# 1 Introduction to Path Planning

Path planning is a crucial aspect of robotics and autonomous systems. It involves determining the optimal path for a robot or vehicle to follow in order to reach a specific destination. Path planning algorithms are used in a variety of applications, from self-driving cars to industrial automation.

Path planning is the process of finding an optimal path from a starting point to a goal point while avoiding obstacles. The goal of path planning is to find the shortest or fastest route while avoiding collisions with obstacles. Path planning algorithms typically take into account the shape and size of the robot or vehicle, as well as the environment it is operating in. The path can be a set of states (position and/or orientation) or way points. Path planning requires a map of the environment along with start and goal states as input. The map can be represented in different ways such as grid maps, state spaces, and topological roadmaps. Maps can be multilayered to add bias to the path.

# 2 Types of Path Planning Algorithm

There are several types of path planning algorithms, each with its own strengths and weaknesses. Some of the most common algorithms include:

## 2.1 Dijkstra's Algorithm

Dijkstra's algorithm is a classic algorithm for finding the shortest path between two points in a graph. It works by maintaining a priority queue of nodes to be visited and updating the distance to each node as it explores the graph.

## 2.2 A* Algorithm

The A* algorithm is an extension of Dijkstra's algorithm that uses heuristics to guide the search towards the goal. It combines the cost of traversal with an estimate of the remaining distance to the goal to prioritize nodes for exploration.

## 2.3 Rapidly-exploring Random Trees (RRT)

RRT is a probabilistic algorithm that generates a tree of random samples in the configuration space of the robot. It incrementally grows the tree by connecting new samples to the nearest existing node, while avoiding collisions with obstacles.

## 2.4 Probabilistic Roadmap (PRM)

PRM is another probabilistic approach that constructs a roadmap of collision-free paths in the configuration space. It precomputes a set of valid configurations and connects them with feasible paths, allowing for efficient path planning.

## 2.5 Potential Field Methods

These methods use artificial potential fields to guide the robot towards the goal while avoiding obstacles. The robot is attracted to the goal and repelled by obstacles based on their respective potentials.

## 2.6 Genetic Algorithms

Genetic algorithms are inspired by natural evolution and use a population-based search to find optimal paths. They work by iteratively evolving a set of candidate solutions through selection, crossover, and mutation operations.

### 2.7 Particle Swarm Optimization (PSO)

PSO is a population-based optimization technique that simulates the behavior of a swarm of particles. Each particle represents a potential solution, and they move through the search space to find the optimal path.

## 3 Local Planner and Global Planner

Path planning can be divided into two categories local planner and global planner: Local planners are used for short-term planning, such as obstacle avoidance. Global planners are used for long-term planning, such as finding the optimal route from start to finish.

The global planner relies on a map of the environment to determine the optimal route, with methods such as Roadmaps or Voronoi assigning values to regions for cost-effective pathfinding. However, the resulting node-based map is not always smooth or compliant with vehicle constraints. To address this, the local planner creates dynamic waypoints based on updated local maps and global waypoints, using techniques like Clothoids, Bezier lines, arcs, segments, or splines. The chosen method for the iCab research platform is Time Elastic Bands, which deforms the global plan while factoring in vehicle kinematics and obstacle detection for low computational cost.

| Global Planner | Local Planner |
|---|---|
| Relies on a map of the environment to determine the optimal route | Creates dynamic waypoints based on updated local maps and global waypoints |
| Assigns values to regions for cost-effective pathfinding | Uses techniques like Clothoids, Bezier lines, arcs, segments, or splines to create smooth paths |
| Resulting node-based map may not be compliant with vehicle constraints | Factoring in vehicle kinematics and obstacle detection for low computational cost |
| Optimizes for the overall path | Optimizes for the immediate path |
| Computational cost is higher | Computational cost is lower |

## 4 Challenges and Future Trends in Path Planning

One of the main challenges in path planning is dealing with dynamic environments, where obstacles can move or appear suddenly. Another challenge is optimizing the path for multiple objectives, such as time and energy.

Future trends in path planning include using machine learning to improve the accuracy and efficiency of path planning algorithms. Reinforcement learning, in particular, has shown promise in generating optimal paths in complex environments.

## 5 Practical Applications of Path Planning

Path planning has many practical applications, including:

1. Self-driving cars: Path planning is essential for autonomous vehicles to navigate safely and efficiently on the road.
2. Industrial automation: Path planning is used in manufacturing and logistics to optimize the movement of goods and materials.
3. Search and rescue: Path planning is used to guide robots and drones in search and rescue missions, helping them navigate through complex environments.
4. Robotics: Path planning is used in robotics for navigation and manipulation tasks. Robots need to plan their path to avoid obstacles and reach their goal efficiently.
5. Autonomous Vehicles: Autonomous vehicles rely heavily on path planning to navigate safely and efficiently on roads. The planner needs to consider factors like traffic, road conditions, and other vehicles to determine the optimal route.

6. Logistics: Path planning is used in logistics to optimize routes for delivery trucks, drones, and other transportation systems. It helps to reduce travel time, fuel consumption, and operating costs.

7. Video Games: Path planning is used in video games to control the movement of non-player characters (NPCs). It helps to create realistic and challenging gameplay by simulating the behavior of human-like characters.

# 6 Conclusion

Path planning is a fundamental problem in robotics with many practical applications. There are many different algorithms and techniques for path planning, each with its own strengths and weaknesses. As robotics technology continues to advance, path planning algorithms will become increasingly important for enabling robots to navigate complex environments.

# 7 References


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