Comparison Study of Mamdani Method and Sugeno Method in The Navigation System for Indoor Mobile Robot

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ABSTRACT
Robotics is rapidly growing field and has attracted many researchers for the evolution of human social needs. Robotics has wide range of applications like construction robotics, medical robotics, industrial robotics, space robotics and many more. Among of these fields particularly in manufacturing industry robots can assist the human to make the task simpler or even can replace the human to perform a task. Basically robot is a mechanical device that interacts with the environment physically and navigates through the environment. The movement of autonomous robots in unknown environment is a complex task that further require a complex control system which can command the robot to deal with that uncertainty and make them decide to take appropriate step according to some algorithm or rules which will be defined in that particular control system. Lofti Zadeh proposed a mathematical system, called fuzzy logic that can model the nonlinear problems with less complexity.

Keywords - fuzzy logic, Mamdani method, MATLAB simulation, Sugeno, Obstacle Avoidance, wall following.

I. INTRODUCTION
This work wall following and obstacle collision prevention behavior of mobile robot is carried by implementing fuzzy logic controller. Although using control as well as conventional control techniques [1, 2] controller can be designed but an absolute mathematical model is required in these techniques. Robotics field involves high degree of uncertainty and complexity. Due to nonlinearity property of mobile robot, it is difficult to obtain absolute mathematical model of a system for designing its controller [3]. Fuzzy logic is a soft computing technique that does not require mathematical model; it requires if-then rules using linguistic variables to deal with the real time problems. Besides controlling the mobile robot [4, 5], path planning and tracking of robot [6-8], fuzzy logic has wide range of applications like electrical motors speed control [9], robot manipulator position control [10], complex and ill-defined plants [11, 12]. Whenever a robot navigates through the environment autonomously there are a lot of uncertainties that a robot needs to cope with. There can be number of obstacles, rough surface, sharp angles and turns, stairs etc. the control technique should be accurate enough to make robot not only to navigate through that unknown environment but also can prevent obstacle collision. Fuzzy based controller is more convenient because it does not require mathematical model of a system, secondly fuzzy logic is very suitable for nonlinear problems and it is very easy to define rules in fuzzy system as it does not require complex mathematical terms.

Fuzzy inference system is decisions making program in which fuzzy logic operators are applied on the linguistic variables. Mamdani inference method and Sugeno inference method are the most commonly used in fuzzy systems.

II. DESIGNING OF MOBILE ROBOT
Rectangular shaped mobile robot consists of two wheels, with fixed distance between them, is implemented and simulated in MATLAB. First, environmental scenario is represented by digital image. A digital image can be thought of as small dots on the screen called pixels. Robot consists of two sensors at the 80° angle apart called rangefinder [13]. These sensors measure the distance from obstacle in terms of pixels. As the digital image represented obstacle matrix where value ‘0’ represents obstacle.

III. FUZZY INFERENCE SYSTEM
Fuzzy control theory is the emerging technology that have targeted the industrial applications and adding new dimension to the existing domain of conventional control system. Fuzzy logic is a mathematical tool for dealing with uncertainty. In fuzzy logic information and data boundary is not completely or clearly defined [14]. FL uses linguistic variables to represent a range of values. An FL controller works in a progression of three steps. First it receives input data that is processed...
through a fuzzification step. Fuzzification involves preset membership functions for data interpretation as defined by the user. This data then enter a rule matrix of IF-THEN statements to create a fuzzy output. In order for the controller to use the processed output, one last step, a defuzzification process turns the fuzzy output into a clear and concise output value to be performed by the system. Fig 1 shows the basic fuzzy inference system diagram. The basic difference between mamdani method and sugeno method lies in the defuzzification section. In mamdani method defuzzification is done using linguistic variables while on sugeno method this part consists of either constant values or the linear values. Fuzzy set theory is an extension of the classical set theory, and is also a difficult mathematical notion [15].

IV. SIMULATION

In [13] Mamdani method was implemented and the path followed by robot was showed. Here further two different conditions are specified. First, path is rough and in second stair case is considered. For both the conditions mamdani method as well as sugeno method is implemented. Here comparison between both the methods is made for each condition. Comparison is made in term of time taken by robot as well as path followed by robot along the wall accurately.

In this work right distance and left distance measured by robot is taken as antecedents while speed of left wheel and right wheel is taken as the consequents. Both the methodologies i.e. mamdani method and sugeno method is applied and comparison is made between them. There are three membership functions (near medium and far) for both the antecedents; there are total nine rules that define the speed of wheels.

Here is considered that robot covers 250 steps. Defuzzification method for Mamdani method is Center of Gravity while for Sugeno method weighted average defuzzification method is considered. If Fig 2 and Fig 3 analyse closely it is clear that in Sugeno method robot can follow the wall more accurately or should say Sugeno method can quickly orient along the wall than Mamdani method.
Now consider the stair case. Now robot has to deal with stairs. Here robot takes stair steps in both ways i.e. ascending as well as descending way. Fig 4 and Fig 5 represents the path followed by the robot using Mamdani technique and Sugeno technique respectively.

V. RESULTS

Simulation results of this work are carried out on MATLAB. Simple fuzzy controller is designed for robot navigation obstacle avoidance. Further two different methodologies are applied for comparison purposes. Table 1 represents the time taken by robot (in seconds) for different methods.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Mamdani method (obstructed path)</th>
<th>Sugeno method (obstructed path)</th>
<th>Mamdani method (path with obstacles)</th>
<th>Sugeno method (path with obstacles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70.435</td>
<td>68.630</td>
<td>32.663</td>
<td>32.860</td>
</tr>
<tr>
<td>2</td>
<td>70.478</td>
<td>67.809</td>
<td>32.700</td>
<td>32.931</td>
</tr>
<tr>
<td>3</td>
<td>69.973</td>
<td>67.253</td>
<td>32.857</td>
<td>32.963</td>
</tr>
</tbody>
</table>

Whenever robot sense the obstacle it has turn or change the direction to avoid collision. Here an assumption is made that after sensing the obstacle when robot takes right turn then change in angle will be taken as positive value otherwise change of angle will be negative.

VI. CONCLUSION

Design and implementation of the robot is a complex task but implying the fuzzy rules makes it less complex. In present work a robot is designed and implemented in MATLAB using fuzzy logic. Sugeno inference method is applied which is computationally efficient but Mamdani method is also implemented which has more expressive power. If Fig. 5 is closely analyzed robot with Sugeno method navigate along the stairs more proficiently as compared to Mamdani method shown in Fig. 4. If we compare both the figures ascending the stairs using Sugeno method shows better results.
Table I. represents the time taken by robot in 250 steps. In first considered case where surface is rough robot approximately takes more than twice the time than the time taken by robot on smooth surface with obstacles. Further in both case Mamdani as well as Sugeno method is applied. In the case of obstructed or rough area Sugeno takes less time than that of Mamdani method. But in the case where obstacles and stairs are present Mamdani takes approximate equal time to that of Sugeno method but the path followed by robot using Sugeno inference method is more adequate.

REFERENCES