PathPlanning

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September 2023

1 Introduction to Path Planning

Path planning, also known as motion planning, is a fundamental concept in the field of robotics and computer science. It refers to the process of finding an optimal path or trajectory for a mobile robot or agent to move from one location to another in an environment while avoiding obstacles and adhering to certain constraints. Path planning plays a crucial role in various applications, including autonomous vehicles, industrial automation, robotics, and video games.

2 Types of Path Planning Algorithm

2.1 Dijkstra's Algorithm:

Dijkstra's algorithm is used to find the shortest path between two points in a graph. It is versatile and works well when the environment is known and represented as a graph. However, it can be computationally expensive in large environments.

2.1.1 A* Algorithm:

A* is an extension of Dijkstra's algorithm that takes into account both the cost to reach a node and an estimate of the remaining cost to the goal. It is more efficient than Dijkstra's algorithm for finding the shortest path in a graph.

2.2 Vector Field Histogram

The vector field histogram (VFH) algorithm computes obstacle-free steering directions for a robot based on range sensor readings. Range sensor readings are used to compute polar density histograms to identify obstacle location and proximity. Based on the specified parameters and thresholds, these histograms are converted to binary histograms to indicate valid steering directions for the robot. The VFH algorithm factors in robot size and turning radius to output a steering direction for the robot to avoid obstacles and follow a target direction

2.3 Rapidly-exploring Random Trees (RRT):

RRTs and their variants are highly popular in the robot motion planning community. RRT is the foundation for various motion planning algorithms and has been extended and adapted in many ways to address specific robotics and automation challenges. Some common variants include RRT* (RRT star) and RRT-Connect, which aim to improve optimality and convergence speed. These algorithms have found applications in autonomous robotics, path planning for drones, self-driving cars, and other robotic systems that need to navigate complex environments while avoiding obstacles.

3 Local planner and Global planner

3.1 Global Planner

The global planner is responsible for generating a high-level path or trajectory for the robot to reach its destination or goal. It operates on a global scale, considering the entire environment and a long-term plan. The global planner requires a map of the environment to calculate the best route. Depending on the analysis of the map. **The output** of the global planner is a rough path or a series of waypoints that provide a high-level route from the robot's current position to the goal. This path usually does not consider obstacles in detail but aims to find an overall feasible route. Global planners often use **algorithms** like A*, Dijkstra's algorithm, or various heuristic-based methods to find an optimal or near-optimal path based on factors such as distance, terrain, or cost.

3.2 Local Planner

The local planner operates at a lower level and focuses on navigating the robot in real time, considering its immediate surroundings. It deals with obstacle avoidance and collision avoidance. The local planner determines the robot's control commands, such as steering angles and velocities. Local planners use algorithms that react quickly to the robot's surroundings. potential field methods, reactive methods, or model predictive control (MPC).

Global planners provide a high-level path for a robot to follow based on the overall environment and goal, while local planners handle the low-level navigation tasks.

Global Path Planning vs Local Path Planning example - YouTube

4 Challenges and Future Trends in Path Planning

4.1 Challenges:

4.1.1 Real-time Planning

One of the challenges is the need for real-time path planning, especially in dynamic environments. Robots must quickly adapt to changing conditions and avoid obstacles in real-time.

4.1.2 High-Dimensional Spaces

In high-dimensional spaces, path planning becomes increasingly complex. Techniques like sampling-based planning algorithms have been developed to address this, but improvements are still needed.

4.1.3 Global vs. Local Planning Integration

The transition between long-term and short-term planning should be smooth to avoid inefficient robot motion.

4.1.4 Autonomous Decision-Making

Future path-planning algorithms should have the capability to make high-level decisions.

4.2 Trends:

4.2.1 Machine learning techniques

Can enhance path planning by allowing robots to learn from experience and adapt to various scenarios.

4.2.2 Human-Robot Collaboration

Path planning algorithms will evolve to support safe and efficient collaboration between robots and humans in shared spaces, such as warehouses, factories,...etc.

4.2.3 Ethical and Legal Considerations

As autonomous robots become more prevalent, ethical and legal considerations regarding path-planning decisions, safety, and liability will need to be considered.

5 Practical Applications of Path Planning

Path planning is a fundamental concept in robotics and has numerous practical applications across various domains. Here are some practical applications of path planning:

- Autonomous Vehicles
- Robotics
- Search and Rescue
- Space Exploration

6 Summary

In conclusion, we have discussed the importance of path planning in robotics. Path planning is a fundamental concept that enables robots to navigate complex environments efficiently and safely. As technology continues to advance, path-planning algorithms are evolving to address real-time challenges and enhance the capabilities of autonomous systems, making them safer, more efficient, and better equipped to handle the demands of an ever-changing world.

References

Path planning - mathworks
Path planning - sciencedirect
Local planner and Global planner - hindawi