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PATH FINDING BASED ON ARTIFICIAL INTELLIGENCE TECHNIQUES: A REVIEW

Dr. Eyad I. Abbas
Department of Electrical Eng.
University of Technology
Baghdad, Iraq

Dr. Sundus D. Hasan
Department of Electrical Eng.
University of Technology
Baghdad, Iraq

Rawaa Jawad
Department of Electrical Eng.
University of Technology
Baghdad, Iraq

Abstract - Path finding reduce the wear and capital investment of mobile robot. Several methodologies have been proposed and reported in the literature for the path planning of mobile robot. Although these methodologies do not guarantee an optimal solution, they have been successfully applied in their works. The purpose of this paper is to review the modeling, optimization criteria and solution algorithms for the path planning of mobile robot. The survey shows GA (genetic algorithm), PSO (particle swarm optimization), Neuro - fuzzy, fuzzy, ACO, from this review of this study finding a researcher used ANFIS, Fuzzy major used for path finding for mobile robot.

Keywords: path finding, artificial intelligent systems

I. INTRODUCTION

Over the past decades, mobile robots have been successfully applied in different areas such as military, industry and security environments to execute crucial unmanned missions [1]. Path planning [2] is one of the most fundamental problems that have to be resolved before the mobile robots can navigate and explore autonomously in complex environments. Beginning with mid-1960s, the path planning has attracted interests from a lot of scholars. The path planning problem can be described in the following [3]: given a robot and its working environment, the mobile robots searches for an optimal or suboptimal path from the initial state to the target state according to a certain performance criteria. good path finding technology of mobile robot can not only save a lot of time, but also reduce the wear and capital investment of mobile robot. Because the path finding of mobile robot has important application value, it has become a hot research topic both at home and abroad. Generally speaking, the path finding can be divided into two categories: the global path finding and the local path finding shown in Figure (1), according to whether all the information of the environment is accessible or not. For the global path planning, all the information of the environment is known to the robot before starting. In contrast, for the local path planning, almost all the information of the environment is unknown to the robot before starting [4].

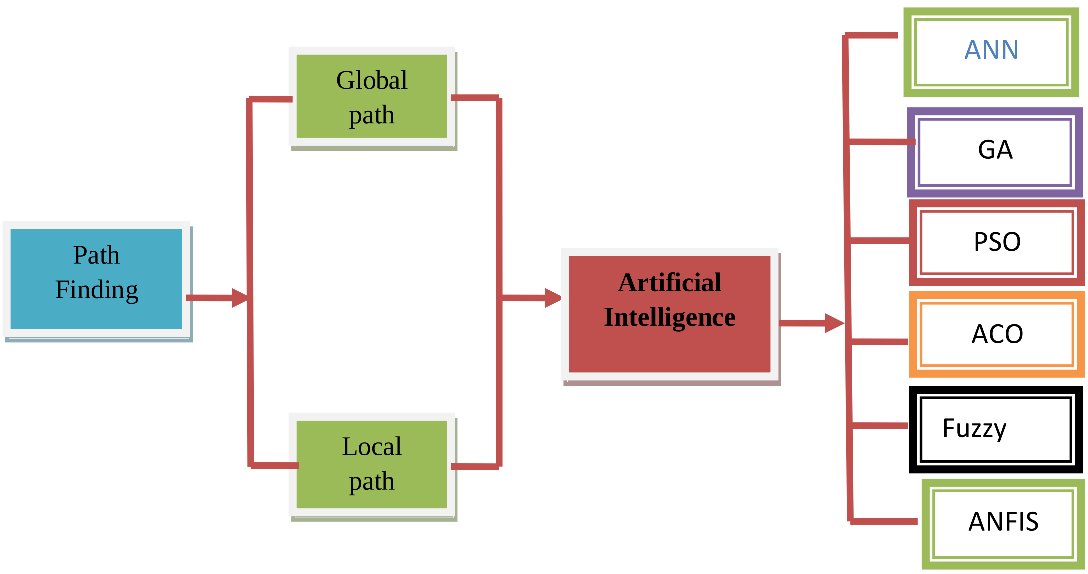

Figure (1): classification of path finding

Several soft computing techniques used of path finding for mobile robot. In the past few years, many soft computing techniques are proposed by the researchers to solve the robot navigation and obstacle avoidance problem in the various environments. The various soft computing techniques applied for mobile robot navigation in the different static and dynamic environments

II. ARTIFICIAL INTELLIGENCE TECHNIQUES

Artificial Intelligence (AI) has seen tremendous progress in recent years. It is a thriving research area with an increasing number of important research and basic technology areas for an increasing number of application areas. In addition to algorithmic innovations. Artificial intelligence is being utilized to enhance sciences and technologies due to its amazing capability of dealing with big data, complexity, high accuracy, and speedy processing. Artificial Neural Network (ANN), Fuzzy Logic, Neuro-Fuzzy Interference System (ANFIS), Genetic algorithm, Particle Swarm Optimization (PSO), etc., are the familiar tools of AI, AI has been employed in various areas such as engineering, science, medicine, computing, finance, economics and so on

A. Fuzzy Logic Technique

The concept of fuzzy logic has been introduced by Zadeh ,[5] which is extensively used in many engineering applications such as mobile robotics, image processing, etc. This method plays a vital role in the field of mobile robots. The fuzzy logic technique has been successfully applied by many researchers to control the position and orientation of mobile robot in the environment. Ren et al.[6] have designed an intelligent fuzzy logic controller to solve the navigation problem of wheeled mobile robot in an unknown and changing environment. Fuzzy logic systems are inspired by human reasoning, which works based on perception. In Yousfi ,[7] the authors have presented the Gradient method based optimal Takagi-Sugeno fuzzy controller to tune the membership function parameters, and applied it to mobile robot navigation and obstacle avoidance. Qing-yong et al.[8] have presented the behavior-based fuzzy architecture for mobile robot navigation in unknown environments. They have designed four basic behaviors: goal-seeking behavior, obstacle avoidance behavior, tracking behavior, etc. for mobile robot navigation and tested it in various simulation environments. The eight rule-based fuzzy controllers have been designed by Boubertakh et al.[9] for obstacle avoidance and goal-seeking behavior of the mobile robot. Muthu et al.[10] have presented the Atmega microcontroller based fuzzy logic controller for the wheeled mobile robot. The proposed controller train the mobile robot to navigate in an environment without any human intervention. The controller receives inputs (obstacle distance) from the group of sensors to control the right and left motor of the mobile robot. The sensor-based mobile robot navigation in an indoor environment using a fuzzy logic controller has been discussed.[11] ,[12] Wu et al.[13] have developed the sensor based mobile robot navigation in the narrow environment using fuzzy controller and genetic algorithm. Where the fuzzy controller provides the initial membership function and the genetic algorithm choose the best membership value to optimize the fuzzy controller for mobile robot navigation. Obstacle avoidance is very important for successful navigation of autonomous mobile robot. Samsudin et al.[14] have combined the reinforcement learning method and genetic algorithm to optimize the fuzzy controller for improving their performance when the mobile robot moves in an unknown environment. Fuzzy reinforcement learning sensor-based mobile robot navigation has been presented by Beom & Cho [15] for complex environments. Pradhan et al.[16] have used fuzzy logic controller with different membership functions for the navigation of one thousand robots in an entirely unknown environment. The authors have compared the performance of different membership functions such as triangular, trapezoidal and gaussian for mobile robot navigation and stated that the gaussian membership function is more efficient for navigation. In Liu,[17] the authors have combined the fuzzy genetic algorithm to solve the path planning and control problem of an autonomous mobile robot (AMR) using ultrasonic range finder sensor information. Farooq et al.[18] have presented the comparative study between the zero order Takagi-Sugeno and Mamdani - type fuzzy logic models for mobile robot navigation and obstacle avoidance. Both the controllers receive inputs (obstacle distance) from the left and right ultrasonic sensors to control the left and right velocities of the motors of the mobile robot. During comparison study, the authors have found that in terms of smoothness Mamdani-type fuzzy model gives a better result. On the other hand, the Takagi-Sugeno fuzzy model takes less memory space in the real-time microcontroller implementation. Figure (2) show inputs and output fuzzy logic

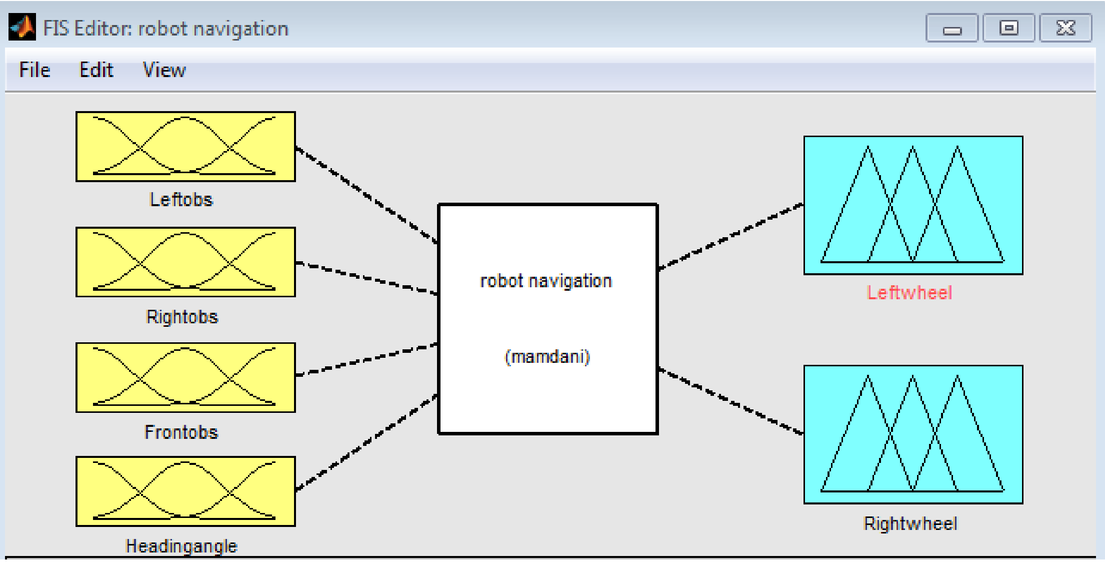

Figure (2) Inputs and output fuzzy logic

B. Artificial Neural Network Technique

The neural network is one of the important technique for the mobile robot navigation. This neural network technique is motivated from the human brain, which is being applied by many researchers in the different fields such as signal and image processing, pattern recognition, mobile robot path planning, and business, etc. Zou et al.[19] have presented the literature survey of neural networks and its applications in mobile robotics. In Xiao,[20] the authors have combined the multi-layer feed forward artificial neural network with Q-reinforcement learning method to construct a robust path-planning algorithm for the mobile robot. Rai & Rai [21] have designed the Arduino Uno microcontroller-based DC motor speed control system using the Multilayer neural network controller and Proportional Integral Derivative (PID) controller. Patino & Carelli [22] have designed the automatic steering controller for a mobile vehicle using neural network architecture. Yang & Meng [23] have applied the biologically inspired neural network to generate a collision-free path in a nonstationary environment. Biologically inspired neural network based wall-following mobile robot has been presented by Nichols et al.[24] Online path planning between unknown obstacles in the environment is an interesting problem in the field of mobile robotics. Motlagh et al.[25] have presented the target seeking, and obstacle avoidance behaviours using neural networks and reinforcement learning. Mobile robot navigation using hybrid neural network has been addressed by Gavrilov & Lee.[26] Singh & Parhi [27] have designed multilayer feed forward neural network, which controls the steering angle of the robot autonomously in the static and dynamic environments. The different obstacle distances are the inputs of the four-layered neural network, and the steering angle is the output. Real-time collision-free path planning becomes more difficult when the robot is moving in a dynamic and unstructured environment.

C. Genetic Algorithm (GA)

From 1975 [28, 29] genetic algorithm has been used for solving the problem of optimal routing for robots. Genetic algorithm is a technique inspired from nature and works based on principle of sustainability of the strongest chromosomes. Using genetic algorithm plays a successful role in robot path planning research. For example, [30] has the suggested usage of genetic algorithm for robot path planning, based on empty nodes map. [31] and [32] presented usage of encryption of different methods to ensure finding the optimal path by the genetic algorithm, regardless of the actual and practical nodes. [33] improved the algorithm efficiency with changing operators in genetic algorithm at certain intervals in order to globally search in dynamic environment. It can be concluded that implementation of genetic algorithm depends on the chromosome coding solutions, accuracy of fitness function and different algorithm's operators, to determine the whole routing process

D. Adaptive Neuro –Fuzzy (ANFIS)

A hybrid Fuzzy-Neuro algorithm for wheeled robot motion planning was given by Kundu, et al. [34]. Pradhan, et al. [35] have reviewed about the navigation of multiple wheeled robots by implementing Neuro-Fuzzy code. Total path length and total time taken has been considered to collate with the predefined method with a rule-based algorithm. Hui, et al. [36] have developed a wheeled robot with the help of Neuro-Fuzzy algorithm is like a car. Algabri, et al. [37] have concluded that regarding distance travelled the mutation of PSO and Fuzzy and mutation of Neuro and Fuzzy methods show better performance in comparison to other methods Li, [38] has performed simulation and found that navigation in difficult and unknown working space can be efficiently upgraded. He enforced the neuro-fuzzy technique to obtain

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the behavior-based control for the robot navigation in non-defined working space. He used two levels, one of them was the high level of environment understanding and the second one was for behavior control. ANFIS is the mutation of Fuzzy logic and neural network. Hegazy, et al. [39] have made it possible for a wheeled robot to arrive the goal in an unknown working space by using the neuro-fuzzy technique. Lee, [40] has found out the direction for robots to move by inputting the neural network, which was resolute by the interspace and presence of other robots. Fitness function as usual done the most important job, there it described how much group behaviors fit sufficiently with the target. Fitness has been validated the system through simulation, and it was found using a genetic algorithm. Pulasinghe, et al. [41] have figured out to control machines using spoken language commands using the fuzzy-neural network. Rusu, et al. [42] have experimented with the indoor condition by using infrared and contact sensors to dodge collisions and follow its target. Vatankhah, et al. [43] have matured a Nero-Fuzzy system to reach the target and for behaviour control. Abu Baker, [44] has described how we can get a navigation system by shunning obstacles using the hybrid Neuro-Fuzzy algorithm. He performed many iterations to obtain optimum path by reducing the time and using a broad amount of if-then rule. Baturone, et al. [45] have provided navigation structure using neuro-fuzzy algorithm control system for the wheeled robot at low-cost. They found an efficient result for reaching the goal and dodging obstacles. Wheeled robot navigation on the basis of a neuro-fuzzy arrangement has been described by Li, [46]. A neural network is implemented in this study to find out the reference motion direction, and to control coordinate struggle among the multiple layers of aware action, he used a neural As shown in Figure (3)

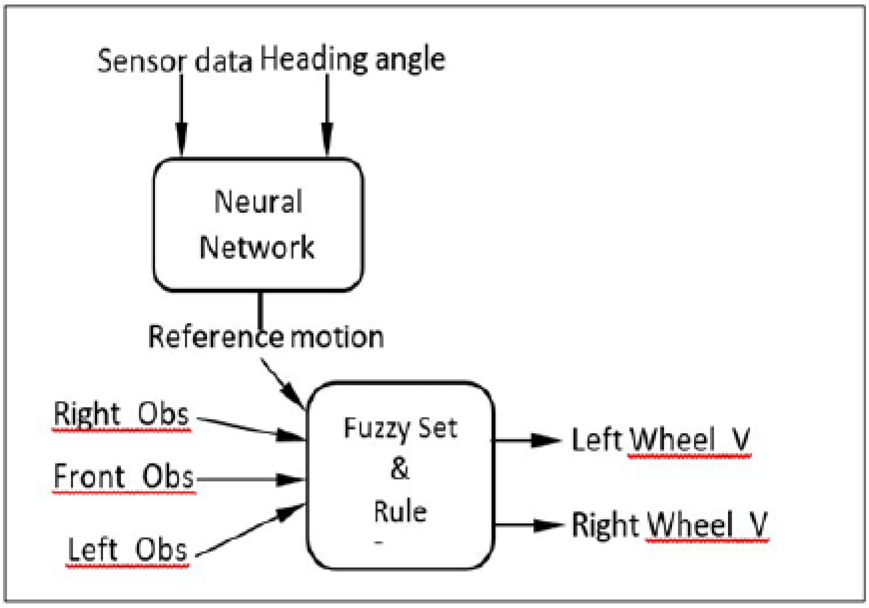

Figure (3) Mobile robot using ANFIS

E. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, with dubbed particles, and moving these particles around in the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position and is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions. PSO is a metaheuristic as it makes few or no assumptions about the problem being optimized and can search very large spaces of candidate solutions. However, metaheuristics such as PSO do not guarantee an optimal solution is ever found. More specifically, PSO does not use the gradient of the problem being optimized, which means PSO does not require that the optimization problem be differentiable as is required by classic optimization methods such as gradient descent and quasi-newton methods. PSO can therefore also be used on optimization problem that are partially irregular, noisy, change over time. Figure (4) show the structure of particle swarm optimization . The PSO technique is based on two essential equations:

$$\mathbf{V}_{\mathbf{i,m}}^{(\mathbf{It.+1})} = \mathrm{W} * \mathbf{V}_{\mathbf{i,m}}^{(\mathbf{It.})} + \mathbf{c_1} * \mathbf{rand} * \left(\mathbf{P}_{\mathbf{best}_{\mathbf{i,m}}} - \mathbf{x}_{\mathbf{i,m}}^{(\mathbf{It.})}\right) + \mathbf{c_2} * \mathbf{rand} * \left(\mathbf{g}_{\mathbf{best}_{\mathbf{m}}} - \mathbf{x}_{\mathbf{i,m}}^{(\mathbf{It.})}\right) \quad \ldots\ldots\ldots\ldots\ldots (\mathbf{1})$$

$$\mathbf{x}_{\mathbf{i,m}}^{(\mathbf{It.+1})} = \mathbf{x}_{\mathbf{i,m}}^{(\mathbf{It.})} + \mathbf{v}_{\mathbf{i,m}}^{(\mathbf{It.})} \quad \ldots\ldots\ldots\ldots (\mathbf{2})$$

Where i=1, 2, 3,……, n

m= 1, 2,3, ….., d
n : Number of particles
d : Dimension
Iter. : Iterations pointer
$V_{i,m}^{(It.)}$: Particle (no. i) velocity at iteration W : Inertia weight factor
c_1, c_2 : Acceleration constant
rand : Random number between 0-1
$x_{i,m}^{(It.)}$: Particle i current position at iteration
P_{best_i} : Best previous position of the particle
g_{best_m} : Best particle among all the particles in the population .

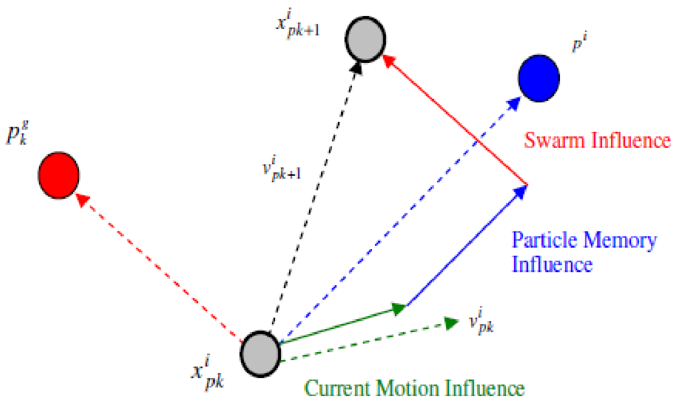

Figure (4) structure of particle swarm optimization

F. Ant Colony Optimization (ACO)

Ant colony optimization algorithm is a newer method introduced by Marco Dorigo in 1992 [47]. The usage of ant algorithm for robot path planning problems is growing rapidly, and this algorithm is used as a powerful method for solving difficult compounds optimization problems. Ant colony optimization algorithm inspired from the behavior of real ants, when they are looking for grain. The usage of ant colony optimization algorithm for sample based on MAKLINK graph has been suggested for finding robot's path [48]. Combining ant colony optimization algorithm with potential field results in routing in dynamic environments [49]. It was proved that ant colony optimization algorithm, by certain proposed equations, can find the optimal path in the networked map [50]. Yet studies show that ant colony optimization algorithm does not pay attention to the details for solving the path planning problems

Table (I) Summary Artificial Intelligence techniques

Authors	ne of different path planning techniques applied by authors	The results
Yogita Gigra S et. al. [51]	Artificial Intelligence in Robot Path Planni	Ant colony optimization is to be applied for robot –motion control such as navigation and obstacle avoidance in an efficient manner. From this, money can be saved and reliability can be increased by allowing them to adapt themselves according to the environment without further
Hachour Ouarda [52]	Neural Path planning For Mobile Robot	The simulation results illustrate the generalization and adaptation capabilities of neural networks. An interesting alternative for future work is the generalization of this approach by increasing the number of possible robot directions.
Indar Sugiarto et .al.[53]	Implementation of Fuzzy Logic in FPGA for Maze Tracking of Mobile Robot Based on Ultrasonic Distance Measurement	This paper deals with the real-time navigation of a mobile robot in a maze using fuzzy approach to endow the robot with the human being ability to reason and avoid collision. The robot equipped with only rudimentary sensing capabilities using ultrasonic transceiver
G. .A	Path Navigation for Robot Using Matlab	Path navigation using fuzzy logic controller and trajectory prediction table is to drive a robot in the dynamic

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Andurkar .B et.al.[54]		environmentto a target position, without collision
Anish Pandey et.al. [55]	Mobile robot navigation and obstacle avo technique:A review	The present article focuses on the study of the intelligent navigation techniques, which are capable of navigating a mobile robot autonomously in static as well as dynamic environments
Alaa A. Ahmed [56]	Path Planning of Mobile Robot Using Fuzzy-PotentialField Method	An approach proposed is introduced in this paper based on Combing the artificial potential field method with fuzzy logic controller to solve drawbacks of artificial potential field method such as local minima problems, make an effective motion planner and improve the quality of the trajectory of mobile robot.
Fatemeh Khosravi Purian et.al.[57]	Path Planning of Mobile Robots Via Fuzzy Logic In Unknown Dynamic Environments with Different Complexities	The 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 t length of the shortest possible path.
Fatemeh Khosravi Purian et.al.[58]	Comparing the Performance of Genetic Algorithm and Ant Colony Optimization Algorithm for Mobile Robot Path Planning in the Dynamic Environments with Different Complexitie	Obtained results from comparing the performance of these two algorithms by considering performance and adjusting the parameters and their advantages beside limitations, developed optimization algorithms for route moving robots.
Rame Likaj et .al. [59]	Path finding for a mobile robot using fuzzy and genetic Algorithms	shown the detection and avoidance of static and dynamic obstacles in a closed environment using a single camera to record the state of environment in which the mobile robot operates
an-ye Zhang [60]	Planning for the Mobile Robot: A Review	The survey shows GA (genetic algorithm), PSO (particle swarm optimization algorithm), APF (artificial potential field), and ACO (ant colony optimization algorithm) are the most used approaches to solve the path planning of mobile robot
Yang Xue et.al.[61]	Solving the Path Planning Problem in Mobile Robotics with the Multi-Objective Evolutionary Algorithm	The results show the advantages of the algorithm . In particular, different quality metrics are used to assess the obtained results. In the end, the research indicates that the proposed multi-objective evolutionary algorithm is a good choice for solving the path planning problem.
JIAN-HUA ZHANG et .al.[62]	Path Planning of Mobile Robot Based on Hybrid Multi-Objective Bare Bones Particle Swarm Optimization With Different Evolution	The mathematical model for robot path planning is _rstly devised as a tri-objective optimization with three indices, i.e., the path length, the smoothness degree of a path, and the safety degree of a path. Then, a hybrid multi-objective bare bones particle swarm optimization is developed to generate feasible paths by combining infeasible paths blocked by obstacles with feasible paths via improved mutation strategies of differential evolution
Ibraheem Kasim Ibraheem et .al.[63]	Multi-Objective Path Planning of an Autonomous Mobile Robot in Static and Dynamic Environments using a Hybrid PSO-MFB Optimization Algorithm	The algorithm was tested in static and dynamic environments different scenarios to minimize a multi-objective measure of path length and minimum angles. In the context of the simulation results, it can be concluded that the proposed hybrid PSO-MFB algorithm proved efficacy in avoiding static and dynamic obstacles in a simple manner and reduced time.
Guoliang Chen et.al.[64]	Mobile Robot Path Planning Using Ant Colony Algorithm and Improved Potential Field Method	The experiment results verify that the method has stronger stability and environmental adaptability.

III. RESULTS

Artificial Intelligence techniques as GA, Fuzzy, ANN, ANFIS, and PSO applied for path finding of mobile robot to move from a starting point to the target point in static environments. These techniques improvement performance to reach of target with shortest path length and shortest time Results of these techniques are very encouraging and they indicate important contributions to the areas of path finding of mobile robot as illustrated in Table(I). the number of papers that used artificial intelligence technique showed that the fuzzy logic and ANFIS techniques are the most used as illustrated Figure (5).

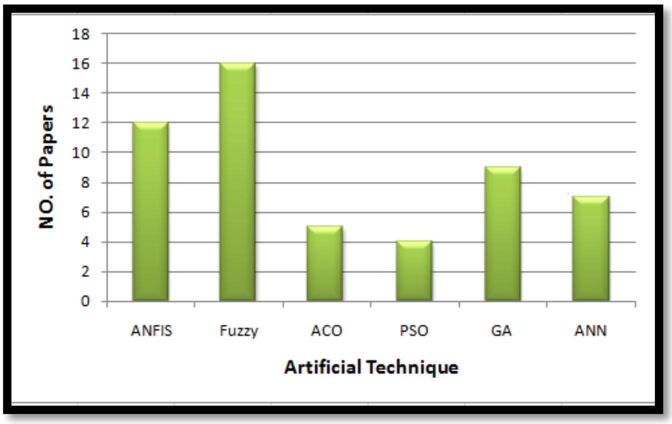

Figure (5). The number of papers retrieved by the data base of Engineering Village

IV. CONCLUSION

This article provides a literature survey of various techniques employed for path finding of mobile robot. According to literature survey, most of the researchers have used these soft computing techniques for mobile robot navigation and obstacle avoidance in only static environments. However, few researchers have considered dynamic environments for mobile robot navigation. From the literature survey, it is observed that many researchers have demonstrated only computer simulation results without implementations of physical robot. The path planning problem is an important research field of the mobile robot which has aroused the interest of many researchers both at home and abroad. good path finding technology of mobile robot can not only save a lot of time, but also reduce the wear and capital investment of mobile robot. different methodologies have been reviewed in this paper. The results shows fuzzy, ANFIS, GA, PSO, and ACO are the most used four approaches to solve the path finding of mobile robot.

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