Introduction

(Automatic motion planning)

⇒ The goal is to be able to specify a task in a high level language and have the robot automatically compile this specification into a set of low-level motion primitives, or feedback controllers, to accomplish the task.

Configuration 1 → Configuration 2

{Avoiding Obstacles}

⇒ The key problem is to make sure no point on the robot hit an obstacle, so we need a way to represent the location of all the points on the robot.

→ This representation is called the Configuration of the robot.

→ Configuration space is the space of all configurations the robot can achieve.

⇒ The configuration space is generally non-Euclidean.

⇒ The dimensions of the configuration space is equal to number of independent variables in the representation of the configuration, also known as degree of freedom (DOF).

⇒ The problem is to find a curve in the configuration space that connects the start and goal points and avoids all configuration space obstacles that arise due to obstacle in the space.

(Nonholonomic constraint)

⇒ When a robot has more degrees of freedom than required to complete its task, the robot is called redundant.

⇒ When a robot has many extra degree of freedom, then it is called hyper-redundant.

★ Overview of Concepts in Motion Planning

① Task

Navigation → {Problem of finding a collision-free motion for the robot system from one configuration to another.}

Coverage → {Problem of passing a sensor or tool over all points in a space}

Localization → {Problem of using map to interpret sensor data to determine the configuration of the robot.}

Mapping → {Mapping is the problem of exploring & sensing an unknown environment}

② Properties of the Robot

Configuration space

degree of freedom

Kinematic / dynamic description

Motion constraints

③ Properties of Algorithm

Optimal / nonoptimal motions

Computational & Memory Complexity

Completeness

Meaning that they will always find a solution to the motion planning problem when one exist or indicate failure in finite time.

Online / Offline

Sensor-based / world model

★ Mathematical Style

⇒ Robots are assumed to operate in a planar ($\mathbb{R}^2$) ambient space, sometimes or three dimensional ($\mathbb{R}^3$) ambient space called the workspace W.

⇒ Let WO_i be the i^{th} obstacle.

$$\boxed{W_{free} = W \setminus \cup_i WO_i}$$

{ \ is substraction operator }

⇒ Motion planning, however does not usually occurs in the workspace. Instead it occurs in the configuration space Q. (also called C-space).

⇒ $R(q)$ is to denote the set of points of the ambient space occupied by the robot at configuration q.

⇒ An obstacle in the configuration space corresponds to configurations of the robot that intersect an obstacle in the workspace.

$$\boxed{QO_i = \{q \mid R(q) \cap WO_i \neq \phi\}}$$

$$\boxed{Q_{free} = Q \setminus \cup_i QO_i}$$

Path planning → {Continuous curve on the configuration space}

$C : [0,1] \to Q$ where $C(0) = q_{start}$ $C(1) = q_{goal}$
and $C(s) \in Q_{free}$ $\forall s \in [0,1]$

⇒ When path is parameterized by time t, then $C(t)$ is a trajectory.

⇒ Finding a feasible trajectory is called trajectory planning or motion planning

$$q = [q_1, q_2 \ldots q_n]^T$$

Scanned by CamScanner