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PATH PLANNING TECHNIQUES FOR MOBILE ROBOT: A REVIEW

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Abstract: *The ability of a mobile robot to plan its path, avoid obstacles and optimize in static as well as dynamic environments is the key task in the field of robotics, which tends to find the shortest, collision free, optimal path in the various scenes. In this paper, the robotic path planning strategy of mobile robots can be categorized as Classical and Intelligent Techniques. A detailed review made based on the several techniques presented especially by focusing on the various cluttered environments, their merits and demerits of each of these strategies. However, the main drawback arises from the classical techniques because of the complex issues compared to intelligent techniques.*

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I. Introduction

In a robot, path planning is the problem of contrive or formulate a path or strategy which makes the robot to move from a pre-specified source to a pre-specified goal based on the fact that the environment structure might be in dynamic or static in nature or both [30]. Path planning is known to be one of the basic and interesting functions for a mobile robot [14] which is classified into global and local path planning as rightly researched by [8] but the motion planning in respect of natural is interesting and challenging task due to the respective constraints and issues related to it [11].

Robotics is an exceedingly inter-disciplinary field of study that takes inputs from several disciples with varying complexities because some mobile robot that explores an unknown terrain or environment has no absolute frame of reference for its position, other than lineament it detects through its sensing elements [28]. The most vital issues associated with the navigation of mobile robot is to find out an optimized collision free path pre-specified source to a pre-specified goal according to some performance merits such as travel time, path-length, smoothness of the path, the minimum cost and minimum energy consumption .

The application of mobile robot path planning and coordination are complex but incorporated into restorative and surgical uses, fire in the rescue mission, surveillance, ocean and space investigation, unmanned bomb transfer robots, automated factories and planet investigation robots [27], [37].

II. Path Planning Techniques

Path planning of a mobile robot is to ascertain a collision-free path from a pre-specified source to a pre-specified goal and optimizing a performance criterion such as less computational complexity, less power consumption, distance and time. The techniques are classified into two, classical and intelligent techniques as shown in Fig. 1. The classical techniques or approaches are Geometric Construction Method, Virtual Impedance Method, Convex Hull Method, Divide and Conquer Method, Grey Wolf Optimization. (2014), Roadmap Cell Decomposition.(1987), Grid Based.(1988), Artificial Potential Field.(1979) and Rapidly Exploring Random Tree.(1998) while the intelligent techniques are Firefly Algorithm Optimization Technique.(2008), Support Vector Machine, Fuzzy Logic Technique.(1965), Neural Network Technique.(1943), Evolutionary Computation Technique.(1930), Ant Colony Optimization Technique.(1992), Particle Swarm Optimization Technique.(1995), Bacterial Foraging Optimization.(2002), Bee Colony Optimization Technique.(2005). These are techniques proposed by numerous researchers with several advantages, disadvantages, and limitations as highlighted in the subsequent sections [40].

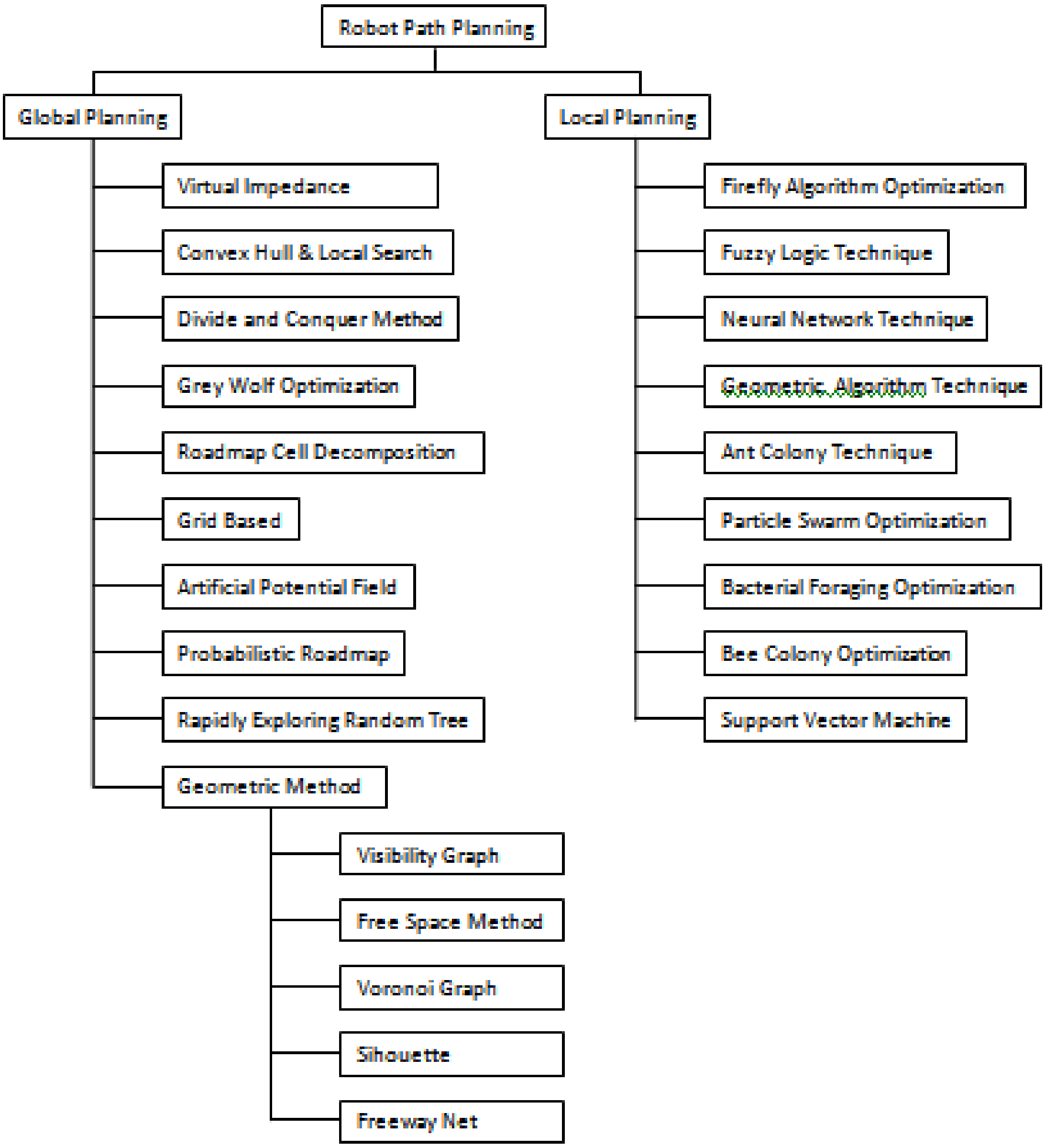

Fig 1: Robotic path planning techniques

2.1 Classical Techniques

2.1.1 Geometric Construction Methods

This is a robust alternative algorithm to determine a collision free path connecting the initial and final configurations of a robot with minimal number of waypoints either in 2D or 3D [39]. This method is also known roadmap approach that can reduce the computation time required to find an optimal collision-free path. The geometric construction method is generally categorized into: Voronoi method, Visibility Graph, Silhouette, Freeway net and Free-space method

- The **Voronoi diagram** is the set of lines equidistant from two or more points which make it an excellent planner since the created paths will be desirable. The Voronoi diagram approach is exact, thus appropriate in two dimensions and the speed is faster compared to other methods in the same category
- **Visibility Graph** sees the robot as a point, the robot, goal and the vertices of polygon obstacle are connected all of the connecting line cannot through the obstacles which finds out the shortest path as the merit but lacks flexibility.
- **Silhouette** literally means a dark shadow or outline of an object against a light background. As the name implies, the silhouette path planning technique consists of generating the silhouette of the work cell and developing the roadmap by connecting these silhouette curves to each other. This is a network of semi-free paths which is searched to select the path from the start configuration to the goal configuration

- **Freeway net**
- **Free space method** is flexible compared to visibility graph method and the complexity depends or is directly proportional to the number of obstacles. In this method, the environmental space is divided into free space and the obstacle space, extending out the obstacle to the robot maximum diameter. The major setback of free space method is that the shortest path is not achieved at any time

2.1.2 Rapidly Exploring Random Tree Method
This is an approach in robotics that has gained tremendous interest in the recent time [24].

2.1.3 Virtual Impedance Method
This technique is employed for a versatile robot enhances motion smoothness and for advances robot execution in dynamic terrain with static and portable hindrances [12]. A research was conducted by [21] on virtual impedance model for obstacle avoidance in a limb mechanism robot with promising performance.

2.1.4 Convex Hull Method
Convex hull has shown an exceptionally result in managing numerous computational issues such as robotized highlight acknowledgment from 2-D and additionally 3-D. the problem is all about constructing, developing, articulating, circumscribing or encompassing a given set of points in plane by a polygonal capsule called convex polygon [19].

2.1.5 Grid Method
This strategy divides the working environment into a series of grid cell generally, a two-dimensional Cartesian matrix grid are used to express the work environment in which each of cell has a accumulate value that represent the credibility of existing obstacles. Therefore, in practical use the method is limited but helpful to diminish the effect because of the division as well as affiliation errors [26].

2.1.6 Divide and Conquer Method
This method is based on multi-branched recursion by breaking down problem into two or more sub-problems. This approach is based on efficient algorithm such as computing (discrete Fourier transform), sorting (quicksort), and syntactic analysis (top-down parsers). They are powerful tools for solving conceptually difficult path planning wit algorithm efficiency, parallelism, memory access and roundoff control [32]

2.1.7 Artificial Potential Field
A potential field can be visualized as the differential of fascination and repugnance factors [27]. There are many improved variants of APF such as randomized path planner (RPP). The APF is distinct across the complete free space, and in each step time, at the robot position. The drawback of this method it is easy to fall into local minimum in trap region; it is not find path between adjacent obstacles. [6]

2.1.8 Cell Decomposition Method
The cell decomposition method gives an idea to identify between geometric areas, or cells, that are free and occupied areas by objects. The path between the initial configuration and the goal configuration can be determined by subdividing the free space into smaller regions known as cells before a connectivity graph is constructed. In cell decomposition methods, in a situation where the borders are assigned as a function of the structure of the environment, such scenario is termed is lossless, and therefore, the method is called exact cell decomposition but if the decomposition results in an approximation of the actual map, then the system is termed approximate cell decomposition. The probabilistic cell decomposition is fairly similar to approximate cell decomposition except that cells borders do not represent any physical meaning. [3]

2.2 Intelligent Systems for Robot Path Planning
2.2.1 Fuzzy Logic Based Path Planning Technique
Zadeh, who developed the concept of fuzzy logic (FL), was the first to coin the term Soft Computing (SC). In a broad sense, Fuzzy logic (FL) mimics the reasoning of a human expert, preserving information through the use of continuous "interest" or "membership" values until the output is produced. FL has the ability to handle complex decisions by verbalizing the whole approaches and operations with potential algorithm but achieves the tremendous results using processing of inputs of a series of if-then directives and usage of several thresholds [5], [29]. Path-of-probability (POP) method was employed to generate better and smoother paths for robotic systems but this approach sometimes fails to generate a path that reaches a target. Fuzzy logic was used to improve POP method by increasing the number of candidate paths and computation time [18].

2.2.2 Evolutionary Computation (EC)

The fusion of evolution strategies (ES), evolutionary programming (EP), and genetic algorithms (GA) had formed the backbone of the field of evolutionary computation which remains an active research area for both old and new researchers [29]. [38] stated the problem of path planning for a robot group as a multiple travelling salesman problem (MTSP) that used total-path-shortest or longest-path-shortest with robust way of solving path planning problem for robot group.

2.2.3 Ant Colony Optimization Technique

ACA inspired by the behavior of real ant colonies observations, was first introduced by [9] as a kind of distributed optimization tool which was applied to solve the traveling salesman problem. ACA has recorded huge success when used to solve other combinatorial problems including graph coloring, data mining and optimization, Machine learning, mobile robots, vehicle routing, fuzzy controller, quadratic assignment and the shortest common super-sequence problem [29]. The ACO research presented by [36], shows that the proposed ACO algorithm for collision avoidance using backtracking to determine the optimum shortest path to reach to the destination. [7] investigated and presented the application of ACO to robot path planning in a dynamic environment which has to do with the comparison of two different pheromone re-initialization schemes

2.2.4 Support Vector Machines Based Path Planning (SVMs), was first introduced in early 90s by Vapnik as a supervised learning system based on statistical theory that gained wider acceptance in the academic and industrial communities. Support vector machines use linear models to implement nonlinear class boundaries and found great applications in a wide variety of fields (Bordes et al., 2009; Shalev-Shwartz et al., 2007). [34] employed the technique support vector machines (SVM) for path planning Player/Stage simulation for various case studies with complex obstacles and maps created

2.2.5 Neural Network Based Path planning: According to Haykin (2009), Neural Network (ANN) is a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. Artificial Neural networks, with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or conventional computer techniques. A neural network based method to coordinate the dynamic, numerous errands task to the gathering of robots of movement arranging is presented by [1] using self-organizing map (SOM) component

2.2.6 Particle Swarm Optimization Based Path planning is a metaheuristic global optimization paradigm that has gained prominence and also of the numerous techniques widely used in solving ill-structured discrete /continuous, constrained as well as unconstrained function optimization problems [23]. In recent times, PSO technique has received a significant growth which is applied to optimal pose selection in reducing friction during robotic machining [33], robotic arm movement [25], detumble and control of space robot [35], Robot path planning is one of the most important tasks in intelligent control [10] which finds application not only in robotic but in bioinformatics [13], medicine and virtual reality [17] and others fields of studies. [2] proposed an improved PSO algorithm that finds the optimal path with respect to distance covered, form convergence to global minimum and generates the coordinates of the search space

2.2.7 Fire Fly Algorithm Optimization Technique

Firefly pass off it light by the process of bioluminescence and the emitted light utilized as a signal to fascinate the other fireflies. Bioluminescence is the process by which firefly emits the light [15], [20]. It is new in artificial intelligence approach and is popularly employed in every field of optimization and autonomous system. [4] presented a paper on application and implementation of Firefly Algorithm (FA) for Mobile Robot Navigation (MRN) in uncertain terrain, in which the propose algorithm efficiently explores the environment and improves the global search in less number of iterations and also easily implemented for real time obstacle avoidance.

2.2.8 Bee Colony Optimization Technique

The artificial bee colony (ABC) algorithm is a swarm based meta-heuristic algorithm utilized for enhancing numerical issues which was spirited by the intelligent foraging behaviour of honey bees [22]. [31] present ABC algorithm and employed it to find collision free shortest path from the start position to destination with excellent convergence and low consumption time recorded.

III. Hybrid Technique Based Path Planning

A well planned and better path planning technique can reduce robot loss, save lots of time, save human resources, reduce investment of the capital, and lay the good foundation for robot to be employed in several of industry with the use of two of more techniques to achieve goal. [33] proposed an intelligent system based on PSO and adaptive iteration algorithm to control and regulate the parameters in accordance with robotic machining state and significantly reduced the vibration and strain associated with robotic machine. Since PSO is a population based stochastic global optimization techniques inspired biologically, [16] proposed trajectory optimization for manipulator motion planning and store the parameters together with the corresponding normalized step cost (NSC) vectors. The merit is that optimization was successful while satisfying the constraints and is less likely to converge to a local minimum. [35] proposed a novel hybrid algorithm based on BP neural network (BPNN) and PSO is applied to search for the optimal variables which are employed to compensate for the error of the kinematic parameters and improve the positioning accuracy

IV. Conclusion

In the review paper, most of the commonly employed robotic paths planning techniques were investigated in the domain of global and local planning. The merit and the demerits are also discussed along with the hybridization of two techniques for better performance.

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