Path Planning

Mohamed Aboabdallah

September 9, 2023

Autonomous vehicles and robots rely on a sophisticated process known as path planning to navigate from one location to another. This involves identifying the optimal and secure route while circumventing obstacles. The journey may comprise various positions or waypoints. Path planning requires information about the environment, the starting and ending points, and a map. These maps can take different forms, such as grid maps, state spaces, or topological road maps, and may entail multiple layers that affect the path selection.

] A few popular categories of path-planning algorithms for autonomous vehicles include:

- Grid-based search algorithms, which find a path based on minimum travel cost in a grid map. They can be used for applications such as mobile robots in a 2D environment. However, the memory requirements to implement grid-based algorithms could increase with the number of dimensions, such as for a 6-DOF robot manipulator.
- Sampling-based search algorithms, which create a searchable tree by randomly sampling new nodes or robot configurations in a state space. Sampling-based algorithms can be suitable for high-dimensional search spaces such as those used to find a valid set of configurations for a robot arm to pick up an object. Generating dynamically feasible paths for various practical applications makes sampling-based planning popular, even though it does not provide a complete solution.
- Trajectory optimization algorithms are used to plan the path of a vehicle by solving an optimization problem that takes into account the desired performance of the vehicle, relevant constraints, and vehicle dynamics. These algorithms can generate feasible trajectories and can be used for online path planning in uncertain environments. However, real-time planning may be difficult depending on the complexity of the optimization problem.

The global planner is in charge of creating a long-term plan or path for the robot to reach its destination. It considers the overall environment map and calculates the best route from the starting point to the end goal. Factors such as obstacles, terrain, distance, and optimization criteria are taken into account during the planning process. Global planners typically employ popular algorithms such as A*, Dijkstra's algorithm, or RRT (Rapidly-exploring Random Tree) to determine the most efficient or near-optimal route.

The local planner operates at a shorter time scale compared to the global planner. Its main purpose is to navigate the robot around dynamic obstacles and fine-tune the robot's trajectory based on real-time sensor data. The local planner handles immediate obstacles, local terrain variations, and potential collisions that may not have been considered by the global planner. Local planners often employ reactive techniques like potential fields, artificial potential fields, or elastic bands to determine the best immediate actions to avoid obstacles and stay on track.

Together, the global planner and local planner form a hierarchical planning system for robot navigation. The global planner handles long-term planning and creates an initial trajectory, while the local planner handles short-term adjustments and reacts to immediate obstacles and situations. This combination allows the robot to efficiently and safely navigate through complex environments towards its goal.

Path planning is not free from challenges. Some challenges are addressed below: <u>State of Regulation and certification:</u> The flying robot's success depends upon its affirmation by certification bodies. Multiplex set of regulations placed by National agencies and regulatory bodies to ensure the safety of aerial vehicles brings challenges to the researchers to develop aerial robots which can meet all constraints set by regulatory bodies. <u>Man-Machine interaction:</u>The design issues of human and machine interface are also a major issue in the area of aerial robots. <u>Navigation, Safety, and Reliability:</u> The major issue in flying robots is to find comparative and non-comparative positions. The challenge is to develop an automatic navigation system that will not depend on a human-made external navigation system. The safety of flying robots is the most debated topic as they should be able to operate at higher altitudes and also at adverse conditions which is again a challenge to the researchers in this domain <u>Obstacle avoidance:</u> In the case of a flying robot, it is important to plan the path of navigation effectively to avoid obstacles coming into the path of a flying robot. Pathfinding is the foremost important part of designing a flying robot. <u>Multi-vehicle coordination:</u> In numerous tasks flying robot

has to function as a group rather than an individual system. It is also a challenge faced by researchers to optimize and plan effective paths by task scheduling and routing algorithms to avoid any collisions with flying robots.

There are many applications for Path Planning. Path planning, along with perception (or vision) and control systems, comprise the three main building blocks of autonomous navigation for any robot or vehicle. Path planning adds autonomy to systems such as self-driving cars, robot manipulators, unmanned ground vehicles (UGVs), and unmanned aerial vehicles (UAVs).

In conclusion, path planning is a crucial process for autonomous vehicles and robots to navigate effectively and safely. It involves finding the optimal route while avoiding obstacles, using various types of maps and algorithms. Grid-based search algorithms, sampling-based search algorithms, and trajectory optimization algorithms are commonly used for path planning. The path planning system consists of global and local planners, who work together to generate long-term plans and adjust trajectories in real time. Path planning faces challenges such as regulations and certification, human-machine interaction design, navigation safety and reliability, obstacle avoidance, and multi-vehicle coordination. Despite these challenges, path planning has numerous applications and plays a key role in enabling autonomous systems to navigate complex environments.

refrences:

- S. Mannar et al. Vision-based control for aerial obstacle avoidance in forest environments Science direct, IFAC PapersOnLine (2018)
- Survey of robot 3D path planning algorithms J. Control Sci. Eng. (2016)
- "Principles of Robot Motion: Theory, Algorithms, and Implementations" by Howie Choset, Kevin M. Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia E. Kavraki, and Sebastian Thrun.
- "Robotics: Modelling, Planning and Control" by Bruno Siciliano and Lorenzo Sciavicco.
- https://www.mathworks.com/discovery/path-planning.html: :text=Path