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Review on Techniques for Path Planning Process in Robot Designing

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Abstract

Path-planning is one of the basic and quite interesting issues in mobile robotic design since Mobile robot path planning has a few main properties according to type of environment, algorithm and completeness. The properties are whether it is static or dynamic, local or global and complete or heuristic. The static path planning refers to environment which contains no moving objects or obstacles other than a navigating robot and dynamic path planning refers to environment which contains dynamic moving and changing object such as moving obstacle. Meanwhile the local and global path planning depend on algorithm where the information about the environment is a priori or not to the algorithm. If the path planning is a global, information about the environment already known based of map, cells, grid or etc and if the path planning is a local, the robot has no information about the environment and robot has to sense the environment before decides to move for obstacle avoidance and generate trajectory planning toward target. The problems in path planning and its optimization is thus a popular research topic for many researchers across the globe, efforts are made in past to solve this problem and quite interesting results have been seen. In the present paper, a brief idea about the process of path planning in mobile robots with a short review of various contributions in improvising path planning process are presented.

Keywords: path planning, optimization, algorithm, mobile robot, industrial robot, probabilistic roadmap (PRM), genetic algorithm (GA), degree of freedom (DOF).

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INTRODUCTION

Nowadays, no one can deny the importance of robotics in our daily life. It is a continuously expanding field because of its wide applications in agriculture, industry, home, surveillance, hospitals, etc. Robots can be roughly divided into two types based on their structure and usage, namely mobile robots and industrial robots. Mobile robots have the capability to move around in their environment and are not fixed to one physical location. In contrast, industrial robots usually consist of a jointed arm (multi-linked manipulator) and gripper assembly (or end effector) that is attached to a fixed surface. Mobile robots have a very diversified and broad area of application. [1] These robots are used in navigation, surveillance, agriculture, cooperation, and in many other fields as it has a larger workspace compared to industrial robot. Coordinating the motion of multiple mobile robots is one of the fundamental problems in robotics. The predominant algorithms for coordinating teams of robots are decoupled and prioritized, thereby avoiding combinatorial hard planning problems typically faced by centralized approaches. While these methods are very efficient, they have two major drawbacks. First, they are incomplete, i.e. they sometimes fail to find a solution even if one exists, and second, the resulting solutions are often not optimal. [4]

Maren Bennewitz et al [2] in his research paper presented a method for finding and optimizing priority schemes for such prioritized and decoupled planning techniques. Existing approaches apply a single priority scheme which makes them overly prone to failure in cases where valid solutions exist. By searching in the space of prioritization schemes, our approach overcomes this limitation. It performs a randomized search with hill-climbing to find solutions and to minimize the overall path length. Hence, the researcher used a centralized approach the configuration spaces of the individual robots are combined into one composite configuration space which is then searched for a path for the whole composite system. In contrast, the decoupled approach first computes separate paths for the individual robots and then resolves possible conflicts of the generated paths an algorithm

PATH PLANNING

Path planning is the determination of a path that a robot must take in order to pass over each point in an environment and path is a plan of geometric locus of the points in a given space where the robot has to pass through. Generally, the problem of path planning is about finding paths by connecting different locations in an environment such as graph, maze and road. Path planning enables mobile robots to see the obstacle and generate an optimum path so as to avoid them. [3]

Properties of Path Planning

Mobile robot path planning has a few main properties according to type of environment, algorithm and completeness. The properties are whether it is static or dynamic, local or global and complete or heuristic. The static path planning refers to environment which contains no moving objects or obstacles other than a navigating robot and dynamic path planning refers to environment which contains dynamic moving and changing object such as moving obstacle. Meanwhile the local and global path planning depend on algorithm where the information about the environment is a priori or not to the algorithm. If the path planning is a global, information about the environment already known based of map, cells, grid or etc and if the path planning is a local, the robot has no information about the environment and robot has to sense the environment before decides to move for obstacle avoidance and generate trajectory planning toward target. [3]

PREVIOUS WORKS ON PATH PLANNING

Preetha Bhattacharjee [1] worked on an alternative approach to path-planning of mobile robots using the artificial bee colony (ABC) optimization algorithm. The problem undertaken here attempts to determine the trajectory of motion of the robots from predefined starting positions to fixed goal positions in the world map with an ultimate objective to minimize the path length of all the robots. A local trajectory planning scheme has been developed with ABC optimization algorithm to optimally obtain the next positions of all the robots in the world map from their current positions, so that the paths to be developed locally for n-robots are sufficiently small with minimum spacing with the obstacles, if any, in the world map. Experiments reveal that the proposed optimization scheme outperforms two well-known algorithms with respect to standard metrics, called average total path deviation and average uncovered target distance.

Maren Bennewitz et al. [2] developed an algorithm which was guided by constraints generated from the task specification. To illustrate the appropriateness of this approach, the researcher discusses experimental results obtained with real robots and through systematic robot simulation. The experimental results illustrate the superior performance of our approach, both in terms of efficiency of robot motion and in the ability to find valid plans.

Martin Saska et al. [5] propose an original approach using a path description by string of cubic splines. Such path is easy executable and natural for car-like robot. Furthermore, it is possible to ensure smooth derivation in connections of particular splines. In this case, the path planning is equivalent to optimization of parameters of splines. An evolutionary technique called particle swarm optimization (PSO) was used hereunder due to its relatively fast convergence and global search character. Various settings of PSO parameters were tested and the best setting was compared to two classical mobile robot path planning algorithms.

In the Motion Planning research field, heuristic methods have demonstrated to outperform classical approaches gaining popularity in the last 35 years. Several ideas have been proposed to overcome the complex nature of this NP-Complete problem. Ant Colony Optimization algorithms are heuristic methods [6] that have been successfully used to deal with this kind of problems. This paper presents a novel proposal to solve the problem of path planning for mobile robots based on Simple Ant Colony Optimization Meta-Heuristic (SACO-MH). The new method was named SACOdm, where d stands for distance and m for memory. In SACOdm, the decision making process is influenced by the existing distance between the source and target nodes; moreover the ants can remember the visited nodes. The new added features give a speed up around 10 in many cases. The selection of the optimal path relies in the criterion of a Fuzzy Inference System, which is adjusted using a Simple Tuning Algorithm. The path planner application has two operating modes, one is for virtual environments, and the second one works with a real mobile robot using wireless communication. Both operating modes are global planners for plain terrain and support static and dynamic obstacle avoidance.

OPTIMIZATION APPROACHES FOR PATH PLANNING

Path Planning Using Probabilistic Roadmap (PRM)

Probabilistic Roadmap (PRM) is a complete path planner so that it always finds a solution or determines that none exists. Nowadays, robotic manipulators are becoming complex day by day with high number of degrees of freedom (DOF) to perform complex tasks. Increase in the number of DOFs increase the complexity in path planning. In this situation, PRM would be the best choice for path planning as it can efficiently plan the path for robots having n-degrees of freedom. PRM can be divided into two phases: a learning/construction phase and a query phase. As appeared from its name, PRM is a probabilistic based method and the results are not repeatable and it is not guaranteed that the obtained solution is optimal one. For these reasons, we ran PRM multiple times to get the best solution based on statistics. [3]

Path Planning Using Genetic Algorithm

Genetic Algorithm (GA) is a parallel and global search technique in which population of candidate solutions, called phenotypes or individuals, are evolved towards better solution. In order to solve a problem, we search all the feasible solutions, called Search Space, and each point in Search space represents one feasible solution. Looking for a solution is then like searching for some extremes in Search Space. In this case, searching becomes very complicated as it is difficult to define the starting search point and region of interest in the Search Space. GA is one of the algorithms that is suitable for this type of search. There are few terms associated with GA that must be explained properly in order to implement for path planning in the presence of obstacles. [3]

Comparison of PRM and GA

PRM is a complete planner. This property of PRM makes it computational expensive as compared to GA, because it has to explore all the allowable workspace and calculate the possible connections from each configuration to its neighborhood configurations. The other possible reason which makes PRM computationally expensive is the implementation of Dijkstra's algorithm after calculating the all possible configurations in workspace. Number of random configurations in allowable workspace also plays an important role in computational efficiency of PRM. As higher will be the number of random configurations the more time it will take. [3]

On the other hand, GA is computationally efficient as compared to PRM. The only computationally expensive step in GA is to calculate the cost function for all chromosomes. Luckily for path planning using GA, the objective function is the distance from initial position to final position which is not a complex function. This makes GA computationally efficient compare to PRM. Another advantage of GA over PRM is that arbitrary constraints can easily be incorporated in path planning. [3]

Although the numerical analysis shows the superior performance of GA but PRM has advantage of complete planner. One can use any of the methods according to its application.

If the working environment is not so complex and there are few obstacles then GA is recommended for path planning. But for robotic manipulators with high Degrees of Freedom (DOFs) or for complex working environment, PRM is recommended for path planning.

FUTURE PROSPECTS

The practicability and the comparison among different techniques are discussed by numerical examples. Besides that there is a room for further improvements and future work. Although a significant amount of research has been done in field of trajectory optimization of robotic manipulators but still we are lagging in online trajectory optimization techniques. Currently, there is no technique for online trajectory optimization and all the existing techniques are offline. This area requires investigation and research that would be beneficial.

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