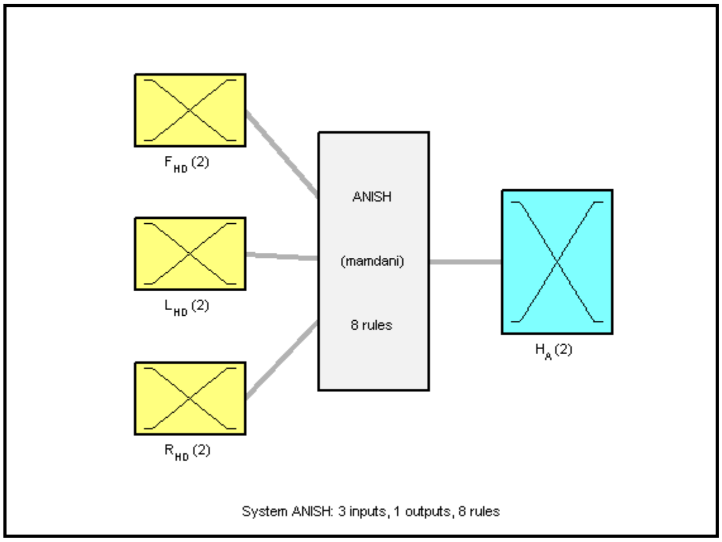


Fig. 1. Mamdani Model Fuzzy Logic Controller for Mobile Robot Navigation in Cluttered Environment

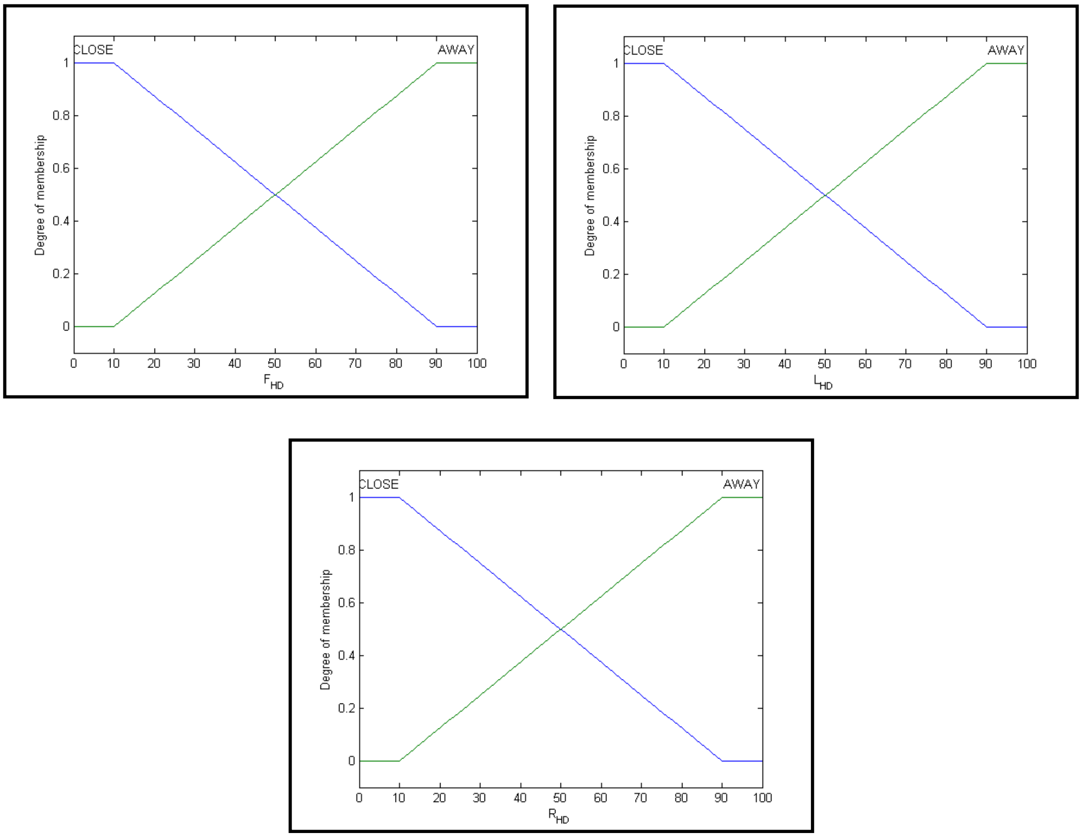


Fig. 2. Fuzzy Membership Functions for Inputs (a) Front hurdle Distance, (b) Left hurdle Distance, and (c) Right hurdle Distance

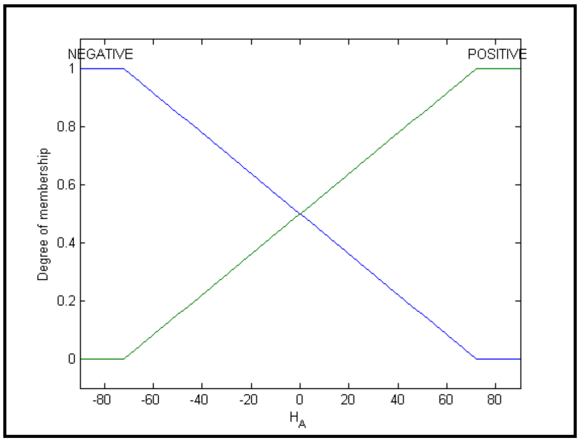


Fig. 3. Mamdani Type Fuzzy Membership Function for Output Heading Angle

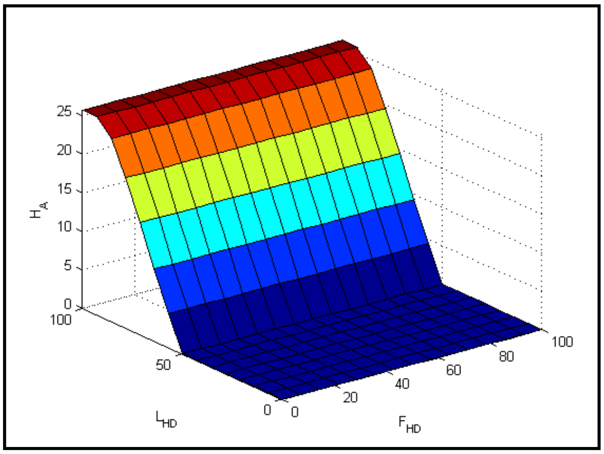


Fig. 4. Heading Angle (H_A) control surface Rule Distribution

Table 1. Mamdani Type Minimum Rule Based Fuzzy Logic Controller for Mobile Robot Navigation with Hurdles in Cluttered Environment.

Fuzzy Rule No.	Front Hurdle Distance	Left Hurdles Distance	Right Hurdles Distance	Heading Angle	Turn
1	Away	Close	Close	Positive	Left
2	Away	Close	Away	Negative	Right
3	Away	Away	Close	Positive	Left
4	Away	Away	Away	Positive	Left
5	Close	Close	Close	Positive	Left
6	Close	Close	Away	Negative	Right

7	Close	Away	Close	Positive	Left
8	Close	Away	Away	Positive	Left

Table 2. Example of the Fuzzy Inference Rules

IF (Antecedent)

Hurdle Distance on Front (F_H_D) is *AWAY* and

Hurdle Distance on Left (L_H_D) is *AWAY* and

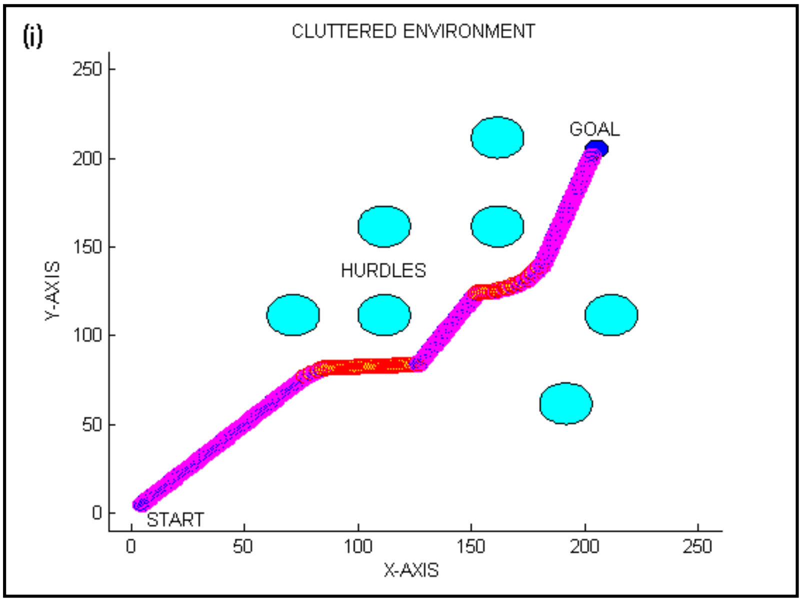
Hurdle Distance on Left (R_H_D) is *CLOSE*

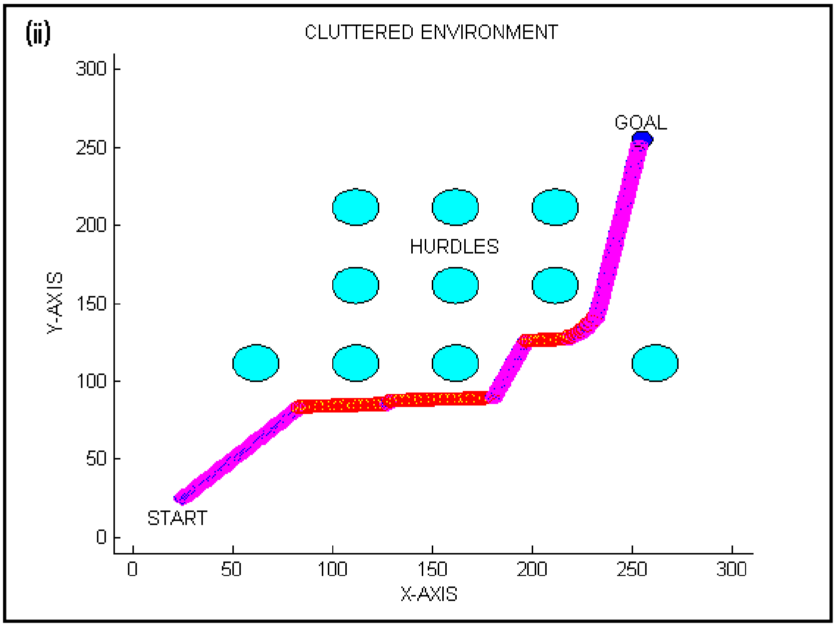
THAN (Consequent)

Heading Angle (H_A) Theta is *POSITIVE*

3. Simulation Result and Discussion

This paper presents a fuzzy logic controller minimum rule based approach to mobile robot localization in front, left, and right of a certain local object (hurdles). Further the application of this fuzzy logic controller for mobile robot navigation has been discussed. The simulation results by using MATLAB exhibit that the mobile robot can start moving from start position, avoids the lot of hurdles in cluttered environment to reaches goal position. The proposed navigation strategy is tested by simulating the two navigation actions such as avoid hurdles, and goal-seeking in cluttered environment. Fig. 5 (i), (ii), and (iii) are the different navigation path simulation hurdles avoidance in cluttered environment with lot of hurdles and the goal position is located above the hurdles. In all scenarios, it is observed that the resulting simulation shows the mobile robot movement directly towards the goal while avoiding hurdles on its path, and preforming a smooth trajectory. In simulation shows that the robot can only move in the forward direction (i.e., reverse motion is not allowed). The robot avoids lot of hurdles in simulation successfully in different cluttered scenarios.




(ii)
CLUTTERED ENVIRONMENT
GOAL
HURDLES
START
Y-AXIS
X-AXIS
0
50
100
150
200
250
300

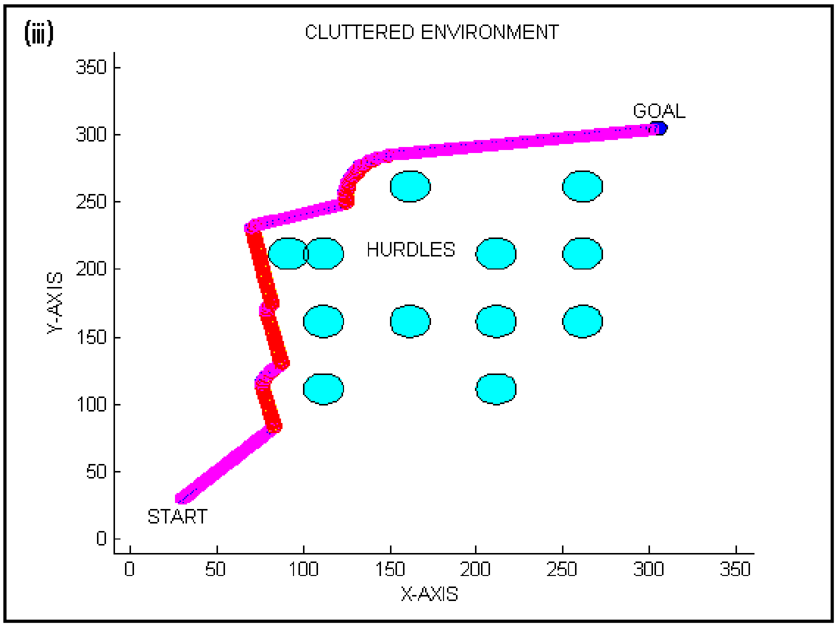

(iii)
CLUTTERED ENVIRONMENT
GOAL
HURDLES
START
Y-AXIS
X-AXIS
0
50
100
150
200
250
300
350

Fig. 5. (i), (ii), and (iii) Different Navigation Path Simulation Hurdles Avoidance in Cluttered Environment for Mobile Robot Using Mamdani Type Minimum Rule Based Fuzzy Controller

4. Conclusion and Future Scope

In this paper we have discussed a Mamdani type minimum rule base fuzzy logic system which has been used successfully in a control system for robot hurdles avoidance in cluttered environment. Fuzzy system has a capability to express the knowledge acquired from input (antecedent) -output (consequent) data in the form of fuzzy inference rules. In order to help the mobile robot to move out of the environment autonomously, a fuzzy logic is developed to select feasible actions for the mobile robot. In particular, the fuzzy logic will collect the sonar measurement data as inputs, and select an action for the robot so that it can navigate in the environment successfully. When applied to the control of the robot in simulations, satisfactory performance is also achieved. The method presented can be easily extended to include multiple mobile robots for increasing its performance. Also, the controller will be modified to navigate within dynamic environments simulation with experimental setup mobile robot.

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