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Study of Path Finding and Constraints of Two wheeled Mobile Robots

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Abstract

Due to the increasing number of tasks that are being performed by robots, the need for them to have intelligence has become more prevalent. This has led to the development of various research problems related to the design and implementation of robotic systems. One of these is the planning of the path, which is a common problem in the development of robotic applications. This paper discusses the various research findings related to this issue.

1.1 Introduction

One of the most common tasks that humans perform is moving from one place to another. For a robot, this task is very challenging since it involves deciding how to move in a split second. In autonomous systems, the planning of the path is a central issue. This is usually related to the navigation of a vacuum cleaning robot or a robotic arm. The goal of the project is to find a path that will take the robot from its starting point to its destination.

The planning of the path was addressed in various ways in the literature. For instance, the quality of the path that is generated is very important for the success of the robotic system. This issue can also be solved by developing a robust path planning algorithm. The goal of the navigation process is to minimize the distance that the robot has traveled. This is done through the minimization of the various factors that affect its processing time and energy consumption. This section provides an overview of the global path planning process for mobile robots.

1.2 Overview of the Robot Path Planning Problem

The rise of robotics has led to the development of various robotic systems that can perform various tasks such as performing various tasks in smart homes[1], airports[2], malls[3] and laboratories[4]. In order to maximize the efficiency of the system, an intelligence must be added to it. This can be done through the development of a robust path planning algorithm.

Despite the importance of having intelligence in the system, it can also lead to the development of various research problems related to the navigation process. One of these is the planning of the path, which is a common problem in the design and implementation of robotic systems. Before the robot can complete its navigation task, it has to take into account the environment and its surroundings.

The navigation process is a complex task that involves answering three questions: Where am I going, how am I going, and what do I need to find to get there. These questions can be solved through the development of various navigation functions such as mapping, motion planning, and localization.

Localization: The ability to localize a robot is also a complex task that can be solved through the development of various navigation functions such as cameras[5], GPS[6],sensors [7] and laser rangefinders[8]. This can be done by referring to the location as a symbolic reference. For instance, if a room is located in a certain area, its location can be expressed as absolute coordinate or topological coordinate.

Mapping: A map is also a necessary component of the navigation process that helps the robot identify its surroundings and its current location. It can be placed into the memory of the robot, or it can be gradually built. This can be done through the development of various map types. Despite the importance of mapping, it is still not widely considered as a standard part of robotic navigation.

Motion planning or path planning: Before a robot can start its navigation process, it has to know its goal position. This is done through the development of an appropriate addressing scheme, which can be used to indicate where it will go next. For instance, if a robot is asked to go to an office building, it can provide the address of the room with its number.

One of the most critical factors that a robot must consider when it comes to its navigation process is the planning of its path. This process can help it avoid getting stuck in the middle of the road and minimize the path length. In addition to this, the planning of the path can also be influenced by the various functions and functions of the virtual robot as shown in fig.1.1. Various studies have been conducted on the optimization of the path of the virtual robot [9]. In addition, researchers are also developing methods that can help improve the smooth trajectory of the autonomous system. Some of these studies also involve the design of robots that can navigate through complex environments [10][11].

One of the most critical factors that a robot must consider when it comes to its navigation process is the planning of its path. This process can help it avoid getting stuck in the middle of the road and minimize the path length. Aside from this, it also has to avoid getting hit by obstacles in the environment. The planning of a path in large-scale environments can be more time-consuming and complex due to the complexity of the task [12]. This is not ideal for robotic applications that require real-time aspect of the navigation process. In our studies, we focus on finding the most effective method to solve this problem in a short time. One of the most challenging factors that the researchers considered when it comes to designing a path for a robot is the complexity of the environment.

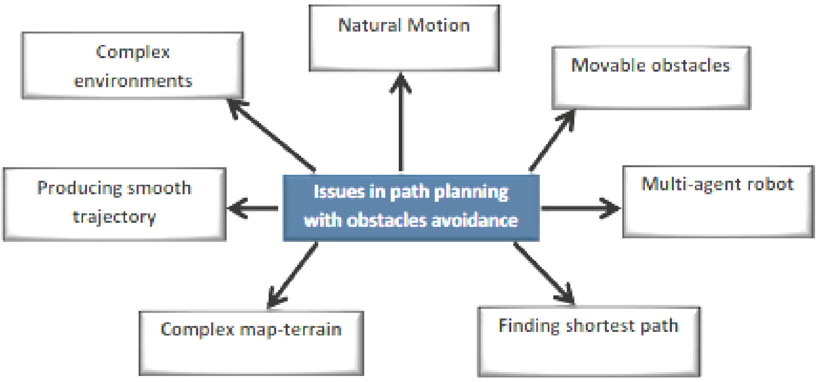


Figure-1.1 Different issues of path planning

1.3 Problem Formulation

In this paper, [13] Latombe presents the path planning problem as a series of steps that involve representing a single moving object in the world W as R2 or R3. The various factors that affect the movement of this object are known as priori.

Given a start and goal position of A and B, the path planning process should start with creating a path P $\subset$ W that follows the set of positions. It should also terminate and report if a path has been found or not. The quality of the path is evaluated by taking into account various factors such as the length of the path, its energy consumption, and its shortest duration.

The four concepts that are used in the path planning process should be well-defined. These include the degree of freedom of the robot's motion, the geometry of its environment, and the workspace. Before a robot can start its path planning process, it has to first determine its target configuration and the initial and the target position of the environment.

In order to create the mobile robot's workspace, the researchers use 3D modeling to visualize the various constraints and geometry of the environment. This process can be done in a 3D environment, but it can't handle complex paths with mechanical and geometric constraints. To solve this issue, the researchers use a new space called the configuration space. The researchers use the configuration space to create a 3D model of a complex robot that has a complex geometric shape. The movement of the robot is represented by a continuous curve in the space, which makes it easier to search for paths. The advantage of this method is that it eliminates the need for the robot to be rigid. In order to create a realistic environment for a robot, the researcher uses the concept of the configuration space [14]. This space holds all the necessary robot configurations. In real-world applications, the environment that the robot is working in contains various obstacles. For instance, if the robot is configured at c, it can't perform certain actions if it hits an obstacle in the workspace as shown in figure 1.2. This is because the configuration at c is forbidden if the robot hits an obstacle.

The path of the robot is a continuous function. In order to find an ideal path for the robot, the researchers first need to determine the start and goal position of the entity. They then need to find an obstacle-free path between the start and goal configurations. This is done by taking into account the configuration space C. If the path of the robot does not exist, then failure should be reported. In addition to this, one may also define a quality of measure that will be used to improve the performance of the robot.

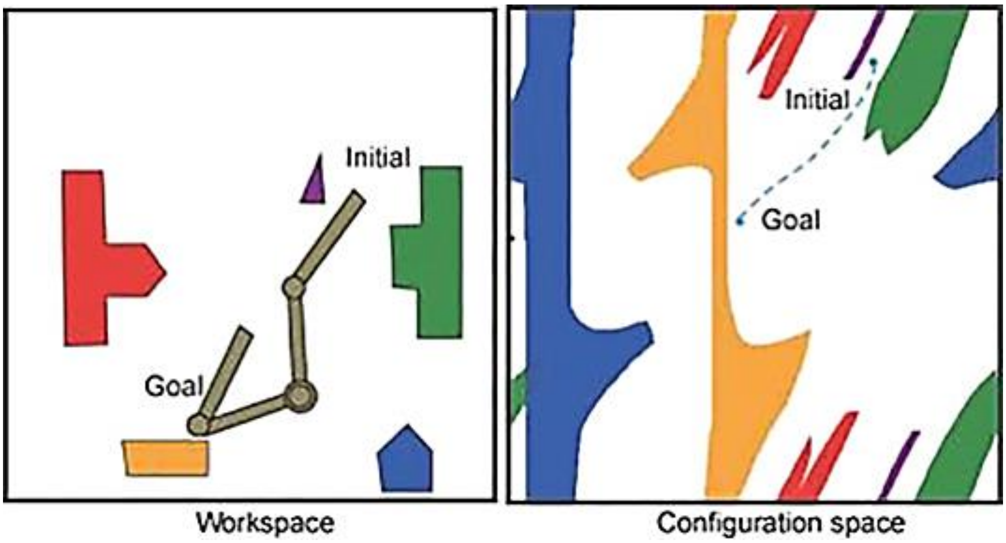


Figure 1.2 Workspace and configuration space

1.4 Path Planning Categories

In this section, we discuss the various problems that arise during the path planning process for mobile robots. They can be categorized into three categories depending on the knowledge that the robot has about the environment and its approach to solving the problem as depicted in figure 1.3.

Environment Nature:

The path planning process can be performed in different environments, such as static and dynamic. In a static environment, the source and destination locations are fixed, and the obstacles are not variable over time. However, in dynamic environments, the goal and location of the obstacles can change. This type of process is more complex due to the uncertainty of the environment.

The algorithms must be able to adapt to the changes in the environment, such as the emergence of new obstacles or the continuous movement of the target. This is because the path planning process must be able to react in real time to both the goal and the moving obstacles. In order to perform well in dynamic environments, the path planning techniques should not be implemented in static environments.

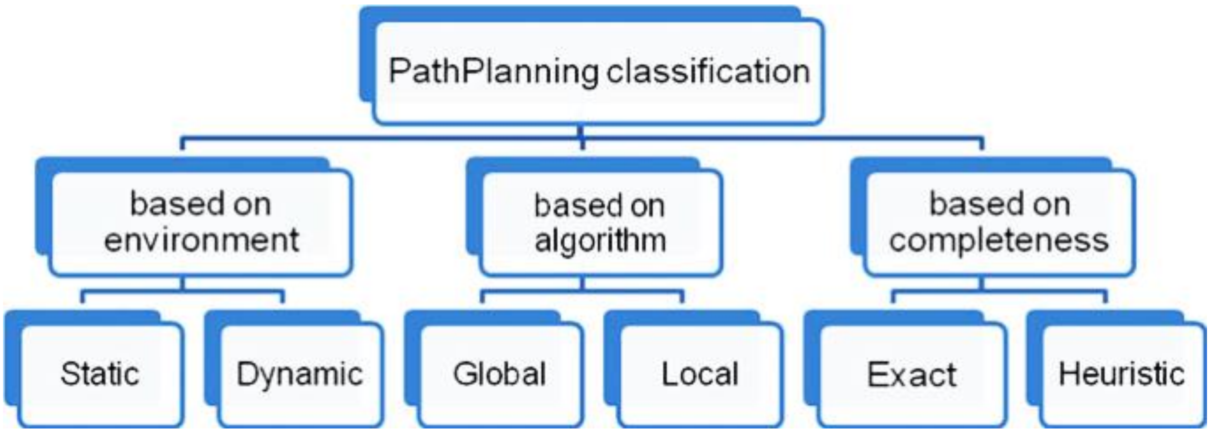


Fig. 1.3 Path Planning Categories

Map knowledge: Mobile robots rely on an existing map to identify their initial and goal locations. The amount of knowledge that the map provides is also used to develop the algorithm for the path planning process. In order to improve the efficiency of the algorithm, the level of knowledge that the robot has about the environment can be divided into two classes. The first class is composed of robots with a priori knowledge of the environment, while the second class is composed of robots with a more advanced knowledge of the environment. The second type of path planning is called global path planning, which involves the robot having a greater level of knowledge about the environment. However, this class does not have the necessary priori knowledge about the environment to perform effective path planning. In order to avoid getting stuck in an area, the robot has to first identify the locations of the obstacles and map out a suitable route for its goal. Local path planning is a type of path planning that involves the robot mapping out a route for its destination as shown in table 1.1. This type of process is different from global path planning.

Completeness: The path planning algorithm can be classified into two categories: exact and heuristic. The former uses a specific algorithm to find the optimal solution while the latter uses a heuristic to search for a better-quality solution.

The number of robots that perform the same mission in the same environment can also be classified as a factor that influences the path planning process. For instance, in many applications, multiple robots are working together to solve a problem. This type of problem is called multi-robot path planning.

This type of solution allows multiple robots to work together seamlessly to achieve spatial position goals. It also ensures that no two robots get stuck in each other while following the same route.

Table 1.1 Global and local path planning

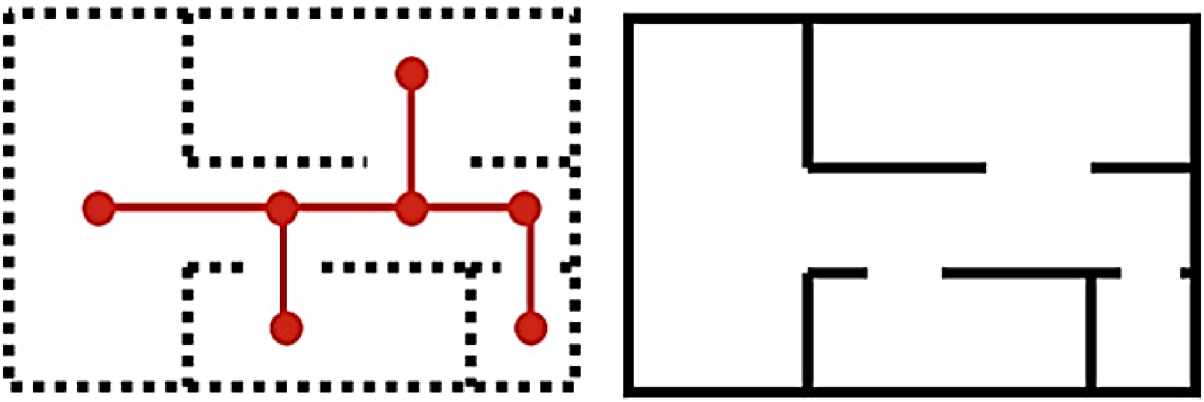
Local path planning	**Global path planning**
Sensor-based	Map-based
Reactive navigation	Deliberative navigation
Fast response	Relatively slower response
Suppose that the workspace area is incomplete or partially incomplete	The workspace area is known
Generate the path and moving toward target while avoiding obstacles or objects	Generate a feasible path before moving toward the goal position
Done online	Done offline

1.5 Spatial Representations Commonly Used in Path Planning

Roughly, map-based path planning models fall into two categories depending on the way of looking at the world [15].

Qualitative (Route) Path Planning: (Figure 1.4a)

This type of solution is also used to map out a route for a target location. Unlike other types of path planning, this method does not require a priori map. The world is represented as a series of connected landmarks, and a sequence of these landmarks will represent the route. This type of solution is similar to how people describe a road in their natural language. For instance, if a person talks about a route in their natural language, then they will describe a sequence of steps that will take them to their destination.



(a) Qualitative Path Planning (b) Metric Path Planning

Figure. 1.4 Spatial representations commonly used in path planning

Metric (Layout) Path Planning: (Figure 1.4b)

The world is represented by a layout representation, which is a map that shows the various elements of the environment. This type of solution can be used to generate a route based on the environment's layout. Compared to qualitative path planning, metric path planning is more effective in robotics as it allows the robot to visualize the environment in a clear and simple structure. It also allows the robot to reason about the space within the environment. In addition, metric maps can decompose the environment into points that are fixed locations. The goal of the path planning process is to find the sequence of connected paths that will lead to the goal position. The cost of the path can be calculated by taking into account various factors such as the minimum energy consumption and the path delay.

1.5.1 Environment Characterization

The robotic environments are characterized in terms of the shape of their obstacles.

There are two main types of environments:

Structured environment: In order to avoid obstacles, a robotic map can be used to specify the way the robot should move. For instance, if an obstacle has a structured shape, then it can be represented by a circle or a dot. In some research, robots are designed to deal with environments that have only rectangular obstacles[16]. In this case, the quad tree and grids are used to represent the obstacles[17].

Unstructured environment or semi-structured: In real-world environments, there are usually multiple types of obstacles that can be placed on the ground. Since the algorithm has to consider the various factors that affect the path planning process, it is often complex. In a recent study, researchers proposed a method that allows autonomous vehicles to plan their routes in real time[18].

1.5.2 Path Planning Complexity

The proposed method for the path planning process is based on the PSPACE-hard formulation, which is because the configuration space is an unbounded dimension[19]. This allows the algorithm to solve the shortest path problem in polynomial time. For instance, if the working space is bounded, then the shortest path problem can be solved in polynomial time[20].

There are many different methods that can be used to solve a path planning problem, such as exact methods and heuristic techniques. One of the main reasons why exponential techniques are commonly used to solve a polynomial problem is because it allows the algorithm to perform a quick and efficient computation.

Exact methods, on the other hand, are very inefficient when it comes to solving a path planning problem. For instance, the well-known Djikstra algorithm[21] generates a lot of irrelevant computations when it comes to reaching the goal.

The state space of a path planning problem can also be large due to the various factors that affect its design. For instance, the search problem has to be large and the fine-grain resolution required for it is very high.

One of the most important factors that can be considered when it comes to choosing a path planning algorithm is the use of intelligent exact techniques. For instance, if the algorithm has to search for promising regions, then it should use Astar[22] techniques instead of inefficient ones. However, since the exact methods are only able to work under low-resolution workspace, they may not be able to perform as well as efficiently. In theory, the path planning problem can be solved using a polynomial technique. However, due to the complexity of the problem and the limitations of the algorithm, it is not feasible to implement a proper polynomial technique in practice.

Conclusion

This paper aims to provide an overview of the various types of path planning problems and the various approaches that are used to solve them. In addition, we discuss the various kinds of intelligent algorithms that are commonly used to solve these problems. Due to the diversity of techniques and the complexity of the problem, it is hard for a robotic system designer to choose the right one for a particular task. Usually, researchers design and develop an algorithm while others use different techniques. This led to the creation of a classification and a taxonomy of the various algorithms being used in the field.

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