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A survey on path planning techniques for autonomous mobilerobots

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ABSTRACT: *Autonomous navigation of mobile robots is an area that has witnessed a lot of research activity in the recent years due to its increasing applications. Several approaches have been proposed for the navigation of mobile robots. This review paper describes the various developments and techniques that have been applied for navigation of robots in dynamic environments with special focus on the soft computing approaches.*

Keywords: navigation, robot motion planning, soft computing.

I. INTRODUCTION

Mobile autonomous robots are finding widespread applications in several fields like mining, manufacturing, underwater exploration, space missions and as service robots. Mobile robot agents need to move around and interact with different environments. The fundamental requirement in motion planning of an autonomous robot includes trajectory tracking and obstacle avoidance [8]. The problem of motion planning is complex for robots operating in dynamic and unstructured environments as prior information about the environment is usually partial or absent.

The past few decades have witnessed a lot of research activity in the field of mobile robotics which involves the behaviour of robots under dynamic and challenging conditions to achieve a certain goal. The classical techniques like visibility graphs, Cell Decomposition, and Potential fields have been widely used in motion planning [18]. These classical techniques however suffer from some disadvantages like high time complexity in high dimensions and problems of getting trapped in local minima [17]. Soft computing techniques like fuzzy logic and other biologically inspired methods like artificial neural networks, genetic algorithms, ant colony optimization and other techniques have also been widely used for robot motion planning [1,4,8]. This paper presents an overview of the various techniques that have been developed for path planning of mobile robots.

Robot Motion Planning

Motion planning for mobile robots is very complex as it constitutes several tasks. Given a particular location and a goal, the robot needs to find a geometric path towards the given goal. The problem becomes even more complicated if the robot needs to find an optimal path given some constraints or an objective function like shortest path or minimum time or even minimization of energy [8]. The robot may also come across several obstacles, static or dynamic and hence obstacle avoidance is extremely important for mobile robots. Obstacle avoidance refers to the methodologies of shaping the robot's path to overcome unexpected obstacles.

2.1 Local and global path planning

The Robot motion planning can be basically divided into two main categories i.e. local path planning and global path planning. In global path planning, the environment is known in advance and the terrain is static or the obstacles are known in advance. Hence, the path planning algorithm is able to make a complete map of the environment form the start point to the goal even before the robot starts motion [8]. Global path planning requires a completely known environment and a static terrain. On the other hand, in local path planning, the environment is completely unknown to the mobile robot i.e. the environment is dynamic and unstructured or the obstacles are not known in advance [12]. In such a situation, the robot needs to gather information about the environment in real time and update its control laws so as to achieve this. Usually information about the environment is obtained in the form of sensor data.

The motion planning approaches can also be divided into conventional and biologically inspired methods.

Conventional methods for robot motion planning

3.1 Graph Searching Technique

Graph-based representation is one of the earliest attempts towards motion planning[19]. In this approach a well-defined, well-organized and fully structured map of the agent's world is constructed for the purpose of planning a safe navigation. After a construction of the free and occupied spaces, the next attempt is to connect the available free spaces of the field (i.e. places that are obstacle-free) via connected networks of lines. Robot's trajectories are planned along such network and thus robot can perform a safe, target-oriented, collision-free motion Thus in road map approach, path planning is thus reduced to connecting the starting and final positions of the robot to the road network, then finding a series of roads from the starting robot position to its destination.

Two roadmap approaches are discussed, the visibility graph and Voronoi diagram. In the visibility graph, the path of the mobile robot is very close to the obstacle and theresulting minimum path distance solutions, whereas in the Voronoi Diagram path, the mobile robot stays away from the obstacle as much as possible.

3.1.1 Visibility graph

The Visibility Graph (VG) is the collection of lines in the free space that connects a feature of an object to that of another[19]. In its principal form, these features are vertices of polygonal obstacles that can see each other, including the starting point and the goal as well as the vertices as shown in figure 1. These unobstructed vertices are the shortest distance. The goal of path planning is to find the shortest path along these roads.

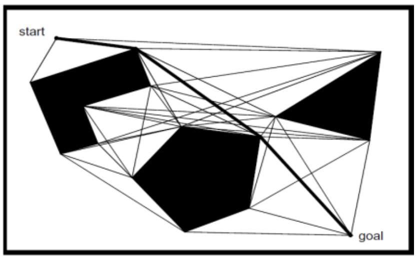

Figure1: Visibility graph

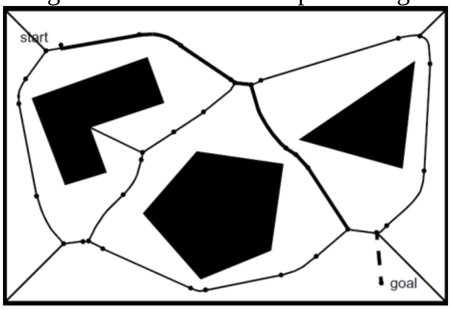

Figure 2. Voronoi diagram

3.1.2 VORONOI diagram

The Voronoi diagram (VD) is a complete road map methodthat tends to maximize the distance between the robot and the obstacle[19].For each point in free space, the distance to the nearest obstacle is computed. The voroniodiagram for polygonal obstacles has only straight line and parabolic segment as in figure.2.

3.2 Artificial Potential Fields

The application of artificial potential fields to obstacle avoidance was first developed by Khatib[19]. The concept is that artificial forces generated by the obstacles and target, are applied to the robot in order to move about the environment collision-free. The obstacles and goal position are assigned repulsive and attractive forces respectively. Thus the potential function can be defined over free space as the sum of an attractive potential pulling the robot toward the goal configuration, and a repulsive potential pushing the robot away from the obstacles as shown in figure 3. Thus the robot moves towards the goal and is pushed away from the obstacles that are known in advance. If new obstacles occur during motion, the potential field can be updated to accommodate this. The main disadvantages of the potential field methodology are that trap situations can occur due to the presence of local minima and that it is computationally extensive [19].

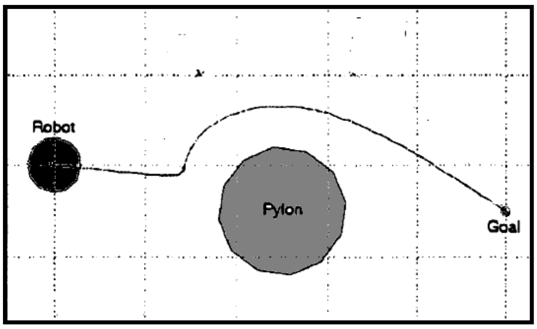

Figure 3.ArtificialPotential field

Soft computing techniques

The above mentioned classic approaches suffer from many drawbacks, such as high time complexity in high dimensions, and trapping in local minima. In order to improve the efficiency of Classic methods, several modifications have been made like probabilistic road maps, extended potential field method etc[19].

Soft computing techniques or intelligent control systems are a new class of techniques that have been found to be very promising for path planning. These techniques are based on the ability of the human brain to perform complex tasks by reasoning, adapting and responding to the changed environments. Such behaviourlearning methods can be used to solve complex control problems that autonomous robots encounter in an unfamiliar real-world environment. Some of the soft computing techniques include neural networks, fuzzy logic, genetic algorithms, ant colony optimization etc.

Neural Networks

The neural network was inspired from its inception by the recognition that the human brain computes differently than that of a conventional digital computer [2]. The brain acts as a highly complex, nonlinear and parallel computer. A neural network is massively parallel distributed processor made up of simple processing units, known as neurons, which has a propensity for storing, and making easily available, experiential knowledge[2].

The main advantage of neural networks is that it is possible to train a neural network to perform a particular function by adjusting the values of connection (weights) between elements. For example, if we want to train a neuron model to approximate a specific function, the weights that multiply each input signal will be updated until the output from the neuron is similar to the function [2]. This process is referred to as training. When used for robot motion planning, the state space of the neural network is the configuration space of the robot, and the dynamically varying environment is represented by the dynamic activity landscape of the neural net. The target globally attracts the robot in the entire state space, whereas obstacle(s) locally push the robot away. Artificial neural network for navigation control of mobile robots have been developed [1,2].

Fuzzy Logic

Fuzzy logic provides a formal technique representing and implementing human experts' heuristic knowledge and perception-base actions, and was developed by Prof.Zadeh in1965. Fuzzy logic and fuzzy languages have also been used in navigation algorithms for mobile robots. In fuzzy logic controller based navigation, the problem is down into simpler tasks and each behaviour is composed of a set of fuzzy logic rule statements intended at achieving a well-defined set of objectives. A comprehensive study of fuzzy logic control for motion planning has been extensively detailed [4].

Genetic Algorithm

Genetic Algorithms (GA's) are a stochastic global search method that mimics the process of natural evolution[8]. It was introduced by John Holland of the University of Michigan. The genetic algorithm starts with no knowledge of the correct solution and depends entirely on responses from its environment and evolution operators (i.e. reproduction, crossover and mutation) to arrive at the best solution. By starting at several independent points and searching in parallel, the algorithm avoids local minima and converging to suboptimal solutions.Genetic searching algorithm is used in generating via-points after finding the objects by the vision system. The fitness value of the generated paths is evaluated in terms of the safety from the obstructing dynamic objects and the distance to the goal position. Genetic algorithm finds wide applications in path planning [5-9].

Ant Colony Optimisation

Ant colony optimization is a relatively recent approach for optimization problems and is based on simulating the collective behaviour of a group behaviour of real ant colonies foraging from a nest to a food source[12]. The ants are able to find the shortest path from the source to the food. This is possible because each ant has a certain quantity of pheromone to be dropped along the path. The ants track down the pheromone trails previously dropped by the nest's ants to accomplish the path between the two points of nest and food respectively. In case of any obstacles present in their way, ants move along the contour of the obstacle on either sides and find their path to the food source. An artificial ant makes movements based on the attraction of pheromone. As the concentrations of pheromones are more along the shorter path, ants accumulate more pheromone in a given time interval along the shorter path.This has been used to solve mobile robot navigation problems [10-12].

Hybrid Methods

A combination of classical and intelligent methods has also been used to solve the path planning problem. An integration of neural and fuzzy techniques, potential fields and ant colony optimization [15], and several other such works have been reported [4,13-16].

CONCLUSION

The different path planning algorithms and techniques for mobile robot navigation have been investigated by various researchers. The conventional techniques are seen to have certain drawbacks like greater computational time and trapping in local minima. It is also seen that over the recent years, the application of soft computing techniques in robot motion planning has increased due to their success in coping with the problems of combinatorial explosion and local minima.

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