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Path Planning of Mobile Robots Via Fuzzy Logic in Unknown Dynamic Environments with Different Complexities

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ABSTRACT

In this paper, the problem of mobile robot navigation that is one of the main tasks of the robots and robotics science has been studied. Path planning for mobile robots is finding free way without encountering barriers in different environments. The aim of this paper is finding the shortest path in unknown, dynamic environments with various complexities. Hence in this research a new method is presented with using fuzzy logic. In this way, an optimal path is chosen by two criteria: angle difference to the target and distance to the nearest obstacle. The goal selection the next node based on the obtained coefficient for each node along the way to reach the destination. Survey results of proposed algorithm simulation suggest that navigation of a robot from an obtained path has optimality criteria, and the length of selected path had the lowest cost and is very close to the length of the shortest possible path.
KEYWORDS: dynamic obstacles, path planning, mobile robot, fuzzy logic, unknown environments.

1- INTRODUCTION

Robots are essential elements in today's society. They do many of the exact jobs, frequently and without any utility and human facility. The word of the robot is used for a wide range of mechanical machines that have mobility [1,4]. "Robot" in the Czech language means mandatory work. The word of robot, first time has been used in the science-fiction game Rossum `s Universal Robots in 1921 [1,3]. It is an intelligent and independent moving vehicle. A moving robot can react to the environment via its sensors while the interaction with the environment is in the range of human needs [5,6]. Types of mobile robots are including: wheeled robots [7], tracking [8], winged and humanoid robot and others [9,10]. Path planning for a mobile robot, located in an environment with many obstacles, is defined as finding a path that the helps the robot to reach from source to destination without hitting with obstacles [14]. In this issue, topics such as shortness of the path and simplicity are criteria for the optimality of selected paths. Means of determining the paths from completeness are divided into two types of accurate and constraint satisfaction. The first group tries to find the optimal path or to prove that there is no such path and in terms of time complexity, is time consuming [4]. On the other hand, second group tries to find the appropriate path in a short time [15]. Although these methods are fast but in the complex, issues lead to failure [2]. Among the exact methods, geometric method scan be named [1,15]. Heuristic methods are divided into two categories: potential field [1,16] and soft computing [1,2], that the latter includes neural networks[5], genetic [9,6] and fuzzy algorithms [14,16]. In this paper, it is assumed that robot is point and for solving the problem of planning movement of mobile robots when environment map scan have detailed information of environment or without the map and sufficient information from environment, the proposed method is suggested based on fuzzy logic approach. For mobile robot navigation, if the details of environment are not known, path planning is performed in local mode and on-line and with receiving information from sensors in real time [11,17,10].

In this paper, by providing a new approach based on determining table of fuzzy rules that is a crucial and effective issue of the performance of the fuzzy logic system, path planning for mobile robots when there is no information about their environment is used. Parts of the paper are organized as follows: Part two, methods are described by fuzzy logic. Part three, the simulation results are presented in different workspaces, and finally; the fourth section is discussing about efficiency and usefulness of the proposed method.

2- METHODS

According to workspaces that are designed in [12] navigation of mobile robot in environments where the robot has sufficient information and map of workspace, has done in three spaces, including fairly simple, relatively complicated and complex workspace. In this paper, the proposed method is as follows: in order to have optimality

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criteria for dynamic unknown environments in the three listed workspaces that the mobile robot doesn't have any information from environmental, at any time next node is chosen according to the eight options similar to evolutionary algorithms described [12]. In other words, each node of the eight options is chosen by two criteria: 1-The angle difference to the target, 2-the distance to the nearest obstacle. Here the goal is obtaining an index of selected priority as the next node for each of the eight nodes. After the implementation of fuzzy logic, for inputs of each node, anon-fuzzy or final output is generated. Finally next node is a node that has the highest non-fuzzy priority index.

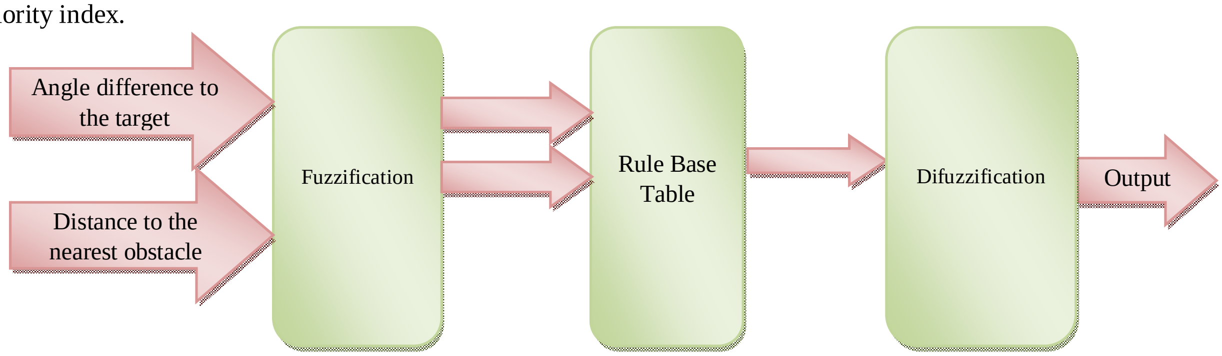

Figure 2-1: Expression mobile robot navigation problem in the proposed fuzzy logic.

2-1. Inputs fuzzy optimization

Choose the path with fuzzy logic is the node to node and fuzzy logic runs for the number of inter mediate nodes along the path. In this paper, the two input of fuzzy has been used to determine the path: one of them is the angle difference to the target, and the other is distance to the nearest obstacle. In each input five membership function, has been fuzzificated obviously, the angle, the size and direction of movement are also included. It makes the connection between the current position and the final position by measuring the length of the path and its direction towards the goal. The angle difference has been used as the most preferred option to optimize and shorten the lateral process [12]. According to figure (2-2) and (2-3), fuzzy membership functions for input angle and distance is visible. It should be noted that at any time non-fuzzy inputs for the next eight nodes are normalized at first, and then the process is fuzzificated. In this paper, for output five membership functions have been used: very low/low/average/ high/very high, figure (2-4). In other words, in each iteration angle difference non-fuzzy input to the target and distance to the nearest obstacle at first normalized in the interval [0, 1], and then the fuzzy membership is determined to different fuzzy functions. In this paper, node selection has been done with using fuzzy logic. In this case, in each location of workplace lattice space, whatever the angle difference between a node to the target is less, and node has been more distant from the nearest obstacle, more fuzzy possibility for selection as the next node is in the path, it means that higher-priority coefficient achieves relative to other nodes.

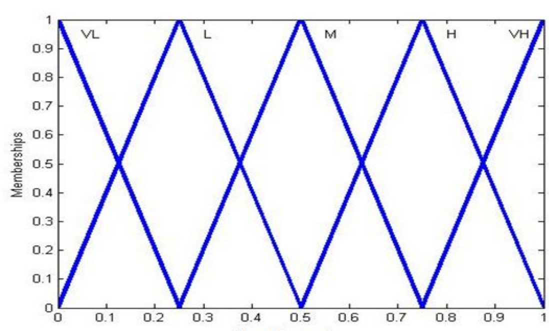

Figure2.2: Membership functions for the input angle difference to determine the path.

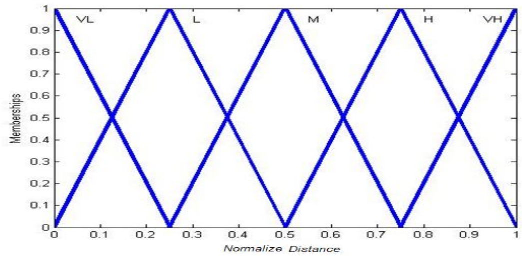

Figure 2-3: Membership functions for the input distance to the nearest obstacle.

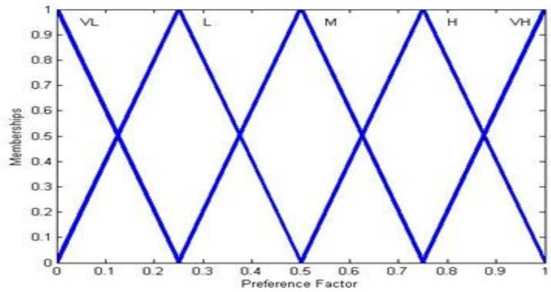

Figure 2-4: Fuzzy membership functions for the output (node priority index for selection).

2-2. Table of fuzzy rules

As mentioned, selection of the next node in the path with using fuzzy logic takes place. Table of fuzzy rules for selection of the subsequent node in the moment path is set node to node in Table (3-1). Generally in this table whatever distance to the nearest obstacle is more and also the angle differences in the target is less, that desired node has higher priority for selection as the next node in the path. As described for determining the fuzzy output for each node table of fuzzy rules is according to table (2-1) where all rules have been considered as AND. In the next step for obtaining output fuzzy shape mamdani method is used [13]. In summary, at this stage table of fuzzy rules runs for each node, at this stage based on the fuzzy input related to nodes, one or more rules of the table (2-1) is executed.

Table 2.1: Fuzzy rules table for choosing the next node in instant node to node path planning by fuzzy logic.

Output: priority of the next node selection	**Input 2: Angle difference with respect to target**	**Input 1: Distance to the nearest obstacle**
Medium	Very low	**Very low**
Low	Low	**Very low**
Very low	Medium	**Very low**
Very low	High	**Very low**
Very low	Very High	**Very low**
Medium	Very low	**Low**
Medium	Low	**Low**
Low	Medium	**Low**
Low	High	**Low**
Very low	Very High	**Low**
High	Very low	**Medium**
Medium	Low	**Medium**
Medium	Medium	**Medium**
Low	High	**Medium**
Very low	Very low	**Medium**
Very High	Very low	**High**
Very High	Low	**High**
High	Medium	**High**
Medium	High	**High**
Low	Very High	**High**
Very High	Very low	**Very High**
Very High	Low	**Very High**
High	Medium	**Very High**
Medium	High	**Very High**
Medium	Very High	**Very High**

2-3. Defuzzification

The most common defuzzification methods are including centroid and the weighted average methods [13]. In This study, for the ultimate defuzzification the weighted average method is used, finally, after determining the non-fuzzy outputs for the final eight options, the options which have the maximum output of non-fuzzy, is selected as the next node in the path. This process continues until the robot reaches the goal.

3- Simulation results

All the simulations was performed using a laptop computer with Intel Dual core processor with a processing speed of 3GHz and 4GB RAM, with Windows 7, by Matlab R2011 software. In all three workspace designed in accordance with [12], three different starting and ending points considered for the robots and In Table (3-1) obtained, paths by the proposed method are presented briefly in different workspaces. Although the details are different, in mobile robot path planning method, but all of them have a general frame work, so that in the first step, a robot with every size and shape can be considered as a point. Then the configuration environment is called workspace become a new environment, [17,2,3]. The robot can move in all directions and have different speeds. The space is considered as a discrete lattice. In fuzzy logic approach without dealing with static and dynamic obstacles the robot will travel across its path in five different states of starting and ending points. Traveled path in addition to optimizing and smoothing in each situation, when faced with static and dynamic obstacles, selects the shortest path. When the obstacle is moving downward at the same time, the robot wants to move upwards and continue his way to the goal. To avoid dealing with the obstacles, the robot changes its path and after path search, select the shortest path by fuzzy method and again continue his path to achieve the desired goal, which in steps 10 to 12, this search and optimize path selection to reach the shortest path between various obstacles is evident (as illustrates in Figures (3-1) and (3-2)).

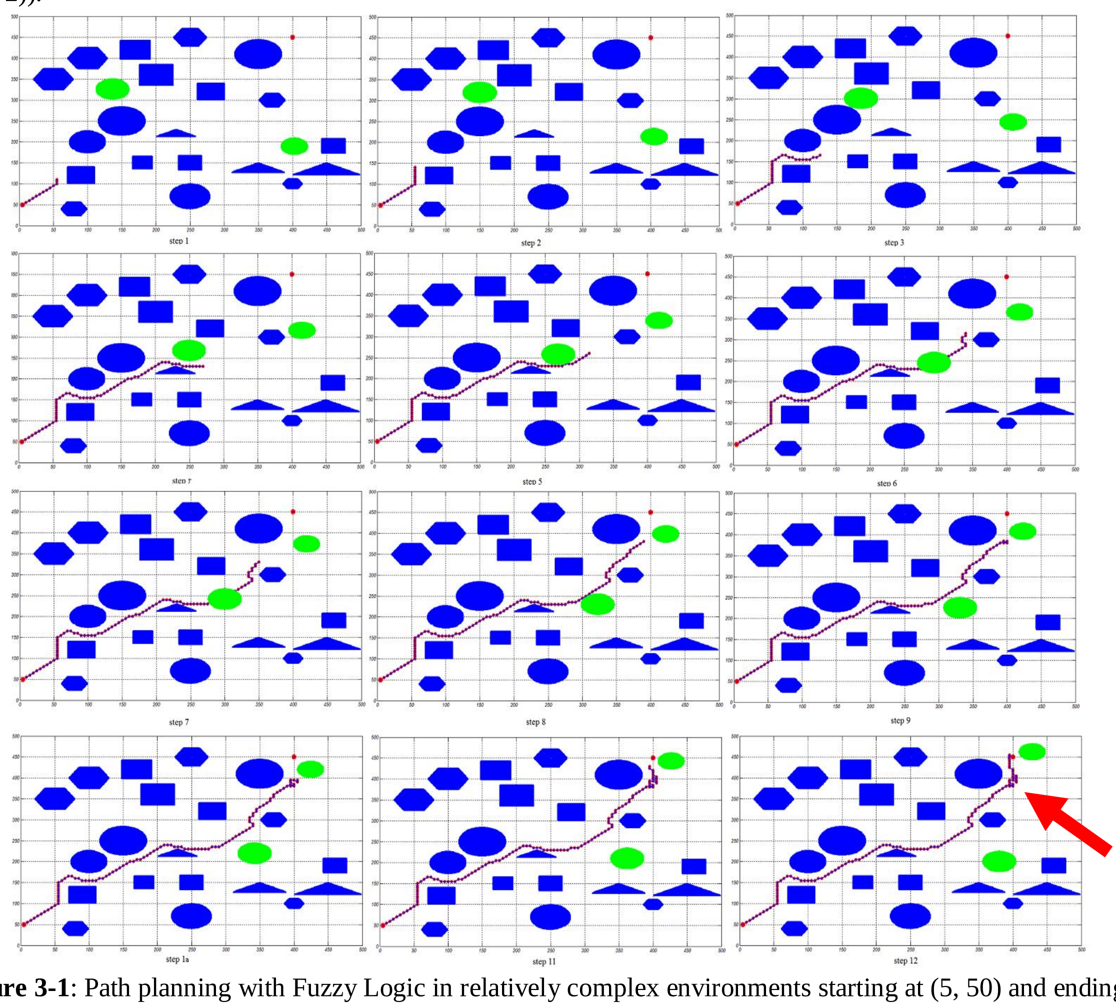

Figure 3-1: Path planning with Fuzzy Logic in relatively complex environments starting at (5, 50) and ending at (400,450), 934.61 cm path length.

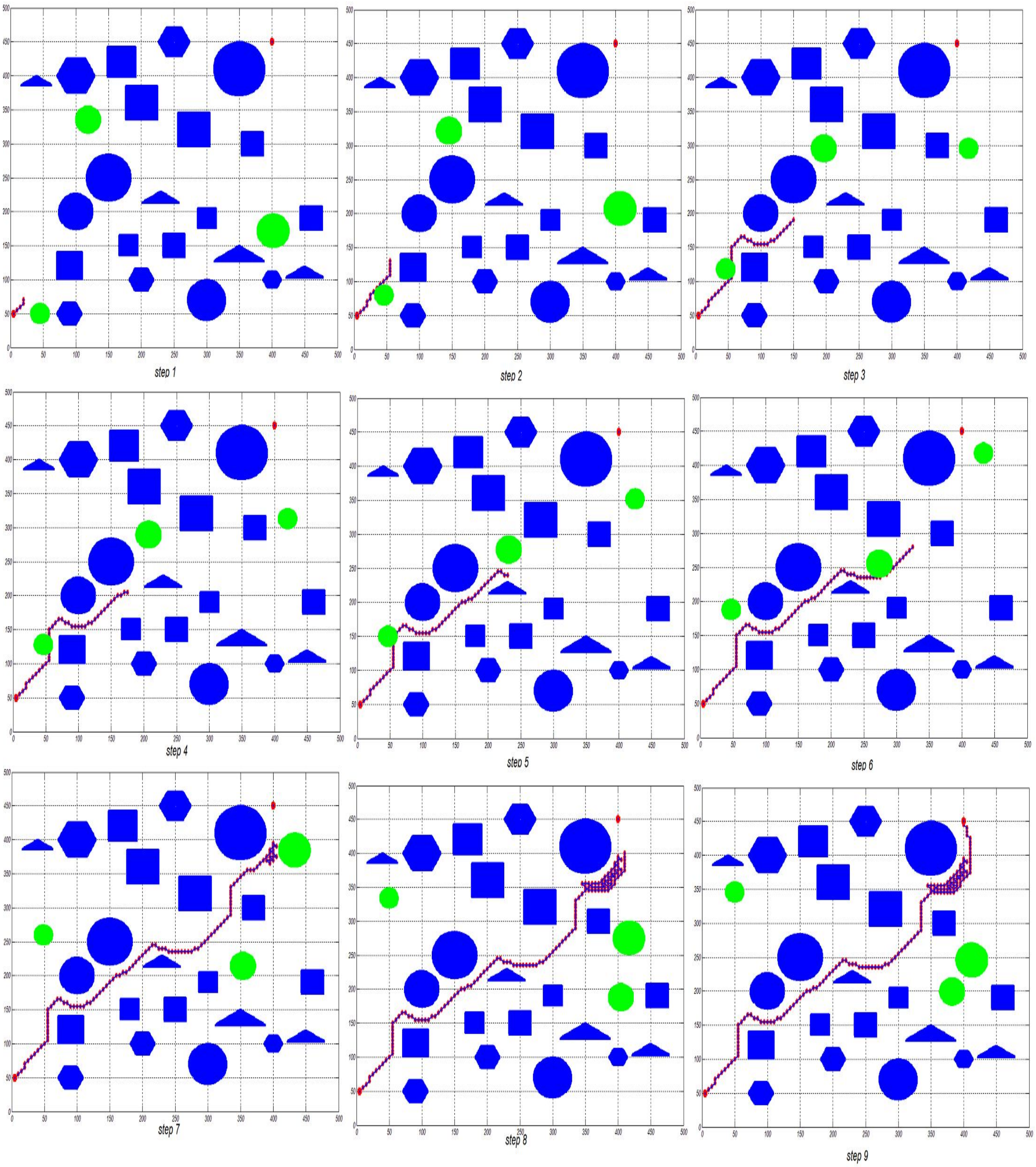

Figure 3-2: Path planning with fuzzy logic in quite complicated environment starting at (5, 50) and ending at (400,450), 952.37 cm path length.

For path planning with fuzzy logic as is explained for each of the eight options around a node, a priority index for selection is achieved. Then the algorithm should be implemented to the number of inter mediate nodes of the path. As a result instantly path planning table after several run-sorted is obtained according to table (3-1). In other words, to improve the path planning, the table has manually changed. After running 18 times, modified fuzzy rules table is according to table (3-1) and the optimized path after 18 times manually change the parameters as shown in figure (3-3) and (3-4) for mobile robot is achieved.

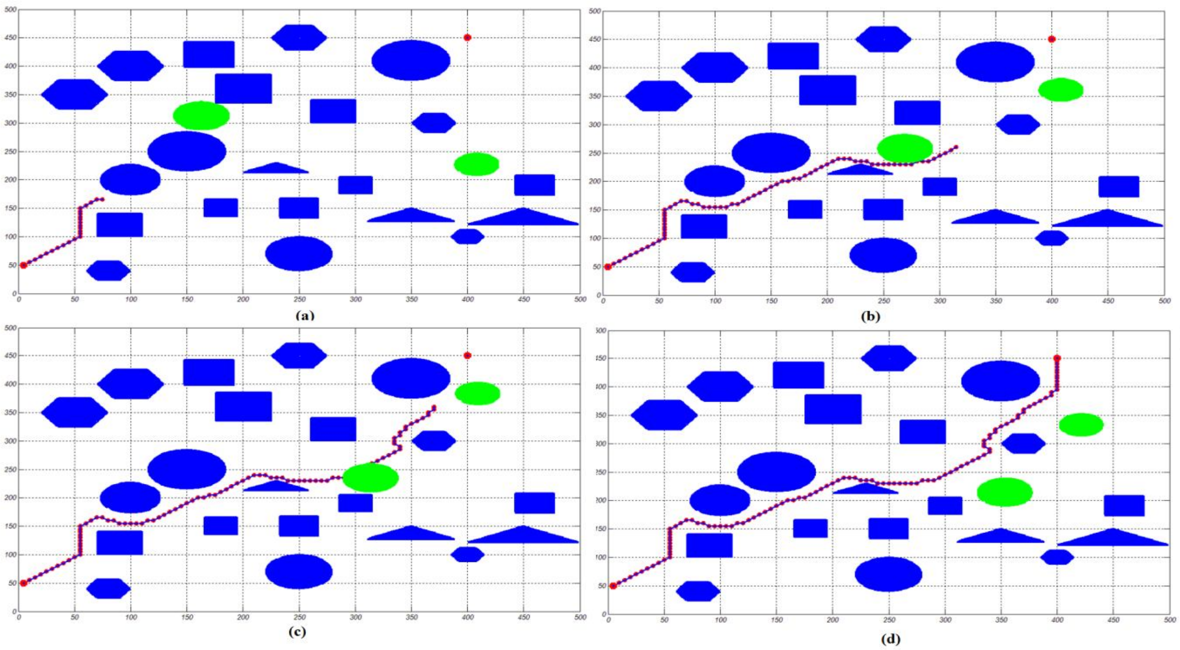

Figure 3-3: Path planning with Fuzzy Logic in relatively complex environments starting at (5,50) and ending at (400,450), 924.37 cm path length.

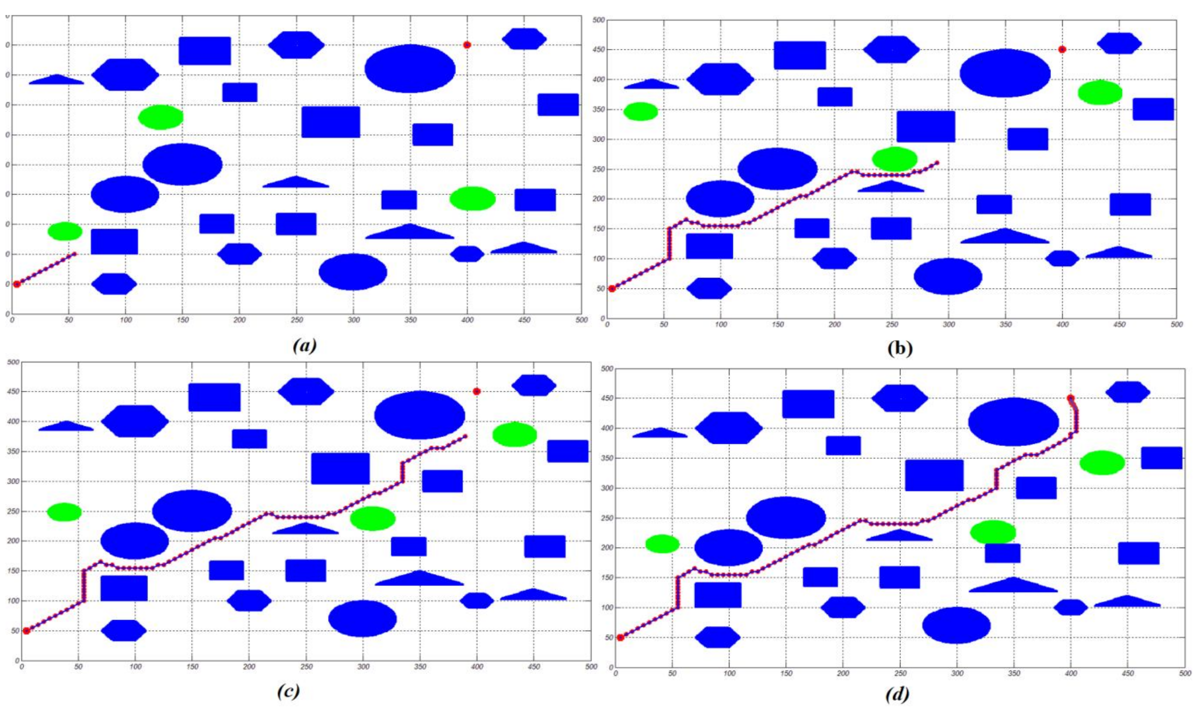

Figure 3-4: Path planning with fuzzy logic in quite complicated starting at (5, 50) and ending as (400,450), 941.47cm path length.

Table (3-2) presents the results in five different states in three workspaces so at any given moment the proposed algorithm with Fuzzy logic when the robot face with fixed obstacles selects the shortest smooth path in the shortest possible time until reaches the final destination in an unknown environment node to node. Length and Fuzzy Optimization columns in table (3-1) are obtained by changing fuzzy rules table 10 and 18 times respectively. As it is evident from the results of the table below manually modified fuzzy rules table after 18 times results in shorter distances and then by changing the fuzzy rules table, the length of paths comes very close to Fuzzy Optimization results. In other words, the distance differences obtained by changes in the parameters of fuzzy rules table more than 18 times and Fuzzy Optimization are minimal. Hence the distance traveled in the table (3-1) has optimality conditions (short path) to a desired workspace.

Table 3-2: Coordinates and the distance traveled by the proposed fuzzy algorithm in different environments.

The workspace complexity	Starting Point	Target Point	Fuzzy	Fuzzy Optimization
Relatively simple workspace	(5‹50)	(400,450)	640.03	630.24
Relatively simple workspace	(20,55)	(460,455)	683.53	668.42
Relatively simple workspace	(30,65)	(465,460)	691.47	676.31
Relatively simple workspace	(50,100)	(470,470)	612.16	596.81
Relatively simple workspace	(25,150)	(450,400)	572.46	563.11
Relatively complicated workspace	(5‹50)	(400,450)	934.61	924.37
Relatively complicated workspace	(20,55)	(460,455)	765.10	745.18
Relatively complicated workspace	(30,65)	(465,460)	744.09	739.17
Relatively complicated workspace	(50,100)	(470,470)	652.67	635.27
Relatively complicated workspace	(25,150)	(450,400)	583.03	569.13
Quite complicated workspace	(5‹50)	(400,450)	952.37	941.47
Quite complicated workspace	(20,55)	(460,455)	734.65	721.18
Quite complicated workspace	(30,65)	(465,460)	717.42	711.64
Quite complicated workspace	(50,100)	(470,470)	652.11	641.27
Quite complicated workspace	(25,150)	(450,400)	641.35	633.04

In Table (3-3) three working areas by the proposed algorithm in terms of time spent in path planning were also analyzed [12]. Among them, Fuzzy logic method needs the shortest time to find the shortest path at any moment. Elapsed time the fuzzy and Fuzzy Optimization is a little different. Because the proposed fuzzy algorithm is the same and only the table parameters of fuzzy rules have changed manually. Times obtained are average times spent in each of the 5 positions at the primary and departure points in 3 workspaces.

Table 3-3: Elapsed path planning time by Algorithms presented in different environments.

workspace complexity	Relatively simple workspace			Relatively complicated workspace			Quite complicated workspace		
Algorithm	ACO	GA	FUZZY	ACO	GA	FUZZY	ACO	GA	FUZZY
Time (sec)	271.47	1522.03	51.67	648.69	1865.28	83.81	972.85	2560.42	109.18

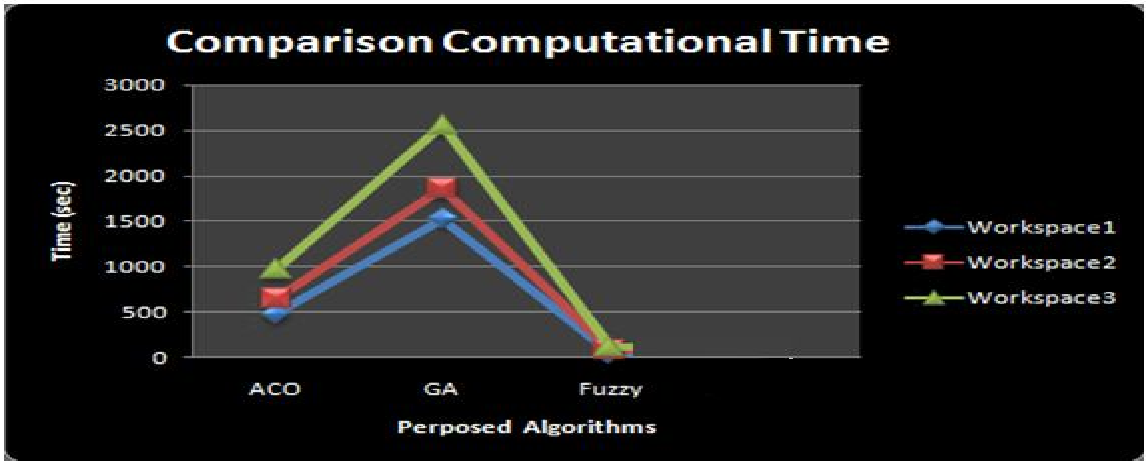

Figure 3-5: Comparison of time spent on the proposed fuzzy algorithm and evolutionary algorithms.

As it is evident in table (3-2) and Figure (3-5) the time elapsed in the proposed fuzzy approach is based on real time methods. Although moving robot doesn’t have adequate and accurate information from the environment, however, in less time than evolutionary algorithms [12], which have already the workspace map passes the path.

4- Conclusion

In this study, one of the major tasks of path planning mobile robot has been studied. Path planning is finding free and without collision path for a robot between the various obstacles in the environment. To obtain the optimal path and shortest collision free path in areas closest to the real-world states (The areas with static and dynamic obstacles in different shape and size), and also for dynamic obstacles with any speed and in any direction, or on the other hand, situations that the robot has a minimal knowledge of the space, Fuzzy logic because of the instant node to node path planning is a very good option in solving these problems and are highly regarded. Basis of fuzzy logic is defined fuzzy rules table, which is determined by an expert and after changing several parameters of the fuzzy rules table. This part is the most influential sectors, and it makes it possible for mobile robots in unknown environments with any obstacle with different shapes to obtain the shortest path to the destination with the lowest elapsed time.

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