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Design of adaptive fuzzy tracking controller for Autonomous navigation system

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Abstract This paper repesent a software implimentation of adaptive fuzzy tracking controller for autonomus navigation system of robot for known environment. The system will be used by robot to reach the destination by avoiding obstacles in its path between source to destination. Fuzzy algorithm will be used to detect the near by obstacles,avoid path obstacles and reach the destination by shortest path distance.
Keyword – Adaptive fuzzy tracking controller,obstacles avoidancce, navigation

I. INTRODUCTION

The task of developing a Navigation system where the robot must find its way to the destination through acquiring information from the environment raises a number of issues. The design of any Navigation system for an Autonomous Mobile Robot is largely dependent on the real time demands placed on the robot and the limitations placed on its operation within the environment. For the successful implementation, robot must be responsive to its environment and the controller which controlling the robot must be robust enough to overcome problems during navigation of robot. For the developing the controller for robot, use of fuzzy logic makes its implementation very easy. The construction of a fuzzy logic control (FLC) system is faster than traditional methods of control. It is understandable, robust and maintainable and in general requires much less memory and computing power than conventional methods. Use of fuzzy logic controller over the traditional linear system are prefer as it is very easy to design and implement. Due to imprecise nature the fuzzy tracking controller are very useful for robot to deal with continuously changing environment if any. The control problems in navigation of the robot along a desired path is effectively implemented using fuzzy controller with fuzzy characteristics. Basically we fuzzy logic play an important role for the interaction between robot and the surrounding during navigation.

II. FUZZY LOGIC APPROACH

We have developed the adaptive fuzzy tracking controller to express the system in more flexible way. The design process of a fuzzy logic system can generally be separated into three different stage

A. Fuzzification
B. Rule base
C. Defuzzification

The fuzzification module transforms numerical variables in fuzzy sets, which can be manipulated by the controller. The input are fuzzified by the membership function. This membership function maps the crisp inputs to a degree of values of membership for each function. Then the rules are developed after the membership functions are developed. After the rules evaluation, in the defuzzification stage the output fuzzy values are again mapped to provide the crisp output & this can be done by defuzzification.

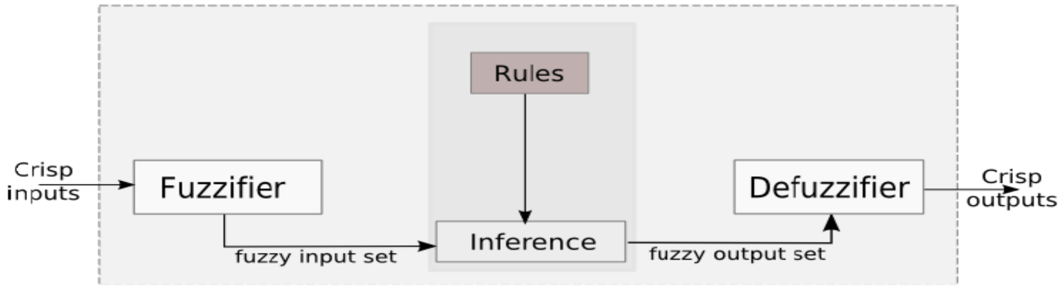


Figure 1: A Fuzzy Logic System.

III. FUZZY LOGIC CONTROLLER

As we are designing the navigation for indoor environment we have created one map (lets called it room) in the MATLAB where all the black circle indicating the obstacles in the room and rest of the free path is open for robot for navigation system. We are free to choose the position of robot (source) & final destination point in anywhere in the room.

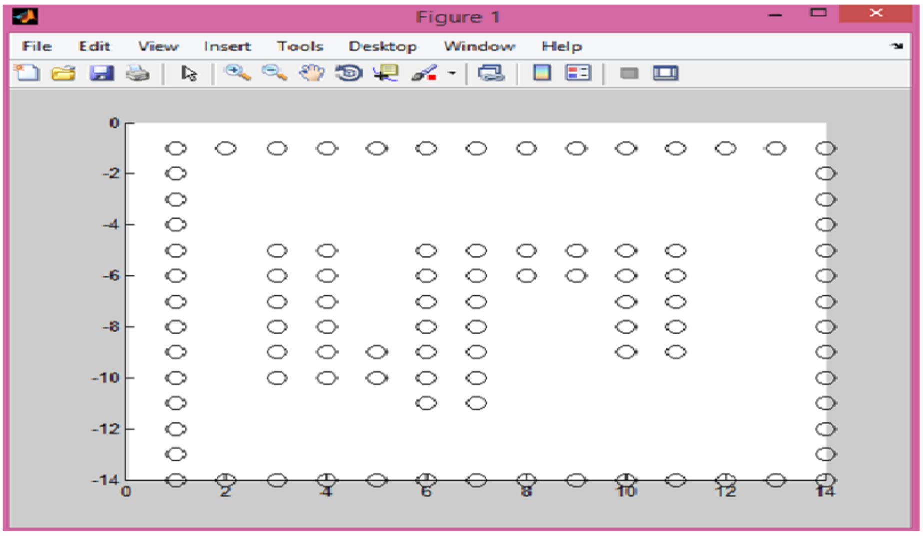


Figure No 2. Indoor room created in MATLAB

In the given figure (room) we have use very basic logic to detect the obstacles and free path available for navigation. All the black circle i.e obstacles are considered as logic 1 and rest of the free area available is considered as logic 0. So during navigation robot count logic 0 as a free path to move forward and count 1 as obstacles. Now we use fuzzy tracking controller to provide rules for obstacles avoidance and creating navigated path from source of robot to final destination.

IV. ADAPTIVE FUZZY CONTROLLER

The word adaptive here means controller adapt the changing environment so as the changing input value and process it accordingly for the navigation of robot

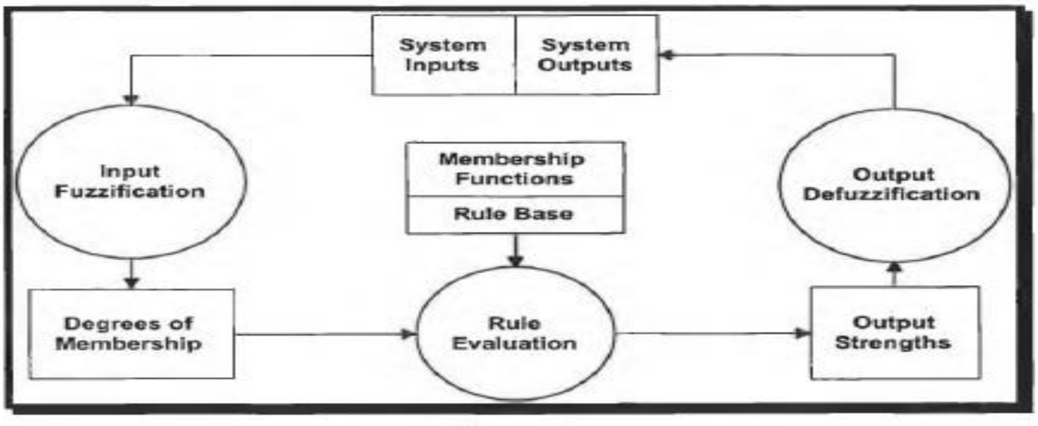


Figure No 3. Block diagram of Fuzzy tracking controller

The structure of controller have 3 input FOD,ROD,LOD which represent distance of obstacles at front direction, at right direction & at left direction from the robot. On the other hand we have RWV & RWV which represent the right wheel velocity and left wheel velocity as a output. The output of system give direction and orientation to the robot navigation to reach destination.

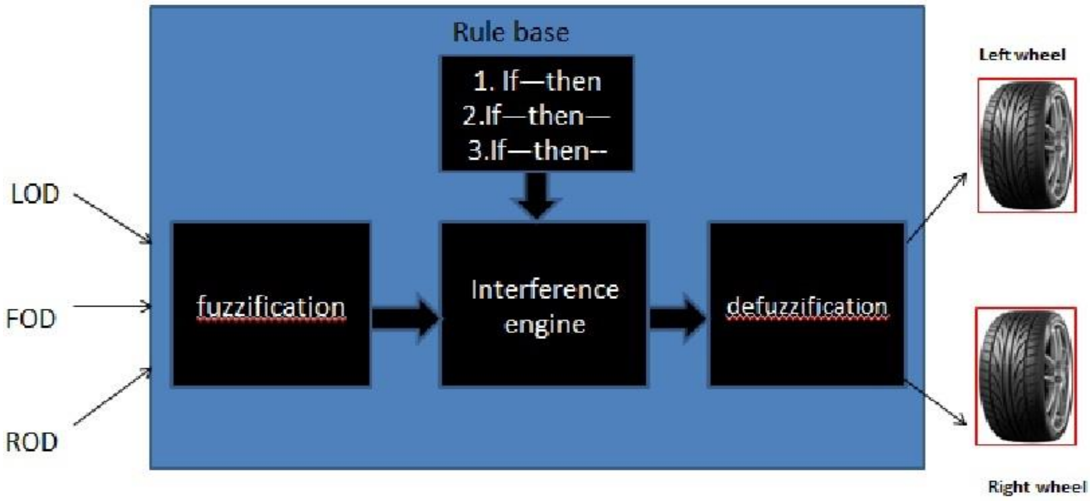


Figure No 4. Applied fuzzy logic system

Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. In another word distance of obstacles at RIGHT, LEFT & FRONT direction will be initially in crisp value which will then converted into linguistic variable ROD, LOD &FOD. Each linguistic variable is further divided in linguistic term (linguistic value) as HIGH, MEDIAM & LOW. Membership functions are used to map the non-fuzzy input values to fuzzy linguistic terms. This whole process is known as Fuzzification.

An inference mechanism emulates the expert's decision making in interpreting and applying knowledge about how to perform a good control. This can be implemented as a fuzzy rule-base. The rules may use the experts experience and control engineering knowledge. In a Fuzzy controller, a rule base is constructed to control the output variable. Here we have use fuzzy rule in a simple IF-THEN rule form with a condition and a conclusion.

After the inference step, the overall result is a fuzzy value. This result should be defuzzified to obtain a final crisp output. This is the purpose of the defuzzifier component of a Fuzzy tracking controller. Defuzzification is performed according to the membership function of the output variable.

Fuzzy logic algorithm

1. Define the linguistic variables and terms (initialization)
2. Construct the membership functions (initialization)
3. Construct the rule base (initialization)
4. Convert crisp input data to fuzzy values using the membership functions (fuzzification)
5. Evaluate the rules in the rule base (inference)
6. Combine the results of each rule (inference)
7. Convert the output data to non-fuzzy values (defuzzification)

Following are the 35 rule we have used for obstacles avoidance during navigation of the robot.

Sr.N	FOD	LOD	ROD	LWV	RWV
1	FAR	NEAR	NEAR	FAST	FAST
2	FAR	NEAR	MEDIAM	FAST	FAST
3	FAR	NEAR	FAR	FAST	FAST
4	FAR	MED	NEAR	FAST	FAST
5	FAR	MED	MED	FAST	FAST
6	FAR	MED	FAR	FAST	FAST
7	FAR	FAR	NEAR	FAST	FAST
8	FAR	FAR	MED	FAST	FAST
9	FAR	FAR	FAR	FAST	FAST
10	FAR	MED	FAR	FAST	FAST
11	MED	NEAR	NEAR	MED	MED
12	MED	NEAR	MED	FAST	SLOW
13	MED	NEAR	FAR	MED	SLOW
14	MED	MED	NEAR	SLOW	FAST
15	MED	MED	MED	MED	MED
16	MED	MED	FAR	FAST	MED
17	MED	FAR	NEAR	SLOW	FAST
18	MED	FAR	MED	MED	SLOW
19	MED	FAR	FAR	MED	MED
20	MED	MED	FAR	MED	SLOW
21	MED	FAR	NEAR	MED	MED
22	NEAR	NEAR	NEAR	SLOW	SLOE
23	NEAR	NEAR	MED	MED	SLOW
24	NEAR	NEAR	FAR	FAST	SLOW
25	NEAR	MED	NEAR	SLOW	FAST
26	MEAR	MED	MED	MED	MED
27	NEAR	MED	FAR	FAST	SLOE
28	NEAR	FAR	NEAR	SLOW	FAST
29	NEAR	FAR	MED	SLOW	FAST
30	NEAR	FAR	FAR	FAST	SLOW
31	NEAR	NEAR	FAR	MED	SLOW
32	NEAR	FAR	NEAR	SLOW	FAST
33	NEAR	NEAR	FAR	SLOW	SLOW
34	NEAR	FAR	FAR	SLOW	SLOW
35	FAR	NEAR	FAR	SLOW	SLOW

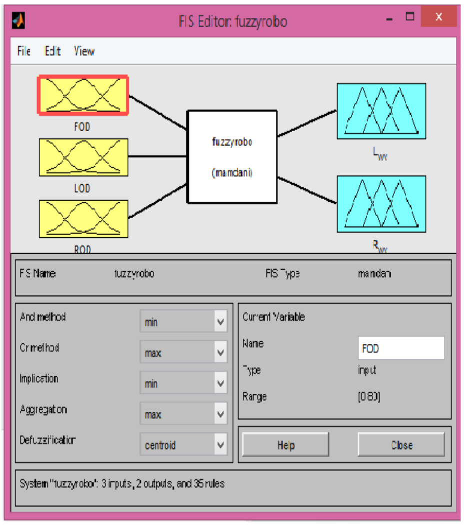


Figure No. 5. Fuzzy Interference System Editor

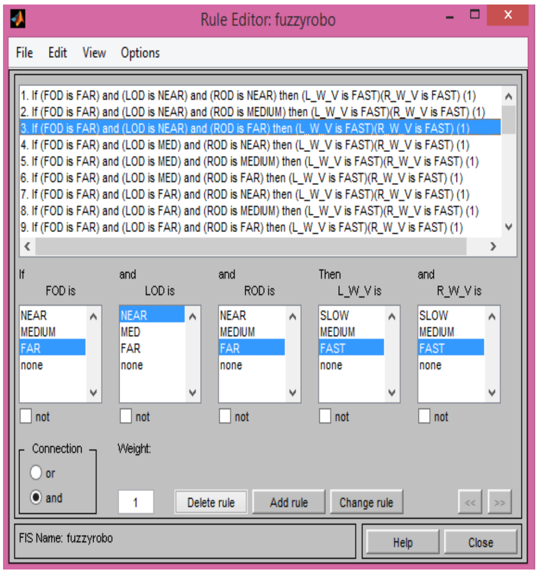


Figure No 6. Fuzzy rule editor of FTC

V. PATH PLANNING

The task of automatic path planning introduces problems that are central to mobile robot applications. In this context, given the mobile robot's initial and final goal locations and an obstacle map, the problem is to find the appropriate path from the initial position to the goal position such that the mobile robot can smoothly travel through the area without colliding with the obstacles. Unlike manipulators that generally work in a fixed environment performing a set number of movements, when planning for mobile robots, it is more important to develop a negotiable path quickly than to develop an "optimal" path, which is usually a costly operation. A mobile robot may be following some previously computed path when it finds it must modify the path to bypass some obstacle. Path planning for a robot is therefore a continuous on-line process rather than a single off-line process.

The time saved in travelling a shortest distance path may not be justified by the long period of time required in planning the path and no efficient algorithms currently exist for finding optimal paths among three-dimensional obstacles. A compromise is to find a path that is not optimal in absolute Euclidean distance but is optimal (shortest) using the primitive path segments. Therefore the resultant path will not deviate significantly from the optimal path, but the time saved justifies the simplification.

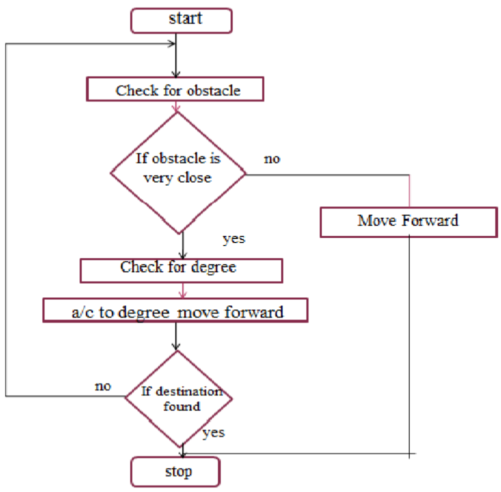


Figure no 7. Flow chart of Adaptive fuzzy controller

Following figure show the navigated path of robot by avoiding the obstacles present in the surrounding environment with the help of fuzzy tracking controller

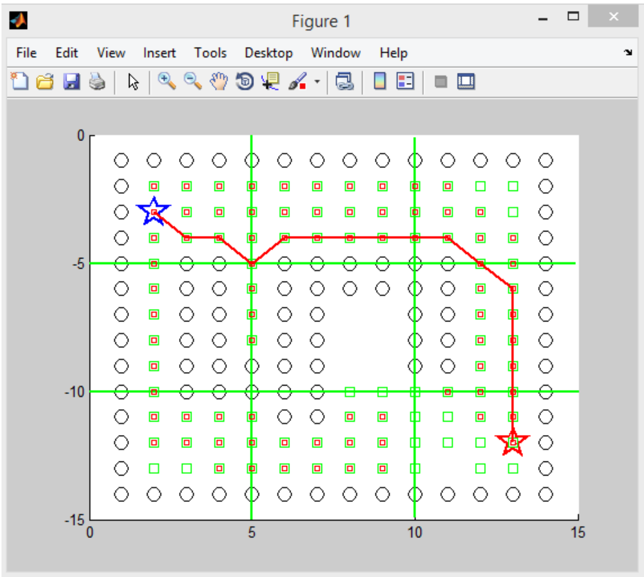
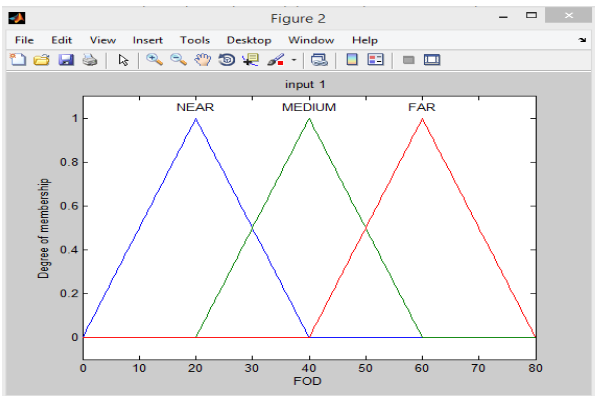


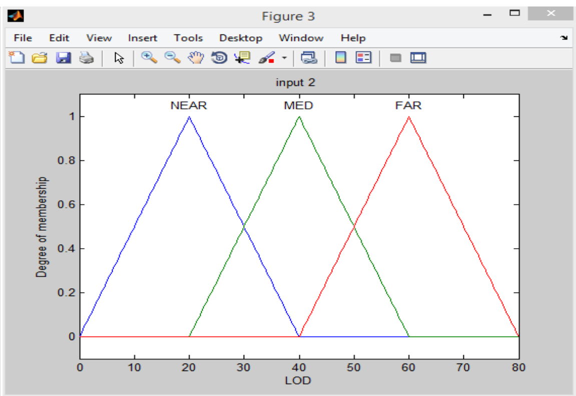
Figure No 8. Navigated path of robot

The result is obtained by fuzzification of input ROD, LOF & FOD in form of NEAR, MEDIUM & FAR. In another word each input (distance between robot and obstacles) is further divided as robot at close distance, at medium distance and at far distance from obstacles.

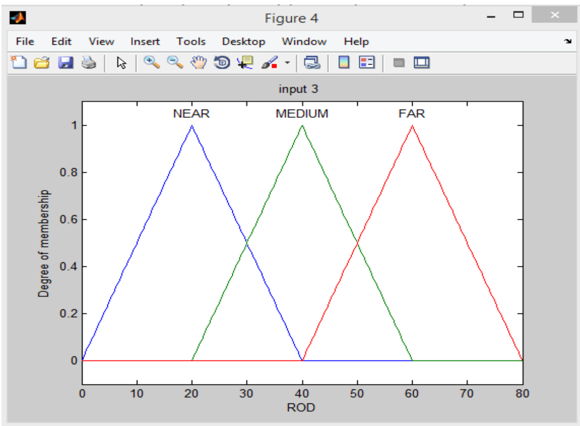
Following figures shows the Membership function ROD, LOD & FOD with respective to the degree of membership function ranging from [0,1]. Membership functions are used in the fuzzification and defuzzification steps of a Fuzzy Logic System, to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic term.



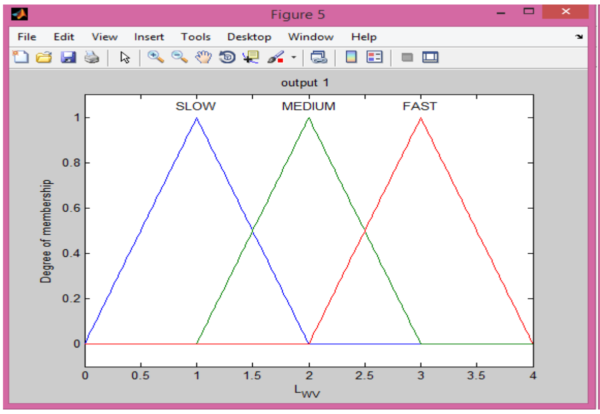
Membership function of ROD



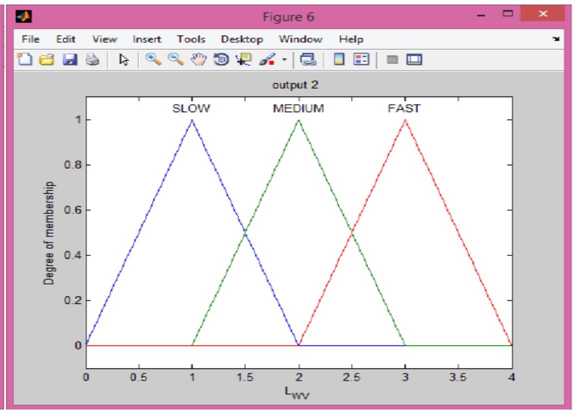
Membership function of LOD



Membership function of FOD



Membership function of LWV



Membership function of RWV

Figure no 9 Membership function of three input (LOD,ROD,FOD) AND TWO OUTPUT (LWV,RWV)

VI. RESULT

The navigation system for robot in indoor environment have been designed successfully with the help of fuzzy tracking controller. Obstacles avoidance have been successfully achieved by the robot by using the fuzzy rules design for fuzzy tracking controller. Navigated path of the robot from source position to destination have been shown in figure no 7. Membership function of three input (ROD,LOD,FOD) and two output (LWV,RWV) is also archived.

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