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Comparative study of soft computing techniques for mobile robot navigation in an unknown environment

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ABSTRACT

An autonomous mobile robot operating in an unstructured environment must be able to deal with dynamic changes of the environment. Navigation and control of a mobile robot in an unstructured environment are one of the most challenging problems. Fuzzy logic control is a useful tool in the field of navigation of mobile robot. In this research, fuzzy logic controller is optimized by integrating fuzzy logic with other soft computing techniques like genetic algorithm, neural networks, and Particle Swarm Optimization (PSO). Soft computing techniques are used in this work to tune the membership function parameters of fuzzy logic controller to improve the navigation performance. Four methods have been designed and implemented: manually constructed fuzzy logic (M-Fuzzy), fuzzy logic with genetic algorithm (GA-Fuzzy), fuzzy logic with neural network (Neuro-Fuzzy), and fuzzy logic with PSO (PSO-Fuzzy). The performances of these approaches are compared through computer simulations and experiment number of scenarios using Khepera III mobile robot platform. Hybrid fuzzy logic controls with soft computing techniques are found to be most efficient for mobile robot navigation. The GA-Fuzzy technique is found to perform better than the other techniques in most of the test scenarios in terms of travelling time and average speed. The performances of both PSO-Fuzzy and Neuro-Fuzzy are found to be better than the other methods in terms of distance travelled. In terms of bending energy, the PSO-Fuzzy and Neuro-Fuzzy are found to be better in simulation results. Although, the M-Fuzzy is found to be better using real experimental results. Hence, the most important system parameter will dictate which of the four methods to use.

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1. Introduction

Mobile robots are type of robots that are able to move, sense, and react in a given environment and are able to perform tasks and navigate without human intervention (Goris, 2005). There are several applications of robots in our life such as applications in agriculture (Demeter harvesting robot) (Pilarski et al., 2002), cleaning (Roomba) (Jones, 2006), medical service (Chivarov et al., 2012), mining/excavation (groundhog robot) (Thrun et al., 2004), security (MDARS interior robot) (Laird, Everett, Gilbreath, & Inderieden, 1999), military (packbot) (Yamauchi, 2004), and industrial environments (Nickerson et al., 1998). Navigation of mobile robot is the control the movement from a start point to a target point in a given environment with obstacle avoidance capabilities. The environment can be classified as structured (known) environment, semi-structured environment, and unstructured (unknown) environment. Navigation through unknown environment needs an approach that can deal with uncertain situation (Hassan & Deepika, 2012). Soft computing techniques such as fuzzy logic, evolutionary algorithms (genetic algorithm, genetic programming, evolutionary programming), and Particle Swarm Optimization (PSO) are widely used in mobile robot navigation (Zhang, Dai, & Shi, 2007). The term Soft Computing has been proposed by Lotfi A. Zadeh, Professor for Computer Science at the University of California in Berkeley in the early 90s (Zadeh, 1994), it refers to a group of methodologies that aim to use approximation, uncertainty, and imprecision to achieve robust and low cost solution. In Li and Choi (2013), authors used travelled path length and travelled path time as factors to measure performance of the method proposed for mobile robot obstacle avoidance using fuzzy logic controller. The authors in Singh, Parhi, Bhowmik, and Kashyap (2008) used time required of mobile robot during simulation and experiment to measure the robustness of proposed fuzzy logic controller. Fuzzy control with different type of membership functions is discussed in Obe and Dumitrache (2010). Path length in pixels is used

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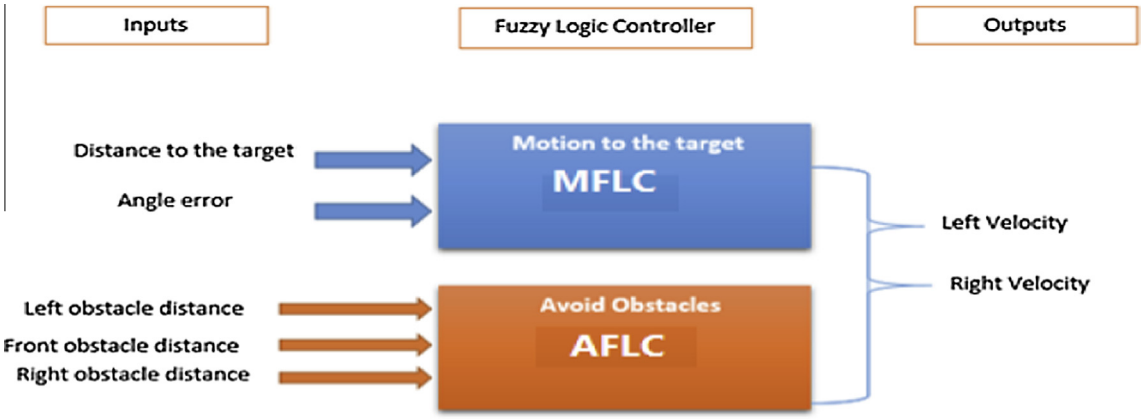

Fig. 1. Fuzzy logic system.

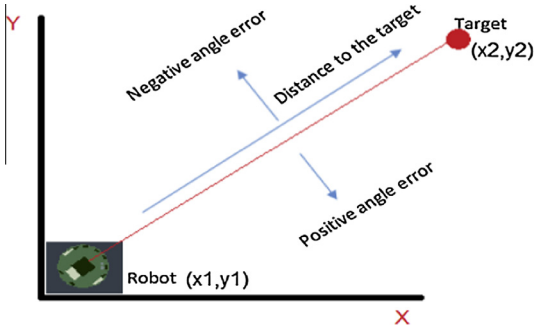

Fig. 2. Robot and target in XY plane.

to show the suitability and efficiency of each membership function. A hybrid fuzzy-neuro technique for mobile robot navigation was proposed in Kundu, Parhi, and Deepak (2012). Path length has been used to compare developed method with other in both simulation and experimentation environment. In Pradhan, Parhi, and Panda (2007), authors have discussed the navigation of multiple mobile robot using rule-based-Neuro-Fuzzy Technique. Total time taken and total path length have been used to compare the proposed method with rule-based technique. Time taken to reach the target and total path are considered in Pradhan, Parhi, and Panda (2009), for navigation of multiple mobile robot using different type of membership function for fuzzy technique. Efficiency and usefulness of the proposed method is discussed in Purian and Sadeghian (2013) and analyzed using the distance travelled and the time elapsed. Neuro-Fuzzy approaches for car-like mobile robot are developed in Hui, Mahendar, and Pratihar (2006). Mean and standard deviation of traveling time is used as a measurement to compare the performance of each approach. Authors in Juang and Chang (2011) have proposed evolutionary group-based particle swarm optimization algorithm to optimize fuzzy logic controller, for mobile robot navigation in unknown environment. Average moving speed and time taken to reach the target have been considered to demonstrate the effectiveness and efficiency for the proposed algorithm. A new fuzzy speed controller to control the speed of mobile robot is offered in Haj-Mahmoud (2013). The average speed of robot shows the efficiency of the proposed fuzzy speed controller. Authors in Huang (2012) have presented genetic algorithm and PSO to find the optimal path of mobile robot. Fitness value shows the convergence behavior for each algorithm. Tuning fuzzy logic parameters using PSO is presented in Debnath, Shill, and Murase (2013). Stable convergence of the proposed method measured using average and best fitness in finding the solution. Automatic tuning of fuzzy knowledge base using genetic algorithm for mobile robot movement is presented in Adriansyah and HM Amin (2005). Comparison of fitness values show the best fitness obtained by learning the rule base. In (Ceballos, Valencia, and Ospina (2010) the authors proposed performance evaluation of mobile robot navigation and applied these criteria on two control algorithm. The first is a reactive algorithm based on potential field algorithm and the other is based on reactive behavior. The authors in Jin and Choi (2011) present simple fuzzy logic control for obstacle avoidance for mobile robot. They used simulation results to measure efficiency of proposed method. The motivation of this research, fuzzy logic control for mobile robot navigation is optimized by integrating fuzzy logic with other soft computing techniques like genetic algorithm, neural networks, and Particle Swarm Optimization (PSO); using automatic tuning membership function parameters. Four important criteria, which have been used to measure the performance of our four proposed methods in this research as following:

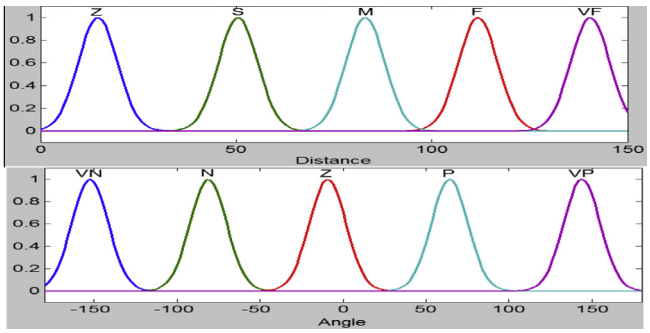

Fig. 3. Distribution of membership function of input variables (distance, angle).

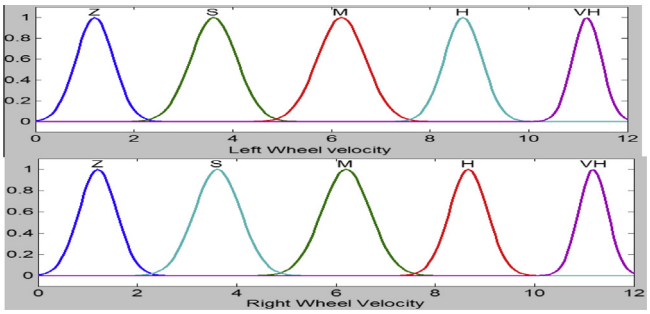

Fig. 4. Distribution of membership function of output variables (LW, RW).

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