CSC 445 - Intro to Intelligent Robotics, Spring 2018

Path Planning

Motion Planning

- Goals
  - Collision-free trajectories
  - The robot should reach the goal location as quickly as possible
- Challenges
  - Calculate the optimal path taking uncertainties in the robot's actions into account.
  - Efficiently and reliably react to dynamic elements.

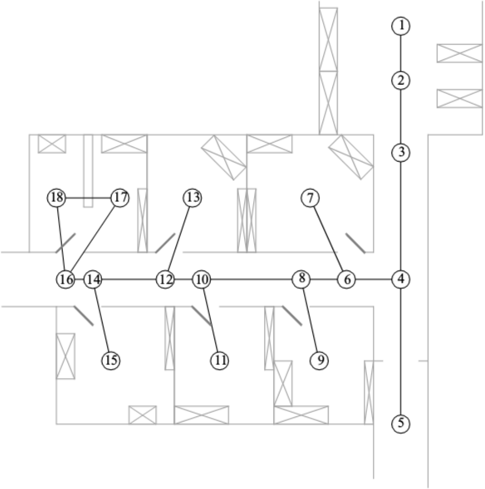
Motion Planning Problem

- The problem of motion planning can be stated as follows. Given
  - A start pose of the robot
  - A desired goal pose
  - A geometric description of the robot
  - A geometric representation of the environment (a map)
- Find a path that moves the robot from the start to the goal without colliding with any obstacles.

Map Representations

- Discrete vs continuous
  - A discrete valued map approximates the environment by subdividing it into discrete chunks.
  - A continuous valued map represents an exact decomposition of the environment.
- Metric vs topological
  - A metric map considers Euclidean space and places objects at precise coordinates.
  - A topological map considers places and relations between them.
- Stochastic vs non-stochastic
  - A stochastic map models uncertainty in the map representation with probability.
  - A non-stochastic map does not model uncertainty in the map representation.

Topological Map Example



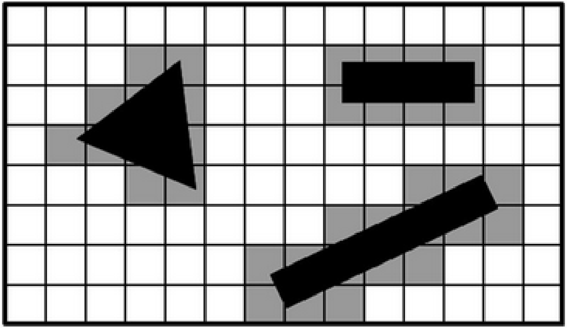
Choosing a Map Representation

- The precision of the map must appropriately match the precision with which the robot needs to achieve its goals.
- The precision of the map and type of features represented must match the precision and data returned by the robot's sensors.
- The complexity of the map representation has a direct impact on the computational complexity of reasoning about the map.

Metric Maps

- Occupancy grid
  - An occupancy grid represents occupied space by discretizing space into appropriate sized chunks where each chunk is occupied or free.
  - An occupancy grid lends itself to graph based path planning.
- Landmark based
  - A landmark based map representation models the environment as the locations of features of interest (landmarks).
  - It is assumed that a robot has the sensing capability to detect the features.

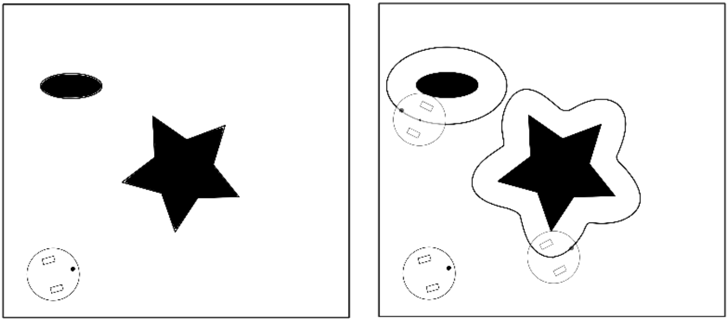
Occupancy Grid Example



Configuration Space

- A configuration describes the pose of the robot.
- A configuration space is the set of all possible configurations.
- The path planning problem is in physical space; there are many ways to represent a configuration space of a particular physical space and robot.
- In 2D path planning, we typically "shrink" the robot to a point (to make the planning problem simpler) thereby "growing" the physical space to create the configuration space.

Configuration Space



Planning at Different Scales

- Global planning
  - Plans a path in the map representation
  - Typically low frequency
- Local planning
  - Plans a path based on local sensor measurements
  - Typically high frequency

Search

- The problem of search is finding a sequence of actions (a path) that leads to a desirable state (a goal).
- Informed search uses information about the domain through heuristics.
- Performance metrics for search algorithms
  - Completeness
  - Optimality
  - Time complexity
  - Space complexity

Path Smoothing

- Paths generated by some algorithms may not be smooth or achievable based on the robot's kinematics.
- Path planning can be improved by post-processing the path to make it smoother.

Examples of Planning Approaches

- Graph search
- Sample based
  - Rapidly-exploring Random Trees (RRT)
  - Probabilistic Roadmaps (PRM)
- Potential fields
- Vector-Field-Histogram+
- Dynamic window

Path Planning Summary

- First step: choose a map representation
- Second step: reduce the robot to a point-mass to plan in configuration space
- Then, generic path planning algorithms can be applied (which have applications in a variety of domains).
- A path planning approach should be based on the problem domain; there is no one-size-fits-all algorithm.