International Journal of Applied Artificial Intelligence in Engineering System 3(2), 2011: 103-108

IJAAIES



# SUGENO FUZZY BASED NAVIGATIONAL CONTROLLER OF AN INTELLIGENT MOBILE ROBOT

Dayal R Parhi and BBVL Deepak

Abstract: This paper deals with the development of fuzzy inference system in order to solve mobile robot navigation problem. The developed system architecture works on the basis of Sugeno fuzzy type. To achieve the better path by an intelligent mobile robot within its work space, the proposed fuzzy model requires two inputs: (1) the distance from the robot to the obstacles in the workspace and (2) position of the target i.e. the robot heading angle towards the destination. Once the system gets the knowledge from the environment, it will obtain the suitable steering angle for an autonomous mobile robot. This process will be continued until the robot reaches its goal. Simulation results are given to verify the feasibility of the proposed methodology for an autonomous mobile robot.

Key words: fuzzy inference system, obstacle avoidance, autonomous mobile robot, mobile robot navigation

## 1. INTRODUCTION

The basic requirement of an autonomous mobile robot is the ability of generating path by avoiding obstacles within its environment. Behaviour-based methodologies have been introduced in order to solve this problem in the recent years as explained in [1]. A large amount of work has been dedicated to solve this problem and reviews on many approaches have been conducted by various authors as described in [2-4].

Fuzzy Logic Algorithm (FLA) have implanted in [5] for a mobile robot controller hardware to avoid obstacles by turning proper steering angle. Behaviour-based fuzzy control has been applied in [6] to sonar based obstacle avoidance for Help-mate mobile robot. Yousfi et al. [7] have developed sugeno fuzzy controller for a mobile robot and the consequences of the fuzzy system have been optimized by using gradient method. Mobile robot navigation in indoor environments has been carried out in [8] using fuzzy logic controller. In their work inputs are the desired direction of motion and the sensors readings; and the output is the accelerations of the robot wheels. Norouzi et al. [9] have introduced a navigation approach using fuzzy controller to produce paths based on extracted lines and fusing data from sensory information. A fuzzy logic-based real-time navigation controller [10] has been addressed which combines path planning and trajectory for an autonomous mobile robot. A rough-fuzzy controller for an autonomous mobile robot based on rough set and fuzzy set theory has been developed in [11]. By this approach they improved uncertainty reasoning of the mobile robot in order to obtain better wall-following behaviour results. A two-stage fuzzy inference system [12] has been introduced for sensor based mobile robot in order to navigate the robot from one position to another. The first stage of the fuzzy system gives the outputs as angular velocity based on the robot's five sonar sensor readings then these values are fed into stage of the fuzzy controller to get the required linear velocity as the output.

The present research work aims to develop efficient system architecture using fuzzy inference system. This paper arranged into six sections as follows: second section outlines the Sugeno fuzzy model; third section describes the selection of member ship functions and the required rules for mobile robot navigation are illustrated in section four. The results obtained from the developed methodology are discussed in section five and in the last section the concluding results are explained.

* Robotics Laboratory, Department of Mechanical Engineering, National Institute of Technology, Rourkela, Orissa, India, E-mail: dayaldoc@yahoo.com; deepakjournal@gmail.com

## 2. SUGENO FUZZY MODEL

The fuzzy inference system is a popular computational method developed based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. The basic configuration of a fuzzy inference system comprises of three theoretical components: (1) rule base: contains fuzzy rules; (2) database: identifies the membership functions used in the fuzzy system and (3) reasoning mechanism: performs the inference process for the rules and gives details to derive a suitable conclusion. The fuzzy inference system can receive either fuzzy inputs or crisp inputs but the outputs it obtains are almost fuzzy sets as shown in Fig. 1.

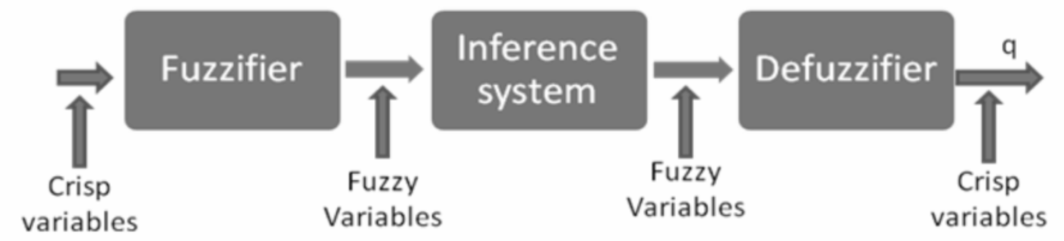


Figure 1: The Structure of the Fuzzy Logic Control

The Sugeno fuzzy inference system was introduced as the first effort to control a steam engine and boiler arrangement by a set of linguistic control rules obtained from human experience. Basic two-rule Sugeno fuzzy inference system is shown in Fig. 2 which derives the overall output z when subjected to two crisp inputs 1 and 2.

The rules for Sugeno fuzzy model are considering as follows:

If input-1 is A and input-2 is B then z = f(x, y)

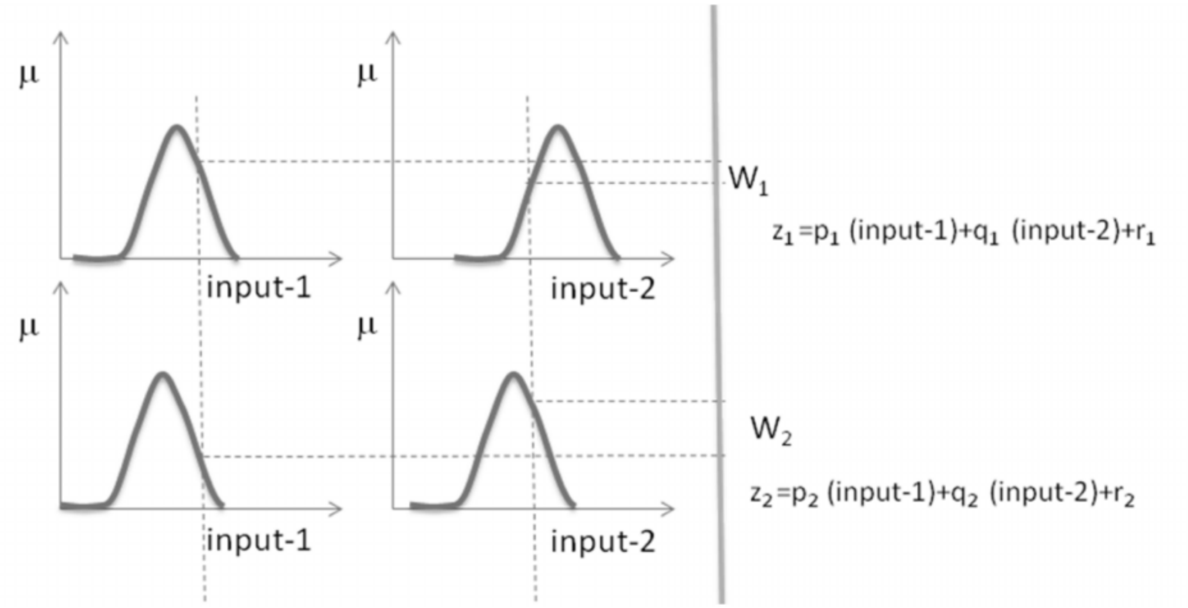


Figure 2: Sugeno Fuzzzy Inference System with Two Inputs and One Output

Defuzzification means the way of a crisp value is takeen out from a fuzzy set as a representative value. For Sugeno fuzzy system defuzzification approach is not necessary and the weighted average can be calculated as follows:

$$z = \frac{W_1 {}^8Z_1 + W_2 {}^8Z_2}{W_1 + W_2} \quad (1)$$

Where Z is the weight aggregated output membership function.

## 3. GENERALIZED BELL MEMBERSHIP FUNCTIONS

This type of membership functions (MF) are indicated by three parameters {a, b, c}:

$$\text{bell}(a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b\ldots}} \tag{2}$$

The parameters ‘a’ for width of the MF, and b is a positive value for representing slope of the curve and ‘c’ for centre of MF. In this paper, two inputs and one output are considering; the membership values for these are the bell-MF.

3.1. Member Ship for First Input: the fuzzy system is taking the sensory information as the inputs from the environment and the suitable steering angle gives as the output. The first input parameter is the distance between the nearest obstacle and the robot. Let us assume the maximum possible distance can be sensed by the robot is 180cm. So the MF values are varying from 0cm to 180cm as shown in fig.3 and is represented by ‘ROB’.

3.2. Member Ship for Second Input: let the system is working in first quadrant so the target angle is varying from 0° to 90° (P/2) as shown in fig. 3 and the membership functions are represented by T_angle.

3.3. Member Ship for Output: like the same condition output as the steering angle also varying from 0° to 90° (P/2) as shown in fig. 3 and the membership functions are represented by S_angle.

## 4. RULES CONSIDERING FOR FUZZY LOGIC CONTROLLER

Rules considering for the system architecture are all connectivity with ‘and’ and the possible rules for mobile robot navigation with the membership functions as shown in fig. 3 as follows:

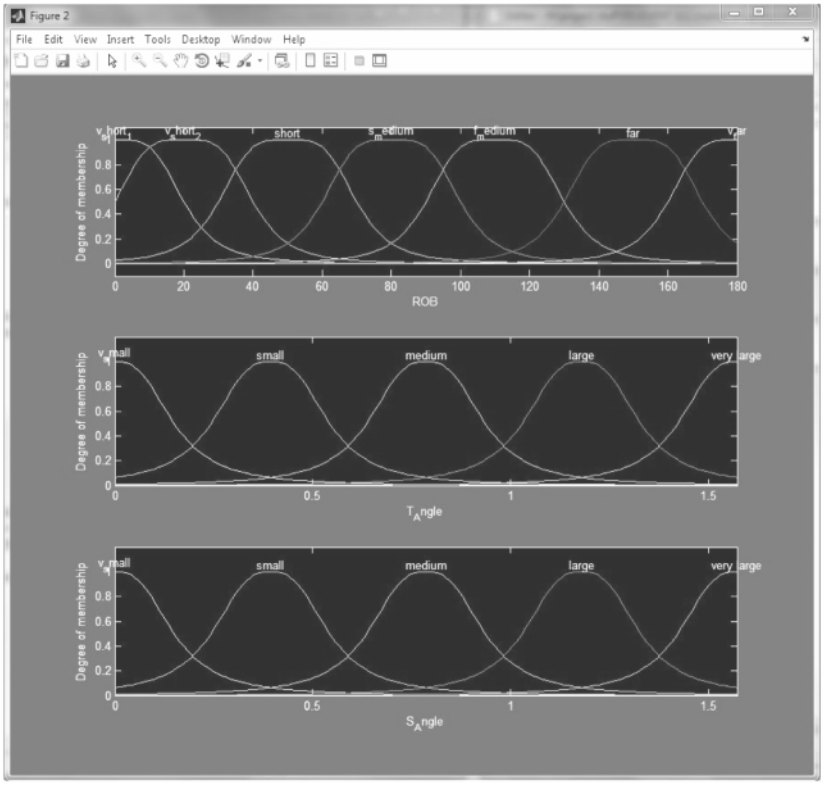


Figure 3: Membership Values of Inputs and Output

Table 1
Fuzzy Rules for Mobile Robot Navigation

| Rule Number | Input_1 (ROB) | Input_2 (T_angle) | Output (S_angle) |
|---|---|---|---|
| 1 | Very short_1 | Very small | Very small |
| 2 | Very short_1 | Small | Very small |
| 3 | Very short_1 | Medium | Very Large |
| 4 | Very short_1 | Large | Very Large |
| 5 | Very short_1 | Very Large | Very Large |
| 6 | Very short_2 | Very small | Very small |
| 7 | Very short_2 | Small | Very small |
| 8 | Very short_2 | Medium | Very Large |
| 9 | Very short_2 | Large | Very Large |
| 10 | Very short_2 | Very Large | Very Large |
| 11 | Short | Very small | Medium |
| 12 | Short | Small | Medium |
| 13 | Short | Medium | Very Large |
| 14 | Short | Large | Very Large |
| 15 | Short | Very Large | Very Large |
| 16 | Short medium | Very small | Medium |
| 17 | Short medium | Small | Medium |
| 18 | Short medium | Medium | Very Large |
| 19 | Short medium | Large | Very Large |
| 20 | Short medium | Very Large | Very Large |
| 21 | Medium | Very small | Medium |
| 22 | Medium | Small | Medium |
| 23 | Medium | Medium | Very Large |
| 24 | Medium | Large | Very Large |
| 25 | Medium | Very Large | Very Large |
| 26 | Far | Very small | Very small |
| 27 | Far | Small | Small |
| 28 | Far | Medium | Medium |
| 29 | Far | Large | Large |
| 30 | Far | Very Large | Very Large |
| 31 | Very Far | Very small | Very small |
| 32 | Very Far | Small | Small |
| 33 | Very Far | Medium | Medium |
| 34 | Very Far | Large | Large |
| 35 | Very Far | Very Large | Very Large |

## 5. SIMULATION RESULTS

Fuzzy logic controller has been developed using MATLAB 2008 version and how the system architecture is working in order to obtain collision free trajectories for an intelligent mobile robot is shown in figs. 4-5.

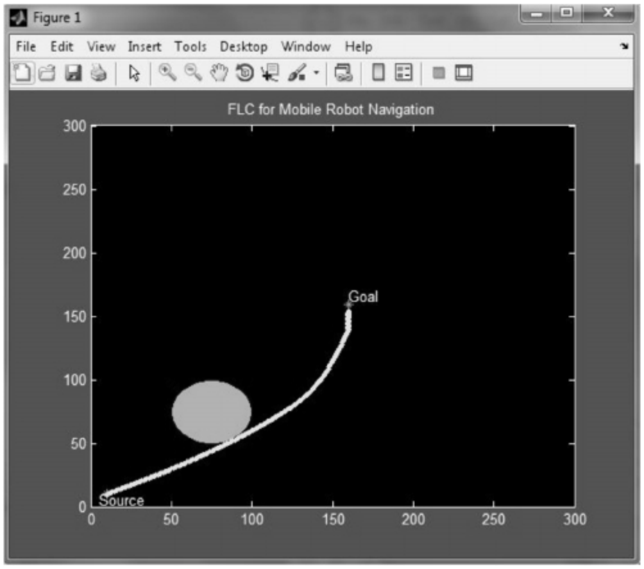


Figure 4: Single Obstacle – Single Target Environment

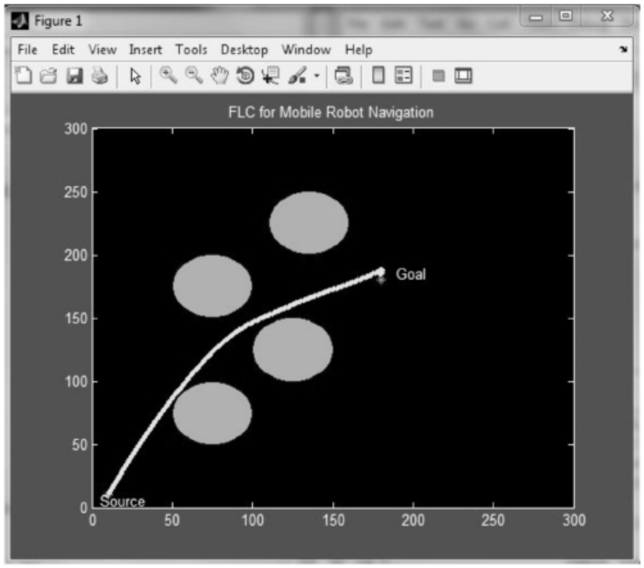


Figure 5: Multi Obstacle – Single Target Environment

## 6. CONCLUSION

New efficient system architecture has been modelled based on fuzzy inference system for solving mobile robot navigation. The proposed system architecture works on the Sugeno fuzzy type and bell shape membership functions has been considered. To obtain feasible path within the robotic work space, fuzzy inference system has modelled with two input parameters and one output parameter. By obtaining the proper steering angle, the mobile robot reaches its goal by avoiding obstacles within its free environment. From the simulation results it has been concluded that the robot can generate optimal collision free paths using the proposed methodology. Although the developed algorithm is suitable for generating collision free trajectories within its environments, it is required to apply more number of rules and fine tune of membership values in order to obtain better results.

## REFERENCES

[1] R. C. Arkin. Behaviour-Based Robotics, MIT Press, Cambridge Massachusetts, 1998.

[2] E Masehian, and D. Sedighizadeh, Classic and Heuristic Approaches in Robot Motion Planning - A chronological Review, World Academy of Science, Engineering and Technology 29, 2007, 101-106.

[3] B. Gabrys, R. J. Howlett, and L. C. Jain, Path Planning and Obstacle Avoidance for Autonomous Mobile Robots: A Review, KES 2006, Part II, LNAI 4252, Springer-Verlag, Berlin, Heidelberg, 2006, pp. 537– 544.

[4] D. Nakhaeinia, S. H. Tang, S. B. M. Noor and O. Motlagh1, A Review of Control Architectures for Autonomous Navigation of Mobile robots, International Journal of the Physical Sciences, 6(2), 2011, 169-174.

[5] S. Islam, M. Zaman, B. Madon, and M. Othman, Designing Fuzzy Based Mobile Robot Controller using VHDL, International Journal of Mathematical Models and Methods in Applied sciences, 2(1), 2008, 138-142.

[6] S. Thongchai and K. Kawamura, Application of Fuzzy Control to a Sonar-based Obstacle Avoidance Mobile Robot, Proceedings of the IEEE International Conference on Control Applications, Anchorage, Alaska, USA, 2006, 425-430.

[7] N. Yousfi, C. Rekik, M. Jallouli and N. Derbel, Optimized Fuzzy Controller for Mobile Robot Navigation in A cluttered Environment, Proceedings of 7$^{th}$ IEEE International Multi-conference on Systems 2010, 1-7.

[8] S. M. Raguraman, D. Tamilselvi, N. Shivakumar, Mobile Robot Navigation using Fuzzy Logic Controller, Proceedings of International Conference on Control, Automation, Communication and Energy Conservation, 2009, 1-5.

[9] M. Norouzi, A. Karambakhsh, M. Namazifar, and B. Savkovic, Object Based Navigation of Mobile Robot with Obstacle Avoidance using Fuzzy Controller, Proceedings of IEEE International Conference on Control and Automation, February 2010, 169–174.

[10] K. Liu and F. L Lewis, Fuzzy Logic-based Navigation Controller for an Autonomous Mobile Robot, Proceeding of IEEE International Conference on Systems, Man, and Cybernetics, 2, 2002, 1782-1789.

[11] C. S. Lee, T. Braunl, and A. Zaknich, A Rough-Fuzzy Controller for Autonomous Mobile Robot Navigation, Proceedings of 3rd International IEEE Conference on Intelligent Systems, April 2007, pp. 679–682.