Path Planning System

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Abstract

Path planning is a critical component in various fields, including robotics, autonomous vehicles, video games, and logistics. This paper provides an overview of path planning, discusses types of path planning algorithms, distinguishes between local and global planning, explores challenges and future trends, and presents practical applications. Path planning is fundamental to automation and autonomy in modern technology, with implications for various industries and research areas.

1 Introduction

Path planning, the process of finding an optimal or feasible path from a starting point to a goal while considering obstacles and constraints, plays a pivotal role in the domains of robotics, autonomous systems, video games. Path planning has attracted attention since the 1970s, and, in the years since, it has been used to solve problems across fields from simple spatial route planning to the selection of an appropriate action sequence that is required to reach a certain goal. Path planning can be used in fully known or partially known environments, as well as in entirely unknown environments where information is received from system-mounted sensors and update environmental maps to inform the desired motion of the robot/AV.

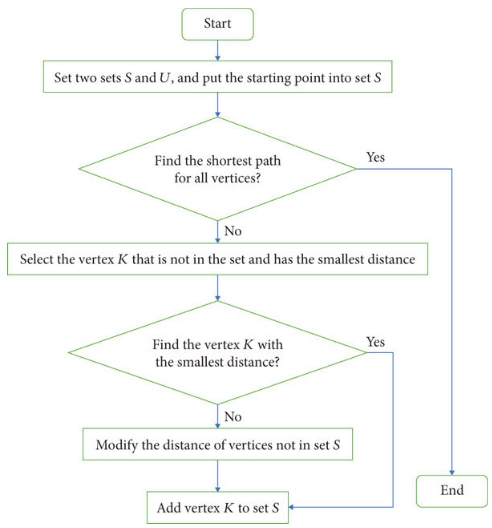
2 Types of Path Planning Algorithm

Path planning algorithms can be categorized into several types, each suited for different scenarios:

2.1 Dijkstra's Algorithm

Dijkstra's algorithm is a classic approach that guarantees finding the shortest path by exploring all possible paths from the start to the goal. It is renowned for its optimality but can be computationally expensive for large maps. The Dijkstra algorithm works by solving sub-problems computing the shortest path from the source to vertices among the closest vertices to the source. It finds the next closest vertex by maintaining the new vertices in a priority-min queue and stores only one intermediate node so that only one shortest path can be found.

Dijkstra finds the shortest path in an acyclic environment and can calculate the shortest path from starting point to every point. We find many versions of Improved Dijkstra's algorithm, this is based on specific applications we find around us. Every Improved Dijkstra's algorithm is different, to reflect the diversity of use cases and applications for the same.



Flowchart of Dijkstra Algorithm

2.2 A* Algorithm

The A* algorithm combines elements of Dijkstra's algorithm and heuristic methods to efficiently search for the best path. It considers both the cost incurred so far and the estimated cost to reach the goal. A* is widely used for its balance between optimality and efficiency. The A* algorithm is widely used in the gaming industry, and with the development of artificial intelligence, the A* algorithm has since been improved and tailored for applications, including robot path planning, urban intelligent transportation, graph theory, and automatic control.

2.3 Rapidly-exploring Random Trees (RRTs)

Primarily used in robotics, RRTs build a tree structure by randomly sampling the configuration space and connecting nodes to grow toward the goal. This algorithm is efficient for high-dimensional spaces and complex environments.

2.4 Probabilistic Roadmaps (PRMs)

PRMs create a roadmap by randomly sampling valid configurations and connecting them with feasible paths. This approach is effective for robotic motion planning and has applications in complex, cluttered spaces.

2.5 Dynamic Programming

Dynamic programming computes the optimal path by solving subproblems and building up to the final solution. It is suitable for scenarios where the environment is known in advance.

2.6 Firefly Algorithm

The Firefly algorithm is a meta-heuristic algorithm based on Firefly mating behavior. It is a promising swarm-intelligence-based algorithm inspired by the collective behavior of insects or animals who cooperate in order to solve complex problems. Colonies of insects act as decentralized, self-organized systems that prevent a single insect from acting. The algorithm is used for solving continuous and discrete optimization problems. In order to tackle optimization problems efficiently, many variants of the Firefly algorithm have been developed. The Firefly algorithm works on huge data sets and can be applied on path planning. Path planning can widely be divided into two branches: Global Path Planning and Local Path Planning. Global planning is done on a larger set, and calculation of the shortest path is done from the start node to the goal node. The Local Planner begins when an obstacle is found to move around, and this is done on previous nodes and near nodes, which are available in the global set.

3 Local Planner and Global Planner

Path planning often involves a distinction between local and global planning:

3.1 Global Planner

The global planner considers the entire map and plans the high-level path from the start to the goal. It doesn't account for dynamic changes in the environment.

3.2 Local Planner

The local planner operates at a lower level and focuses on the immediate surroundings of the entity. It adjusts the path in real-time to handle dynamic obstacles and deviations from the global plan.

4 Challenges and Future Trends in Path Planning

Path planning presents several challenges and ongoing trends:

4.1 Dynamic Environments

In real-world applications, the environment is rarely static. Path planning systems must adapt to changing conditions, such as moving obstacles or road closures.

4.2 Real-time Constraints

Certain applications, like autonomous vehicles, demand rapid path planning to make real-time decisions. Efficient algorithms and hardware acceleration are essential.

4.3 Multi-agent Systems

In scenarios with multiple entities, coordination and collision avoidance become critical. Cooperative path planning is a growing area of research.

4.4 Learning-based Approaches

Machine learning and AI have introduced learning-based path planning methods that can adapt and improve their performance over time, learning from experience and data.

4.5 Human-Robot Interaction

Path planning systems must also consider human safety and interaction, especially in shared spaces where robots and humans coexist.

5 Practical Applications of Path Planning

Path planning is ubiquitous and vital in various domains:

5.1 Robotics

In manufacturing, warehouses, and outdoor environments, robots rely on path planning to navigate and perform tasks autonomously.

5.2 Autonomous Vehicles

Self-driving cars use path planning to safely and efficiently navigate roads, considering traffic conditions, pedestrians, and road rules.

5.3 Video Games

In gaming, path planning controls non-player characters (NPCs) and provides realistic movement, enhancing gameplay.

5.4 Drone Navigation

Drones utilize path planning for search and rescue missions, surveillance, and delivery services.

5.5 Logistics and Warehousing

Optimizing the movement of goods and vehicles in distribution centers streamlines operations and reduces costs.

6 Conclusion

Path planning is a foundational concept that empowers automation and autonomy across various fields. As technology advances, path planning algorithms will continue to evolve, addressing challenges and expanding possibilities. Staying updated with the latest developments in AI and robotics is essential for those interested in the future of path planning.

7 Resources

1. A Survey of Path Planning Algorithms for Mobile Robots
2. A Survey of Path Planning Algorithms for Mobile Robots
3. An improved real 3d A-star algorithm for difficult path finding situation