Research Article

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Development of Novel Average Neuro Fuzzy Hybrid Control Technique for Robot Navigation in Unknown Environments

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Summary

The current research focuses on development and analysis of novel Average Neuro-Fuzzy Controller for path planning and navigation of mobile robot in highly cluttered environment. During the investigation various researches related to robot, control and navigation have been analysed. For mapping the environments several distance sensors mounted on the robot are used. The sensors readings about the environments have been segmented into various sectors (front, left, right and back sectors). Using the sensors reading robots negotiate with the obstacles present in the environments during navigation from start to goal point. Experimental and simulation results obtained during the current research from various exercises are in agreement and are within 3%. Comparisons between results show the effectiveness of the proposed technique for robot navigation in complex environments. This technique can be used to address various engineering optimisation problems.

Keywords: Average Neuro-Fuzzy, Robot, Mobile, Artificial Intelligence, Navigation Control

Introduction

Papers discussed about various AI techniques for control of robots in various complex environments [1-5]. AI techniques play important roles for finding solutions to optimisation problems in engineering and scientific fields [6-8]. Several researchers have used AI techniques for various types of robots control. Paper discusses about meta heuristic algorithm for trajectory planning of robots in various environments [9-12]. Papers give paths for using Artificial Immune system as an AI technique for navigation control of robots. Bacteria Foraging technique is one of the biologically inspired technique used for solving various optimisation problems [13-17]. Particle Swarm Optimisation method is a nature inspired algorithm used for path planning of dynamic robots [18-20]. Paperhas described functioning of manipulator in unknown situations using AI methodology [21]. Differential Evolution Algorithm is one of the best suited techniques for solving various engineering problems [22]. It can be hybridised with other methods to obtain efficient hybrid technique. Neural network is one of the smart biological inspired AI technique used for solving various engineering problems [23-26]. Using neural network robots are auto controlled and successfully find path in cluttered environments [27-30]. Neural network can be efficiently implemented for robot control and for addressing different engineering problems [31-33].

Papers have discussed about Cuckoo Search methodology to address navigational control of mobile robots subjected to various environmental conditions [34-36]. A new variant artificial intelligence technique such as Dayani intelligent method has been used and described in the paper for controlling robots in unknown environments [37]. Daykun-Bip artificial intelligence technique can be employed for addressing various optimisation problems in engineering fields as well as to analyse navigational control of robots [38]. Papers focus on use of neuro-fuzzy controller for robot path determination in complex environments [39-43]. Neuro-fuzzy technique can also be used to address various engineering problems and to get suitable solutions [44-47]. Fuzzy inference techniques can be used as a well suited artificial intelligence method for solving various problems in engineering fields [48-53]. Papers discuss about fuzzy logic method to control mobile robot during path planning [54-57]. In fuzzy inference method difference member-ship functions are used to address robot control in efficient manner [58-61].

Ant Colony AI technique has significant contributions in solving various optimisation problems. With rate of pheromone deposition and decay the ant colony AI technique find an optimised solution in complex situations [62-64]. Papers discuss on finite element

method to analyse various engineering problems. Firefly algorithm is one of the community driven algorithms used for robot navigation control [65-71]. Firefly algorithm can also be used for solving various engineering optimisation problems. AI techniques can be used for fault and damage identifications of various mechanical and dynamic structures used for building various parts of robots [72-79]. Neural network and Fuzzy inference can be hybridised to get neuro-fuzzy AI controller [80-81]. Paper discusses about invasive weed optimisation technique for navigation of robot in unknown environments [82]. The paper discusses on nature driven Bat algorithm used for path planning of robot in complex environment [83]. Gait analysis of dynamic humanoid robot is analysed and discussed in paper [84]. Out of several biological inspired methods, Genetic algorithm is found to be an efficient method for addressing robotic related navigation problems [85-88]. Genetic algorithm can be used as a controller for various robotic hardware platforms [89-90]. Harmonic Search algorithm has been used to control under water robot in obstacles prone environments [91]. Artificial Immune system is a biological inspired algorithm and can be used for handling various optimisation problems [92-94]. Robot kinematic analysis is discussed by several researchers, required for studying robot movements [95-97]. Papers have discussed about mobile computing for intelligent communication purposes [98-99].

Artificial potential field method can be used for robot navigation in unknown fields [100-101]. Real time navigation for robot is described and analysed by researchers [102]. Mathematically formulated rule based techniques have been used by researchers for robot motion and path analysis [103-104]. Papers describe simulated annealing technique for motion analysis of various types of robots [105-106]. Analysis of vibration signatures of various dynamic parts of robots using artificial intelligence methods have been described in papers by various researchers [107-120]. In papers various researchers have used soft computing methods to control various types of robots [121-122]. Swarm intelligence is one of the robust AI techniques being used by researchers to address various optimisation problems [123-127]. Many researchers have used regression based analysis for robot control and navigation [128-130]. Paper focuses on sensor based robot navigation in unknown environments [131]. The current paper discusses and analyses on Average Neuro-Fuzzy Hybrid (ANFH) control technique for navigation control of mobile robot in unknown fields. The details of ANFH controller is discussed in the below section.

Description and Analysis of Average Neuro-Fuzzy Hybrid Controller

In this section analysis and description of Average Neuro-Fuzzy Hybrid (ANFH) controller (Figure 1) has been carried out. The distance sensors mounted in the robot map the surrounding environment comprising of obstacles and target. The inputs to neural and fuzzy segments in the average neuro-fuzzy hybrid controller are left (LOS), right (ROS) and front FOS) obstacles distances obtained from the sensors. Outputs from the individual fuzzy and neural controllers are Steering-Angle-1(SA1) and Steering-Angle-2 (SA2) respectively. Gaussian membership functions are used in fuzzy segment of the hybrid controller. In neural segment of hybrid controller five layers back-propagation neural network has been used. The input and output layers consist of three and one neurons respectively. The three hidden layers consist of six, twelve and four neurons respectively. The Final Steering Angle (FSA) has been obtained by taking the average of SA1 and SA2. Using the FSA obtained from ANFH, robot negotiates with obstacles while trying to find the target. During the process various simulation and experimental exercises are conducted. Hemisson robot is used for carrying out all experimental exercises for navigational purpose [132]. Comparisons have been done between simulation and experimental results and are shown in Table 1 for five no. of exercises. A comparison is also shown as pictorial form (Figure 2 A-F) in six steps for simulation and experimental exercises.

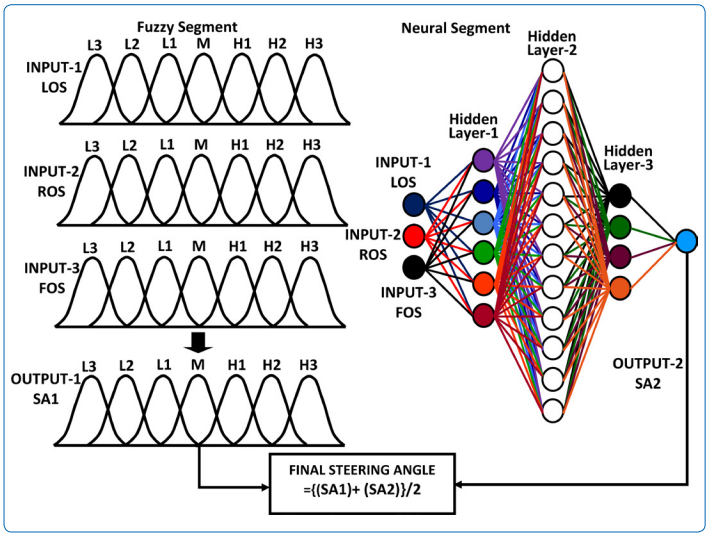

Figure 1: Schematic View of Average Neuro-Fuzzy Hybrid Controller

Table 1: Simulation and Experimental Path Lengths and Time Taken during various

Ex. No.	Path Length (cm) (Simulation)	Path Length (cm) (Experimental)	Percentage Deviation of Path	Time Taken (Milliseconds) (Simulation)	Time Taken (Milliseconds) (Experimental)	Percentage Deviation of Time
1	156	160	2.56	9750	10023	2.80
2	174	178	2.30	10875	11109	2.15
3	214	220	2.80	13375	13750	2.80
4	254	261	2.76	15875	16325	2.83
5	112	114	1.79	7000	7129	1.84

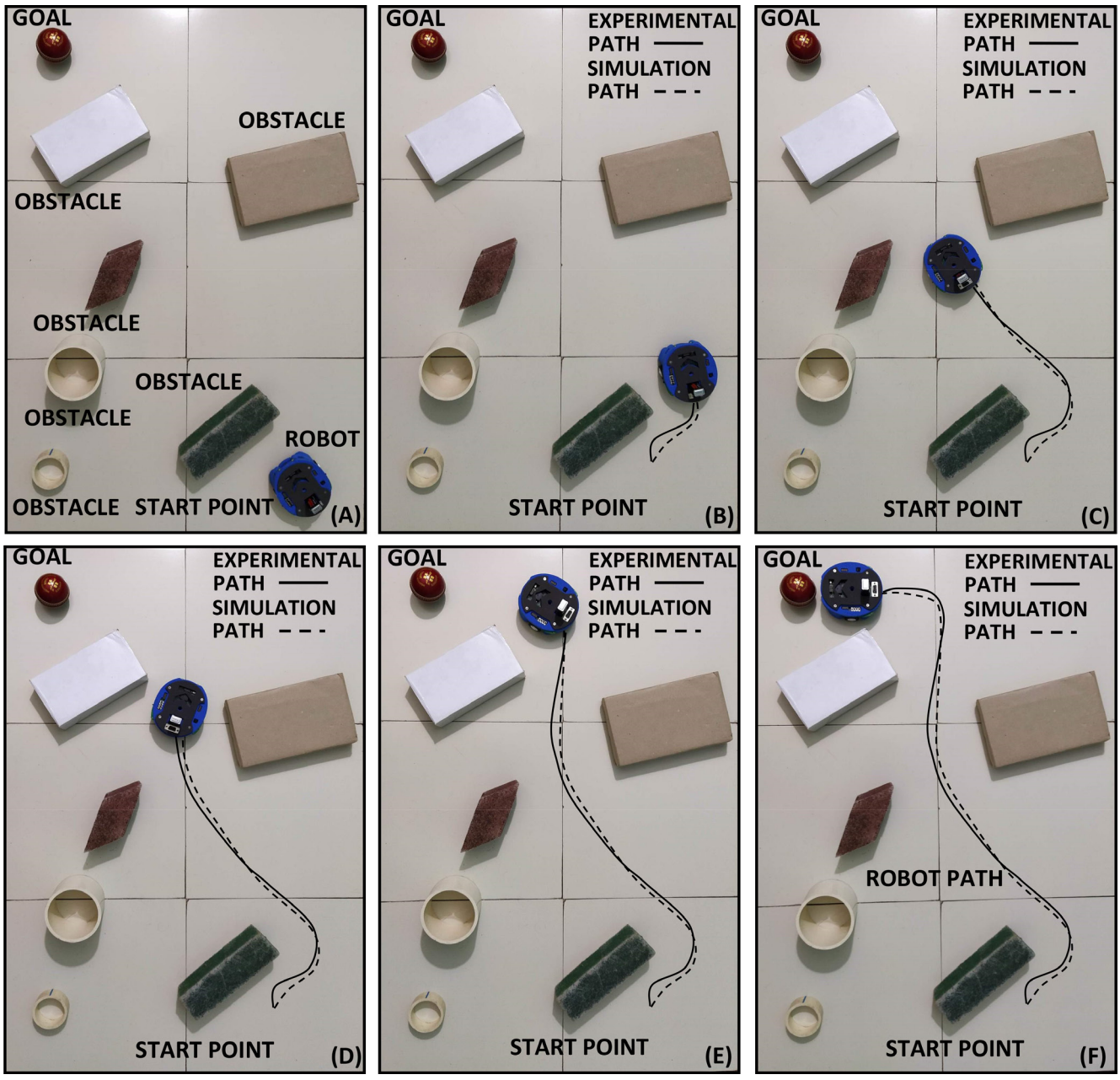

Figure 2: Simulation and Experimental Result of Hemisson Robot [132] from Start to Goal Point

Conclusion

In the current investigation development, analysis and application of a novel Average Neuro-Fuzzy Hybrid controller has been carried out. Using the data obtained from sensors mounted in the robot as inputs, ANFH controller estimates the final steering angle for navigation of robot from start to goal point while avoiding obstacles. FSA is calculated by taking the average of SA1 and SA2. SA1 and SA2 are calculated from Fuzzy and Neural segments of ANFH controller. Using ANFH controller in simulation and experimental modes, robot finds target while avoiding obstacles. During comparison between simulation and experimental results obtained from navigational exercises show an agreement among the results within 3%. From the results it is concluded that ANFH controller can be used efficiently for robot navigational purpose. ANFH artificial intelligence technique can also be used for solving other optimisation problems in engineering fields. In the future other hybrid techniques will be investigated for solving the robot navigation problem in cluttered and unknown environments.

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