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Control Strategy of a Real Mobile Robot using Singleton Takagi Sugeno Fuzzy Inference Methodology within The Frame Work of Artificial Intelligence Techniques

Suranjan Mohanty, Dayal R. Parhi, and Swadhin Sambit Das
1975suranjan@gmail.com,dayaldoc@yahoo.com,swadhinsambit2707@gmail.com
Padmanava College of engineering, N.I.T, Rourkela, Padmanava College of engineering

Abstract— A systematic research methodology has been adapted using singleton Sugeno fuzzy inference technique for solving a complex navigational control problem of a mobile robot from source point to destination point while negotiating with obstacles. A set of simulation and experimental analyses are performed and the results are depicted in graphical and tabular forms. It is observed from the simulation and experimental results that the proposed technique is well suited for navigational control of robots in a densely populated environment. Keeping in view of the methodology used for control of robots several artificial intelligence techniques are also discussed in the current paper.

Index Terms— Artificial, Control strategy, Fuzzy inference, Navigational, Obstacles, Path length, Singleton

1 Introduction

AI techniques are those techniques which can be used for planning pathways for different types of mobile robots. Planning path is a challenging task for mobile robots. Different types of intelligence techniques those are available in research field are fuzzy logic methods, neural network methods, genetic algorithm methods. Leaving these methods there are other methods known as cuckoo search methods, ant colony optimization methods etc [1-4]. In ant colony optimization method pheromone deposition is the criteria of getting optimized route in which ants move. Applying those methods the best route can be designed for a robot.

This paper discusses on possible use of fuzzy inference technique for navigation of mobile robot in an unknown environment from source position to target position. The research has been taken by many engineers and scientists in this field. It has been observed that hybrid fuzzy logic, grid based navigation, potential field have been taken by engineers. They have claimed potential field and grid based method can be successfully implemented for navigation of robot. Papers [5-9] discuss about various use of fuzzy logic technique for navigation and control of robot. Similarly papers [10-15] are focussing on various AI techniques along with fuzzy logic techniques for control of mobile robot and other robots in different environment conditions. Artificial immune system, neuro-fuzzy inference system, fuzzy logic are some of the important tools for mobile robot navigation. These are addressed in various papers [16-21] by many authors but a systematic approach is lacking for implementation of fuzzy logic in navigation of mobile robot. For this a methodology has been developed in this paper to implement fuzzy logic for navigation of mobile robot.

2 Research Focus of AI Techniques in Robotics and Engineering Field

Artificial intelligence technique is becoming more and more popular in current world scenario. These techniques are used in various engineering and robotics fields. Some of the artificial intelligence techniques which are in engineering field are jutted down below.Papers [22-31] elaborate on hybrid fuzzy logic, harmony search optimisation, intelligent neuro controller, fuzzy influence method for control of mobile robots as well as for various engineering applications. MANFIS, swarm optimisation, particle swarm optimisation, probabilistic fuzzy, potential fuzzy, FEA analysis have been covered in papers [32-44]. The corresponding researchers have implemented these artificial intelligence techniques for navigation of mobile robots and also they have verified the results in various exercises and also in numerical forms. It has also been observed that MANFIS, particle swarm optimisation, probabilistic fuzzy, potential fuzzy, FEA analysis has been used in various engineering fields as stated in papers [32-44].During the analysis it is observed that tese methods are suitable for various scientific applications as well as control of mobile robots. Neural network, fuzzy logic, petri potential fuzzy controller, swarm optimisation, frog leeping algorithm, FEA, fuzzy Gaussian, neuro fuzzy, artificial neural network, RBFNN, harmony search, wind driven optimisation tecniques are in limelight as cited in papers [45-61].researchershave used this techniques intelligently for control of various types of robots starting from robotic arm to mobile robots. Papers [62-84] discuss about fuzzy neuro hybrid techniques, fuzzy logic, behaviour based neuro

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fuzzy technique, type-2 fuzzy, ANN and fuzzy logic technique for finding out steering angle for mobile robot during navigation. They have concluded that using these techniques a robot can get proposed steering angle and successfully reach the target. Behaviour based navigation has been cited in papers [85-99] for doing behaviour based navigation. Several artificial intelligence techniques such as potential function, RBFNN, adaptive network based FIS, artificial immune system, rule based fuzzy logic controller, Genetic algorithm and fuzzy interference technique are being used by researchers. Also the characteristic based and behaviour based navigation using invasive weed optimisation has been observed in papers [100-105]. Papers [106-121] dealt with genetic algorithm, mamdani, adaptive genetic , Sugeno-fuzzy, ant colony, frog leaping algorithm, adaptive neuro fuzzy, Bees algorithm, chaotic optimisation for control of mobile robots. Use of these techniques are beneficial for the researchers because they give an obstacle free path for mobile robot from start position to goal position. Similarly rule based neuro fuzzy, neuro fuzzy navigation, particle swarm optimisation, multi objective ANFIS, takagi Sugeno, fuzzy interference technique, fuzzy logic, firefly algorithm, ANFIS are being used by many engineers in papers [122-144]. In these papers the engineers have derived many behaviour such as obstacle avoidance, target seeking using this type of artificial intelligence techniques. Papers [145-164] depict a type to FLC, Genetic Algorithm, Neural network, Cuckoo search algorithm, Fuzzy Neuro controller, IWO based adoptive Neuro-fuzzy controller for successful control of mobile robots from start position to goal position in various conditions. Similarly papers [165-181] describe neuro fuzzy controller, ecologically inspired algorithm, cuckoo search method, immune based algorithm, hybrid fuzzy, sliding mode fuzzy, mamdani type fuzzy, neuro fuzzy algorithm, ANN, FEA for control navigation of mobile robots. It is seen that techniques are vary potential in various complicated and unstructured environments. Takagi Sugeno, type-2 fuzzy, hybrid PSO based fuzzy path planner, adoptive neuro fuzzy, type-1 fuzzy and ANFIS is addressed in papers [182-198] for navigation of mobile robots in a cluttered environment. This type of techniques along with ACO, radial basis function, type-2 fuzzy also been addressed in papers [199-211]. In papers [212-223] a specific focus have been made to elaborate RBFNN, ANN, Potential field, innate immune system, adoptive fuzzy neuro system for possible solution of navigational problem of wheeled robots subjected to various environmental conditions. In papers [224-237] MANFIS, SA, FLC, ANFIS, teaching and learning algorithm have been dealt vigorously for successfully implementation of control of mobile robots from start point to goal point. Papers [238-241] discuss on PID controller, application of PID controller for navigation of mobile robots for various scenarios.

3 ANALYSIS OF FUZZY LOGIC METHOD FOR ROBOT NAVIGATION

3.1Description of inputs and outputs

In the fuzzy controller we have used four inputs and one outputs. The four inputs are FOD, ROD, LOD, TA and output is SA.

3.2 Corresponding fuzzy logic figure in final form

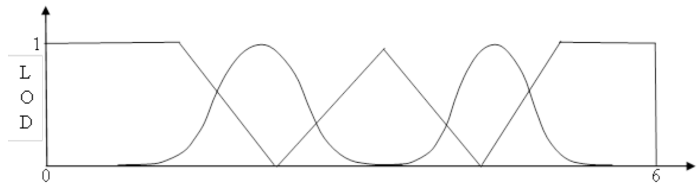

Fig. 1a

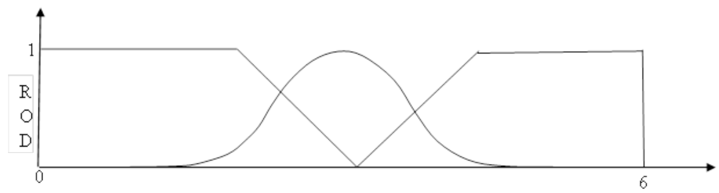

Fig. 1b

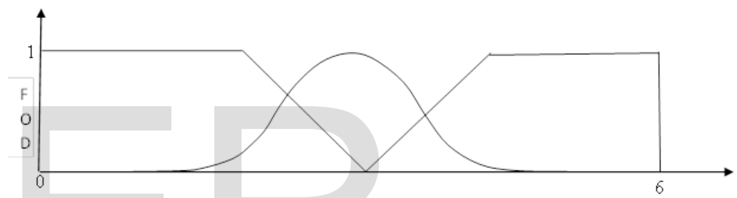

Fig. 1c

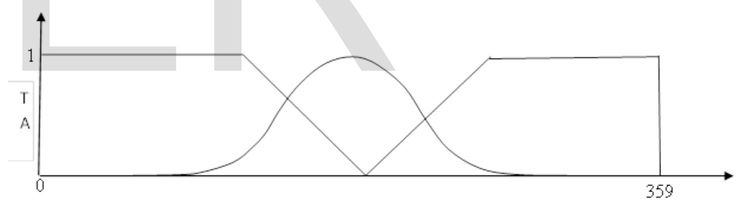

Fig. 1d

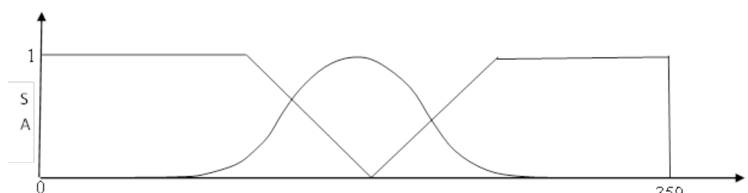

Fig. 1e

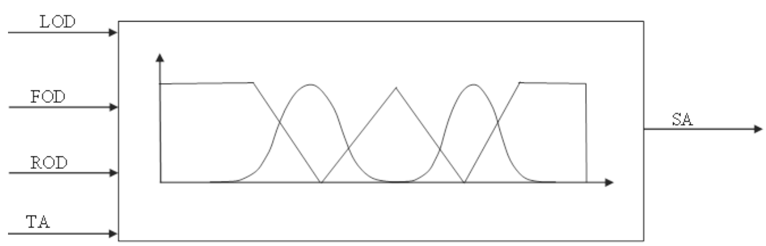

Fig. 1f

Fig. 1 View Fuzzy Architecture

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3.3 Steering Angle (SA) Calculation

$$SA = \frac{\int_a^b \mu_A(x)\, x\, dx}{\int_a^b \mu_A(x)\, dx} \qquad (1)$$

4 Description of Robot Used for Experimental Purpose

Robot(Boebot) :-

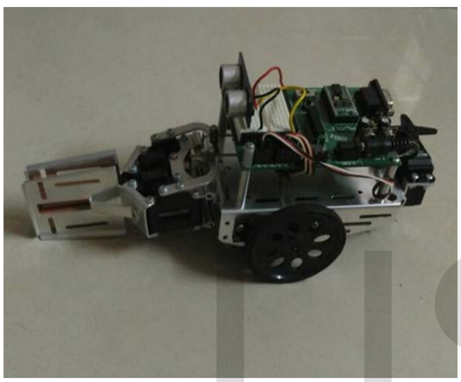

Figure 2: Side View of Robot

Figure 3 Top View of Robot

Description of Boebot:- The Boebot is a mobile robot. It is made by Parallax Inc. Company. The parts of the boebot consist of two geared motors, Aluminum chassis and control electronics. Two geared motors are mounted on the aluminum chassis. Two wheels are mounted on the motor. The rear wheel is made of drilled polyethene ball. Mounting holes and slots may be used to add custom robotic equipment. The controlling part of the robot are parallax's popular micro controller Basic stamp – II. The basic stamp – II processor is programmed using P BASIC language. This language is simple but powerful clone of BASIC language. This language also gets support of many specific peripheral devices. The code is developed within the free integrated development environment basic stamp windows editor which contains the code downloader and the communication terminal.

Control of inputs and outputs:- The processor carries 16 no.of general purpose pins.These pins can be freely configured as inputs and outputs.A LED diode is connected to pin-14. The pin-14 is controlled by a switch which connects the pin-3. The circuit is made on solderless breadboard. The LED works on a short computer program.

Servomotor control:- DC motors having built-in-gears as well as feed back control loop circuitry are called servos.

5 Simulation and Experimental Results

5.1 Simulation results in pictorial form

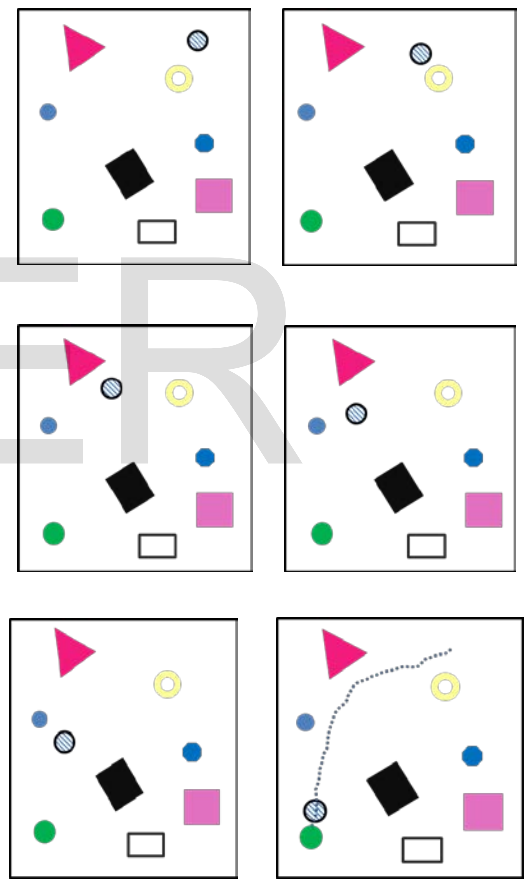

Figure 4 Simulation results of robot

5.2 Experimental results in pictorial form

Figure 5 Experimental results of robot

5.3. Experiment and simulation results of path length in mm

Table-1 Path length of robot during navigation

No. of exercise	Path length in Simulation (PLS) in mm	Path length in Experiment (PLE) In mm	Deviation (PLS- PLE) *100/PLE	Average Deviation
1.	65	67	2.9	3.14
2.	76	79	3.8	
3.	80	84	4.8	
4.	85	87	2.3	
5.	88	90	2.2	
6.	91	94	3.2	
7.	93	97	4.1	
8.	95	98	3.1	
9.	96	99	3.0	
10.	97	99	2.0	

5.4. Experiment and simulation results of time taken in milli second

Table-2 Time taken by robot during navigation

No. of exercise	Time taken in Simulation (TTS) in milli second	Time taken in experiment (TTE) in milli second	Deviation (TTS-TTE) *100/TTE	Average Deviation
1.	4800	4947	2.9	3.24
2.	5612	5833	3.8	
3.	5907	6215	4.9	
4.	6276	6424	2.3	
5.	6498	6660	2.4	
6.	6720	6900	2.6	
7.	6867	7163	4.1	
8.	7015	7250	3.2	
9.	7089	7350	3.5	
10.	7100	7300	2.7	

5.5. Discussion on pictorial and tabular form

In this paper we have given six set of pictures for simulation and six set of pictures for experiment. This six set of picture for simulation depicts the various stages of robots in six position while the robot navigates from start point to goal points while avoiding obstacles. Similarly the corresponding experimental figures are given in six sets and they are depicting the similar situation as that simulation for comparison.

Two tables are given in the present paper named as table no. 1 and table no. 2. Table no. 1 depicts the path length in simulation and experimental; setup for ten number of exercises and the deviation is found to be within 5%. Similarly table no. 2 gives the time taken for simulation and experiment and the deviation is found to be within 5%.

5.6.Discussion on cause of deviation of results in simulation and experiment

Deviation of simulation and experimental results are due to some assumption taken in simulation while these assumption are not taken during the experiment because while the robot is moving in a real form on a floor sleepage occurs between the wheel and the floor that is why simulation and experimental results differ by 5%.

6. Conclusion

The current paper deals with mamdani fuzzy inference system for navigation of mobile robots in a highly cluttered environment. There are four inputs to the fuzzy logic system. They are FOD, ROD, LOD, TA and output from fuzzy logic system is SA. A comparison is also made between simulation and experimental results in pictorial form. They are depicted in figure no. 4 and 5. Similarly numerical comparison has been given in ten exercises in table no. 1 and 2. During the comparison in tabular and pictorial form the deviation is found to be within 5%. It has been observed that using this techniques the robot can successfully navigate in a highly populated environment. In future other hybrid techniques will be taken for navigation of mobile robot.

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