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Heuristic Algorithms for Robot Path Planning: A Review

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Abstract: Path planning is an essential part of autonomous robots so that they can work in real environments with several obstacles. There are two method of path planning classical and heuristic methods which are categorized according to their efficiency and complexity. Heuristic methods are based on machine learning algorithms which can find more feasible solutions. In this paper a review of heuristic algorithms used for path planning are discussed according to their feasibility and complexity. Different papers on heuristic algorithms are discussed to find out the computational complexity and efficiency of the algorithm.

Keywords: Path Planning; Neural Networks; Fuzzy Logic Based Algorithms; Hybrid Algorithms; Nature Inspired Algorithms.

I. INTRODUCTION

Robots can be controlled or autonomous depending on the tasks and the requirements. Controlled robots does not require any path planning as they follow the instructions from the user. Autonomous robots need to be programmed in such a way that they can find their path from the starting point to the target destination while also avoiding the obstacles. Path planning is one of the major areas of research in field of robotics as world is moving towards intelligent cars which can avoid accidents on roads and drive to the destination without any human Intervention [1]. The algorithm for path planning must be designed keeping in mind the machine learning algorithms so that the algorithm becomes more efficient after unsuccessful path planning. The robot must be able to find a path to the target without damaging the surrounding environment or the configuration space [2]. There are two main types of path planning algorithms i.e. classical and heuristic algorithms. In this paper a review of heuristic algorithms is presented. The heuristic algorithms are divided into four categories i.e. Artificial Neural Networks, Fuzzy Logic Based Algorithms, Nature Inspired Algorithms and Hybrid Algorithms. Heuristic algorithms have four steps of execution i.e. perception, localization, path planning and robot motion. Classical methods were used extensively in the field of robotics but due to their less reliability Heuristic methods are widely used but at an expense of high computational complexity.

II. HEURISTIC ALGORITHMS

In this review, the study addresses artificial neural network (ANN), fuzzy logic (FL) some of the most used nature-inspired algorithms. The positive and negative characteristics of the algorithms are available in each section. The section is organized into four parts. Artificial Neural network (ANN) is presented in 2.1 and fuzzy logic (FL) is shown in 2.2. After that, the Nature-inspired algorithms are introduced in 2.3. Lastly hybrid algorithm integrating neural network and fuzzy logic (NN–FL) technique are analyzed in 2.4.

A. *Artificial Neural Network.*

Neural networks are implemented in robots to solve complex environments. There are three steps of neural networks i.e. collection of data from sensors, obstacle avoidance and path planning. In paper by Jian [3] a neural network based path planning technique has been proposed for mobile robots. It is a reinforcement based machine learning algorithm which optimizes the problem. Adaptive resonance theory neural network whose structure consists of two subsystems i.e. attention subsystem and orienting subsystem. Attention subsystem selects the prototype pattern and then the orienting subsystem performs alertness test to the pattern. If pattern passes the test it is selected else other prototype patterns are searched. Figure 1 shows the architecture of adaptive resonance theory neural network with subsystems specified. The simulation results showed that time of obstacle avoidance is greatly decreased as well as this algorithm provides good path results. In paper by Qu and Yang [4] a modified algorithm based on pulse coupled neural networks is proposed for

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nonstationary environments. Algorithm does not require any prior knowledge of the environment so a neuron is fired which triggers other neighboring neurons initiating a wave of neurons. Every neuron collects its results and record it to the neuron which initiated it thus path is planned according to the sequence of returned results from the environment. This method does not increase the computational complexity and can generate collision free paths in moving obstacles environments. Figure 2 shows the architecture of the modified neural network algorithm. The algorithm provided good results but has a drawback that it requires global knowledge of the environment. "Magnetization (A/m) □ 1000" because the reader would not know whether the top axis label in Figure 1 meant 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8 to 12 point type.

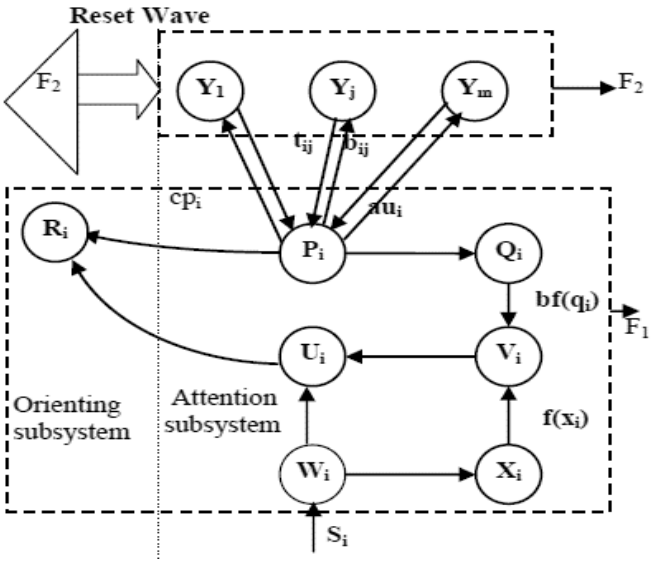

Figure 1: Adaptive Resonance Theory Neural Network [3].

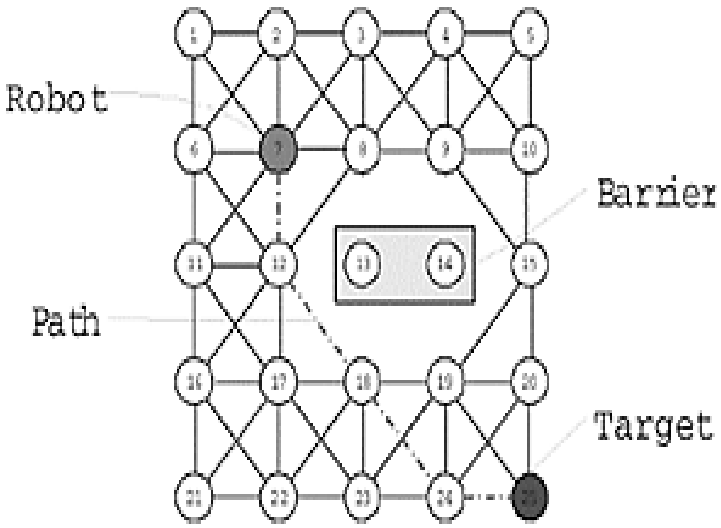

Figure 2: Pulse Coupled Neural Network Architecture [4]

In Paper by Gautam [5] an algorithm for obstacle avoidance in UAV is prosed based on genetic algorithm and artificial neural networks. Genetic algorithm send results to artificial neural networks which provide the output. Figure 3 shows the proposed algorithm in which genetic algorithm finds the best possible path through series of computations and then

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trains the neural network for future reference. The results showed that path can be planned faster compared to only using Genetic algorithm and these paths are accurate.

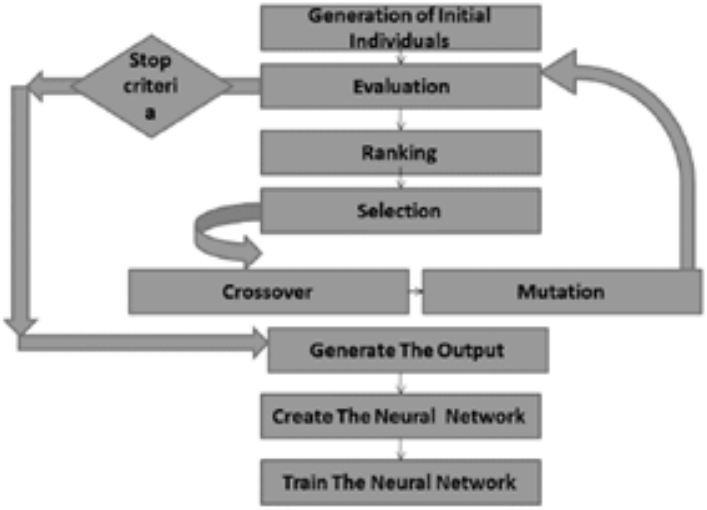

Figure 3: Genetic Algorithm and Artificial neural network based Path planning Algorithm [5].

B. *Fuzzy Logic Based Algorithms.*

Fuzzy logic based algorithms mimic human minds. As human minds does not need computation to predict a path fuzzy logic is designed on if-else conditions. It is easy to implement but sometimes does not provide favorable results. Figure 4 [6] shows the fuzzy logic system. Wang [7] proposes an algorithm based on fuzzy logic for path planning in an unknown environment. This algorithm is designed to work for blind goal oriented navigation like maze path finding etc. The results showed that fuzzy logic outperformed existing techniques for solving maze. In paper by Dirik [8] fuzzy logic is used for static path planning through vision based sensors. The decision set for fuzzy logic is the encoder sensors of the wheel while colored labels are used for navigation. Li and Zhang [9] proposed fuzzy logic based algorithm for static environments. The comparative study with potential field showed that this algorithm can find best shortest path, has less computational complexity and can provide solutions in lesser known environments.
Yang [10] develops a layered goal oriented path planning algorithm based on fuzzy logic. In the first layer of the algorithm data of long range sensors is used to set an intermediate goal which is transmitted to second layer. Second layer guides the robot to the goal by using data from short range sensors while avoiding obstacles. Fuzzy logic is used to implement these layer because of less computational complexity and low latency. The results were excellent in terms of optimized path planning and results can be improved by using sophisticated sensors.

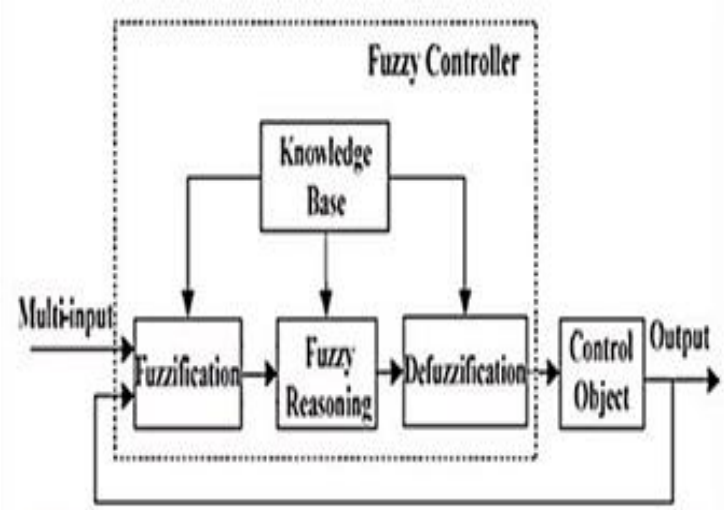

Figure 4: Fuzzy Logic System [6]

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C. *Nature Inspired Algorithms.*

As the name indicated that these algorithms are inspired by surrounding environment or the nature. These algorithms consists of bee swarm, cuckoo algorithms, etc. Liang and lee [11] proposed a path planning algorithm based on bee colony. This algorithm is an advancement of artificial bee colony algorithm which provides a collision free path for mobile robots. The algorithm uses elite individuals, share solutions for better searching and updates the solution providing good solution. Figure 5 shows the illustration of the algorithm. The results showed that this algorithm is feasible for real time path planning, can provide optimized path, can be used for multiple mobile robot and is also feasible in dynamic environments compared to other existing algorithms. In paper by Duan [12] a pigeon inspired algorithm is presented for air robots path planning. Pigeons have an ability to find their way around using sun direction, the magnetic field of the earth and the landmarks. So the algorithm is designed in two steps; the first step is to mathematically model the magnetic field and sun direction which is known as compass modeling and the second step is the landmark modeling. Figure 6 shows the compass modeling of the pigeon based algorithm. The results showed that this algorithm is feasible and effective for air robots path planning but are computationally complex.

Zhang [13] proposed a path planning algorithm based on particle swarm optimization (PSO) algorithm. This algorithm is design for war fields where precise decisions have to be taken to avoid damage. A function evaluates the degree of risk and the distance of path. Based on these two constraints PSO algorithm tackles a particular problem. The results showed that the algorithm can provide feasible solution in environments which have unknown risks involved and this algorithm is also applicable but at high computational cost. In paper by Kumar [14] a cuckoo levy flight based algorithm is proposed for navigation. The algorithm develops an objective function based on its value of each nest the best path is chosen. The simulation results showed that the algorithm found the shortest path in optimum time compared to PSO and genetic algorithm.

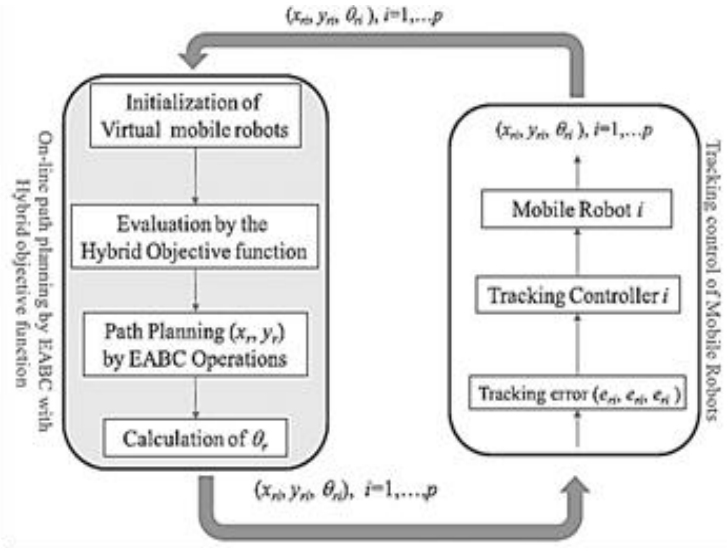

Figure 5: Efficient Artificial Bee Colony Algorithm [11].

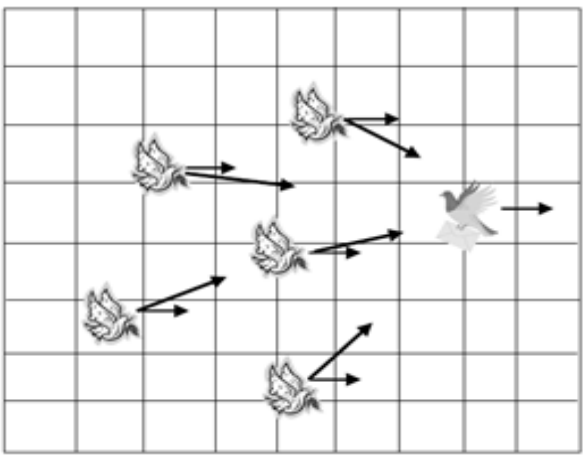

Figure 6: Map and Compass Modeling of the Pigeon Based Algorithm [12]

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D. *Hybrid Algorithms.*

Hybrid algorithms are designed using two or more than two existing algorithms to improve the performance but at the expense of more computational complexity. In paper by Mohanty [15] a hybrid algorithm consisting of cuckoo search (CS) and adaptive neuro fuzzy inference system (ANFIS) is proposed. The optimal path is found based on distance, direction, obstacles, and target. The CS algorithm trains the obstacle avoidance part while path planning is done by ANFIS algorithm shown in figure 7. Compared with other algorithms this algorithm yield shortest paths but took more time to compute results. Wang and Shan [16] presented a hybrid algorithm based on vehicular ad hoc networks VANET for vehicular on the road to provide best path and avoid congestion on the road. The simulation showed that this algorithm can provide better paths to avoid traffic congestion in real time keeping in view the delay caused due to computations. Figure 8 shows the real time VANET based path planning.

Particle swarm optimization with evolution technique is proposed by Zhang [17]. The PSO algorithm is a multi-objective bare bones algorithm which plans the path based on distance of path, smoothness of the path and safety of the path. After these results PSO trains itself to find the best feasible path for the robot. Simulations shows that this algorithms outperforms all algorithms in terms of distance, smoothness and security of the path but is a complex algorithm.

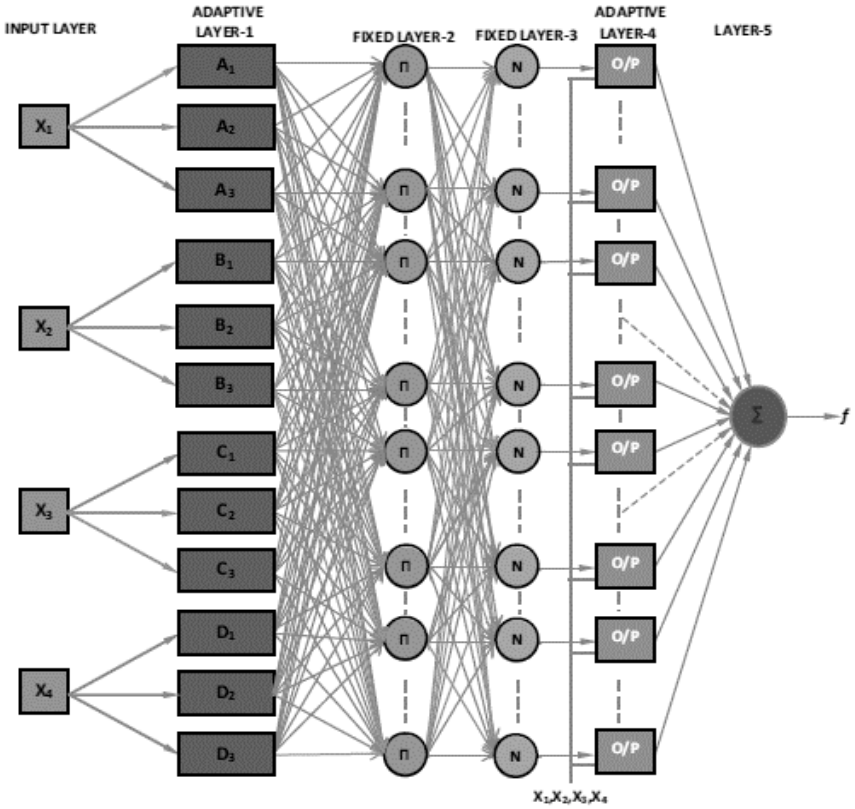

Figure 7: Adaptive Neuro Fuzzy Inference System [15]

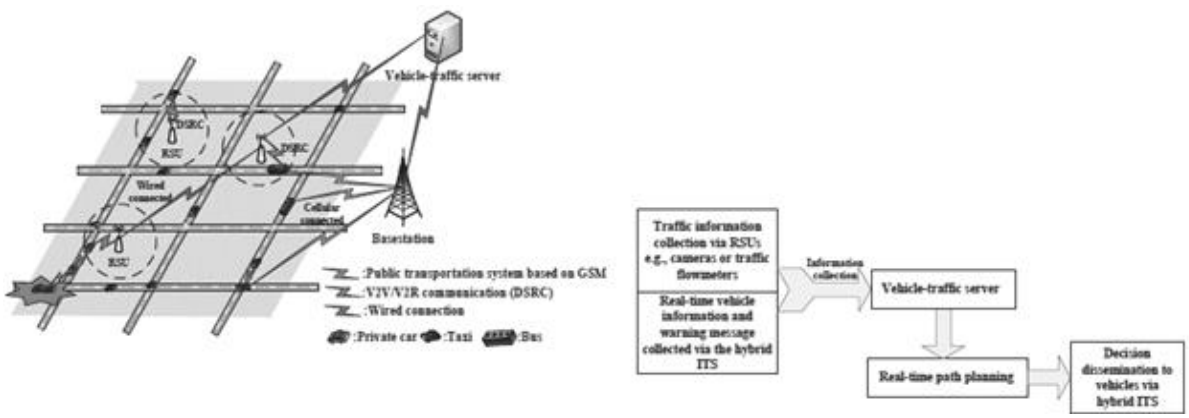

Figure 8: Real Time Path Planning in VANET [16]

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III. CONCLUSION

This papers provides a review of various types of heuristic algorithms used in path planning. The literature related to heuristic algorithms is discussed in detail in which all existing algorithms are included. All discussed algorithms are efficient but are computationally complex compared to classical algorithms. Artificial neural networks are complex in structure but provide good results on every iteration. Nature inspired algorithms are difficult to implement as traits of natural things have to be mathematically modeled which sometimes does not provide the desired results. Fuzzy Logic based algorithms have low computational complexity among all discussed algorithms in this paper and provide feasible results but fails in complex environments. Hybrid algorithms are designed for complex environments but at the expense of high computational complexity.

As mentioned before, there are pros and cons of each algorithm implemented for robot path planning. Same is the case of neural network technique. It has been implemented for path planning of robots as it has learning ability and nonlinear mapping but it takes time to compute parameters and sometimes requires adjustment of parameters. It is also complex to implement as large training databases are needed to enable its learning ability. It is often difficult to predict the functionality and number of neurons and layers in neural networks. There are two categories of machine learning; supervised and unsupervised learning. Neural networks require implementation of labelled training samples to modify it to supervised learning. It works as most of the adaptive filtering techniques as it requires an input signal and a desired response and weights are modified for the actual response to achieve the desired response. Neural networks have the ability to operate in a different environment with a little adjustment of weights and can work in an environment with disturbances. Fuzzy logic is based on the thinking power of a human which is represented mathematically by if-else conditions but sometimes is not robust in selecting the right functions and rules. Fuzzy logic can provide feasible results if it is designed as a skilled and qualified operator. Fuzzy logic is simple and easy to implement and has provided better results in uncertain environments where it is difficult to define it precisely. A hybrid technique based on neural networks and fuzzy logic will provide better results as they have the ability to think and learn. Such an algorithm for robot path planning will be able to learn quickly and adapt to the environment changes. One of the important factors of this technique should be the acquisition of data of training data and it's pre-processing. To deal with the optimization problems nature-inspired algorithms can provide better results such as finding the minimum time of distance travelled required for robot path planning but these algorithms are not robust to dynamic environments. Hybrid techniques consisting of nature-inspired algorithms and other techniques like fuzzy logic and neural networks can provide good results.

Very few algorithms of robot path planning give feasible results out of many implemented algorithms in this field. Most of the theoretical work is appropriate which has been shown in most of the studies through simulation results but when that algorithm has been implemented in the real world the results have not been that encouraging. Research for robotic path planning has not been in the dynamic environments rather researchers have preferred static environments which make those algorithms unsuitable for real-world applications. To develop a feasible algorithm for dynamic environments is still a challenge, therefore, hybrid techniques are used in robot path planning despite their computational complexity.

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REFERENCES

[1] B. Madhevan and M. Sreekumar, "Identification of probabilistic approaches and map-based navigation in motion planning for mobile robots," *Sādhanā*, vol. 43, no. 1, pp. 1–18, 2018.
[2] S. Thrun and T. Fr, "Map Learning and High-Speed Navigation in RHINO."
[3] F. Jian and F. Minrui, "RL-ART2 Neural Network Based Mobile Robot Path Planning," *Sixth Int. Conf. Intell. Syst. Des. Appl.*, vol. 2, pp. 581–585, 2006.
[4] H. Qu, S. X. Yang, S. Member, A. R. Willms, and Z. Yi, "Real-Time Robot Path Planning Based on a Modified Pulse-Coupled Neural Network Model," *IEEE Trans. Neural Networks*, vol. 20, no. 11, pp. 1724–1739, 2009.
[5] S. A. Gautam, "Path Planning for Unmanned Aerial Vehicle Based on Genetic Algorithm & Artificial Neural Network in 3D," *2014 Int. Conf. Data Min. Intell. Comput.*, pp. 1–5, 2014.
[6] B. S. Sandeep and P. Supriya, "Analysis of Fuzzy Rules for Robot Path Planning," *Intl. Conf. Adv. Comput. Commun. Informatics*, pp. 309–314, 2016.
[7] M. Wang and J. N. K. Liu, "FUZZY LOGIC BASED ROBOT PATH PLANNING IN UNKNOWN ENVIRONMENT," *Fourth Int. Conf. Mach. Learn. Cybern.*, vol. 1, no. August, pp. 18–21, 2005.
[8] E. D. Mahmut DİRİK, Adnan Fatih KOCAMAZ, "Static Path Planning Based on Visual Servoing via Fuzzy Logic," *25th Signal Process. Commun. Appl. Conf.*, pp. 1–4, 2017.
[9] Q. Li, C. Zhang, C. Han, Y. Xu, Y. Yin, and W. Zhang, "Path Planning Based on Fuzzy Logic Algorithm for Mobile Robots in Static Environment," *25th Chinese Control Decis. Conf.*, pp. 2866–2871, 2013.
[10] X. Yang, S. Member, M. Moallem, and R. V Patel, "A Layered Goal-Oriented Fuzzy Motion Planning Strategy for Mobile Robot Navigation," *IEEE Trans. Syst. MAN, Cybern. B Cybern.*, vol. 35, no. 6, pp. 1214–1224, 2005.

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[11] J. Liang and C. Lee, "Efficient collision-free path-planning of multiple mobile robots system using efficient artificial bee colony algorithm," *Adv. Eng. Softw.*, vol. 79, pp. 47–56, 2015.
[12] H. D. P. Qiao, "(2014) Pigeon-inspired optimization: a newswarm intelligence optimizer for air robot path planning," *Int. J. Intell. Comput. Cybern.*, vol. 7, no. 1, pp. 24–37, 2014.
[13] Y. Zhang, D. Gong, and J. Zhang, "Robot path planning in uncertain environment using multi-objective particle swarm optimization," *Neurocomputing*, vol. 103, pp. 172–185, 2013.
[14] P. K. Mohanty and D. R. Parhi, "Cuckoo Search Algorithm for the Mobile Robot," pp. 527–536, 2013.
[15] P. K. Mohanty and D. R. Parhi, "A new hybrid optimization algorithm for multiple mobile robots navigation based on the CS-ANFIS approach," *Memetic Comput.*, vol. 7, pp. 255–273, 2015.
[16] M. Wang, H. Shan, R. Lu, R. Zhang, X. S. Shen, and F. Bai, "Real-Time Path Planning Based on Hybrid-VANET-Enhanced Transportation System," *IEEE Trans. Veh. Technol.*, vol. 9545, no. c, 2014.
[17] J. Zhang, Y. Zhang, and Y. Zhou, "Path Planning of Mobile Robot Based on Hybrid Multi-Objective Bare Bones Particle Swarm Optimization With Differential Evolution," *IEEE Access*, vol. 6, pp. 44542–44555, 2018.