Robot Motion Planning

Configuration Space and Bug Algorithms

A. Narayanan[1]

[1]Department of Informatics

Outline

Classification on the basis of . . .

Task	Robot	Algorithm
Navigate	Configuration space, degree of freedom	Optimal/nonoptimal motions
Map	Kinematic/dynamic	Computational complexity
Cover	Omnidirectional or motion constraints	Completeness (resolution, probabilistic)
Localize		Online/offline Sensor-based/world model

Classification by Task

- The most important characterization of a motion planner is according to the problem it solves. The four major tasks are `navigation`, `coverage`, `localization`, and `mapping`.
- **Navigation** is the problem of finding a collision-free motion for the robot system from one configuration (or state) to another.
- **Coverage** is the problem of passing a sensor or tool over all points in a space, such as in demining or painting.
- **Localization** is the problem of using a map to interpret sensor data to determine the configuration of the robot.
- **Mapping** is the problem of exploring and sensing an unknown environment to construct a representation that is useful for navigation, coverage, or localization.
- Localization and mapping can be combined, as in SLAM.

Classification by Robot Properties

Todo. . .

Classification by Algorithm

Todo...

Mathematical Notations

- $\mathcal{W}$ - Workspace
- $\mathcal{WO}_i$ - the i^{th} Obstacle
- $\mathcal{W}_{free}$ - Free Workspace
- $\mathcal{Q}$ - Configuration Space
- $\mathcal{QO}_i$ - the i^{th} Obstacle in Config Space
- $R(q)$ - Set of points in ambient space occupied by the robot at config q

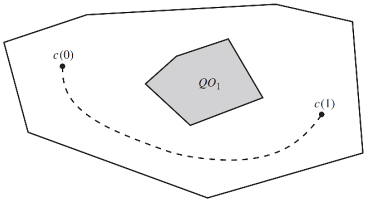

Figure: A path.

Bug Algorithms

Assumptions

- Assume a point robot
- Assume a zero range sensor
- Assume the robot can measure $d(x, y)$ between any $x \in \mathbb{R}^2$ and $y \in \mathbb{R}^2$ in a bounded workspace

Bug 1 Algorithm

Strategy:

- Robot moves directly towards goal.

- If an obstacle is encountered, then mark this hit point as q_{1h} and circumnavigate around the obstacle.

- At every point on obstacle boundary, measure the distance towards goal.

- if q_{1h} has reached again, traverse to q_{1l} point which is the nearest point to the goal.

- leave the obstacle boundary at this point, then move towards the goal again.

- Repeat the same cycle very-time the robot faces a new obstacle, till the goal is reached.

Robot Capabilities:

- Robot must be able to measure and memorize distance from certain point to the goal

- Robot must be able to detect the collision with the obstacle

Bounds on path distance: D: start-to-goal distance

P_i: obstacle perimeter

Worst case: $D + 1.5 \sum P_i$

Bug 2 Algorithm

Strategy:
- Robot moves directly towards goal following a line called M-line.
- If an obstacle is encountered, circumnavigate obstacle till the robot intersects with M-line.
- Leave boundary at this point and keep moving towards the goal.
- Repeat the same cycle very-time the robot faces a new obstacle, till the goal is reached.
Robot Capabilities:
- Robot must be able to know where M-line is and able to follow it
- Robot must be able to detect the collision with the obstacle
Bounds on path distance: Worst case: $D + 0.5 \sum n_i P_i$
Where n_i: number of times the M-line intersects ith obstacle

Tangential Bug Algorithm

Tangenial Bug is an improvement of BUG 2 Algorithm using 360° **range sensor with infinite orientation resolution Strategy:**

- Robot moves directly towards goal till obstance encountered.

- The robot detects all tangential points, which are points of intersection between range sensor tangential and obstacle boundary

- The robot determines the point which extremely reduces what is called heuristic distance.

- $H(heuristic) = d(X, Q_i) + d(Q_i, Q_{goal})$.

- The robot moves towards this point and follow the boundary until $D_{reach} < D_{followed}$, then leave the boundary and move towards the goal.

- Repeat the same cycle at every obstacle encountered till the goal is reached.

Robot Capabilities:

- Robot must be able to determine all tangential points (discontinuity)

- Robot must know where the gaol is and measure the distance between certain point and the goal

Summary

- The first main message of your talk in one or two lines.
- The second main message of your talk in one or two lines.
- Perhaps a third message, but not more than that.

- Outlook
  - Something you haven't solved.
  - Something else you haven't solved.