1 Path planning in Robotics

introduction: Path planning is one of the most important topics that a robotics engineer must grasp. It is with planning that said engineer can make his robot work in the most effecient way possible. In this article we will talk about some of the path planning algorithms that may be used, practical applications of path planning and much more.

1.1 Contents:

2 Types of Path Planning Algorithms

2.1 A*

A* was one of the earlier path planning algorithms. Though pirimitive, it is quite useful and in certain cases could prove to be the optimal path planning algorithm to use. A* works by branching out some "nodes" from the robot's starting position in many directions. It then computes from each node which node has the the least "cost". Now to clarify what cost is as it will mentioned again. Cost is the sum of distances the robot has moved and will move. Hence, the robot will try to select the node with least distance to the destination. Though this method may provide an optimal path to the destination, it may be computationally expensive if the map of the robot is large and we increase the amount of nodes. Also, A* does not account for any dynamic obstacles. Therefore, some more effecient methods were developed.

2.2 RRT

RRT tries to improve on A*'s computationally expensive algorithm, but in said process it may come up with a less optimal path. RRT works by sending out nodes in different directions. Those nodes must still be placed within a defined max distance from the robot as to avoid creating a path through a wall. If any nodes happen to then be placed through a wall, they are simply discarded. No direct pattern has to be followed but once one of the nodes is in the vicenity of the destination it simply connects a path between said node and the destination. Clearly, this method is extremely simple, but in its simplicty it made a path that is quite sub-optimal.

2.3 RRT*

RRT* works in the same way RRT does, but it takes it a step further. Rather than simply accept the path it had made to the destination, it starts branching out new nodes from the previously placed nodes. Whilst placing them, it checks for other nodes in the vicenity from the path to the destination that it can connect to. If it it happens to find any that when connected to decreases the cost of the path then it goes along with that connection. This logic also allows the robot to have many already placed nodes around the map that may allow it to quickly find a cost-effective path to the destination if said destination changes place.

3 Local Path Planner and Global Path Planner

3.1 Global Path Planning

Global path planning is responsible for determining a high-level, long-term path from the starting point (or current location) to the goal destination. It considers the entire environment and takes into account static obstacles, terrain, and other relevant factors. Global planners typically operate in a map or grid-based representation of the environment. They generate a sequence of waypoints or poses that guide the robot from start to finish. The output of global planning is usually a set of waypoints or a trajectory that provides a rough route from the start to the goal. This plan may not be collision-free, as it doesn't consider dynamic obstacles or real-time conditions.

3.2 Local Path Planning

Local path planning operates at a lower level and focuses on short-term decision-making. It considers the current state of the robot, sensor data, and dynamically changing obstacles. The primary goal of local path planning is to generate safe and collision-free motions for the robot to follow, ensuring it adheres to the global path while avoiding obstacles encountered in real time.

Conclusion: In summary, global path planning provides a high-level plan for the robot to follow, while local path planning ensures that the robot adheres to the global plan and avoids obstacles in real time. This division of labor allows autonomous systems to navigate complex and dynamic environments safely and efficiently.

4 Challenges and Future Trends in Path Planning

It is quite known that the robotics field is one of the newest enginnering fields, yet since the emergence of robots engineers have been trying to come up with more powerful path planning algorithms that may help humans with daily tasks that require robots or even greater tasks such as space exploration. Though, there still exists some challenges that we face when coming up with path planning algorithms. Yet some engineers try to come up with solutions to overcome thos challenges.

4.1 Challenges:

Complex Environments: Navigating through complex and dynamic environments with many obstacles, including moving objects and humans, remains a significant challenge. Path planners must handle intricate scenarios effectively.

Real-Time Decision-Making: Autonomous systems, such as self-driving cars and drones, require fast and reliable real-time path planning to respond to rapidly changing conditions and ensure safety.

High-Dimensional Spaces: In high-dimensional configuration spaces, such as those involving robotic arms with many joints, finding feasible paths becomes increasingly complex.

4.2 Future Trends:

Machine Learning and AI Integration: The use of machine learning and artificial intelligence techniques, such as reinforcement learning and neural networks, to enhance path planning by learning from data and improving decision-making.

Edge and Fog Computing: Distributing path planning tasks between edge devices and cloud resources to improve real-time performance and reduce latency.

Simultaneous Localization and Mapping (SLAM): Integration of SLAM techniques with path planning to improve localization and map creation while navigating unknown environments.

5 Practical Applications of Path Planning

As stated before robotics is a new field, thus engineers are coming up with more ways to effectively incorporate path planning in previously ardous or even impossible tasks:

1. Autonomous cars that can avoid other cars and transport passengers from point A to point B safely and effeciently
2. Warehouse organization robots that help effeciently move goods and transport them.

3. UAVs that scout areas that may be impossible to reach otherwise (e.g. dense forests)
4. extra-planetary vehicles (e.g. Mars rover) that can explore previously uncharted areas or planets
5. delivery robots that follow sidewalks and try to pass by pedestrians and traffic
6. disaster response robots that can navigate the extremly hazardous terrain

6 Conclusion and Resources

In summary, robot path planning is a crucial field driving advancements in automation and robotics. It enables robots to navigate complex environments and interact effectively with their surroundings. As technology progresses, path planning continues to play a vital role in various applications, from autonomous vehicles to industrial automation, shaping the future of automation and smart solutions across industries.

Resources: Path Planning with A* and RRT
Robot Motion Planning using A* (Cyrill Stachniss)
Path planning in robotics