Robótica Móvel e Inteligente

Mobile Robot Mapping

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Contents

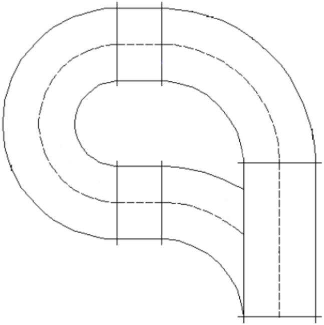
Navigation
Questions and topics

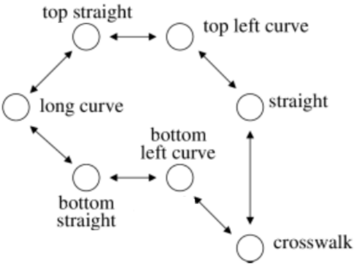
- Where am I?
  - localization
- **Where have I been?**
  - **mapping**
- Where should I going?
  - decision
- What's the best way to get there?
  - Path planning
- How do I get there?
  - Path following and obstacle avoidance (Motion)

Mapping
Purpose

- Mapping is the process of building an internal estimate of the map of the environment
  - What does the world look like (for navigation purposes)?
- Approaches
  - Topological map
  - Features map
  - Metric map
    - Occupancy grid map

Mapping
Example of metric and topological maps





Occupancy Grid
Method

- Map is composed of cells of equal dimension
- Every cell may be occupied or free
- Every cell keeps the probability of being occupied
  - Probability that each cell is occupied $P(H)$ and probability that each cell is unoccupied $P(\tilde{}H)$

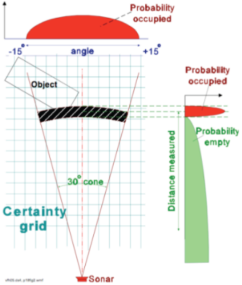
$$0 \leq P(H) \leq 1$$

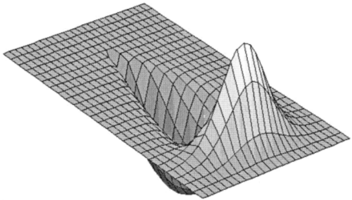
$$P(\tilde{}H) = 1 - P(H)$$

- Other methods store 2 different functions: one for occupied probability and another for empty probability

Occupancy Grid
Mapping problem

- We want to determine $P(H|s)$
  - Probability cell H is occupied given a certain measure s
- Let's start by determining $P(s|H)$
  - Probability of getting measure s if H is occupied
  - This is the sensor model





Occupancy Grid
Mapping problem (2)

- One can determine $P(H|s)$ from $P(s|H)$
- From Bayes' Rule

$$P(H|s) = \frac{P(s|H) * P(H)}{P(s)} = \frac{P(s|H) * P(H)}{P(s|H) * P(H) + P(s|\tilde{}H) * P(\tilde{}H)}$$

- $P(s|H)$ and $P(s|\tilde{}H)$ are known from the sensor model
- $P(H)$ and $P(\tilde{}H)$ are unconditional probabilities or prior probabilities
  - If no information is available, one can assume $P(H) = P(\tilde{}H) = 0.5$

Occupancy Grid
Mapping problem (3)

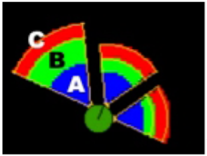
- Updating with the Bayes' rule

$$P(H|s_n) = \frac{P(s_n|H) * P(H|s_{n-1})}{P(s_n|H) * P(H|s_{n-1}) + P(s_n|\tilde{}H) * P(\tilde{}H|s_{n-1})}$$

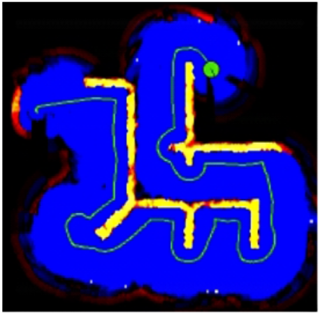
- This is the recursive version of the update formula
- Each time a new observation is made that can be employed to update the occupancy grid

Occupancy Grid
Mapping example – YAM algorithm

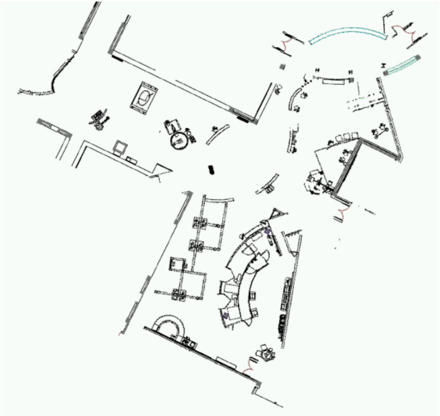
- Probabilities (?) may be positive or negative
  - Positive means probably occupied
  - Negative means probably empty
- Estimated position of the robot is assigned minimum probability
- Field of view of obstacle sensors is divided in 3 regions:
  - Cells in Region A are assigned a low probability
  - Cells in Region B decrease their probability
  - Cells in Region C increase their probability
  - Increase in region C is 4 times the value of decrease in region B

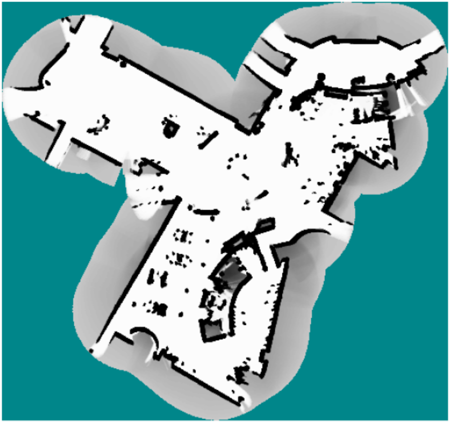


YAM

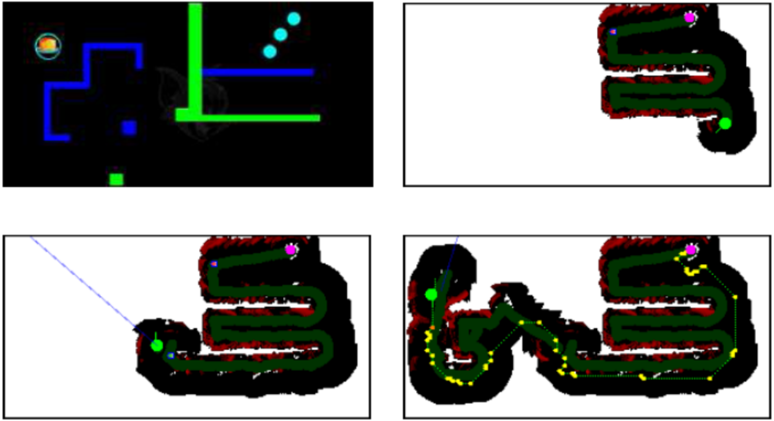


Occupancy Grid
Mapping example – laser range finder sensor





Occupancy Grid
Mapping example – XIP approach



SLAM

Simultaneous Localization and Mapping

- Mapping, as presented in the previous slides, assumes the pose of the robot is known
- Often this is not true and, while mapping, the robot must simultaneously estimate its pose
  - To estimate its pose it may use the already known map
- The general problem is denoted as the Simultaneous Localization and Mapping (SLAM) problem

- SLAM problem
  - A robot is exploring an unknown, static environment
- Inputs
  - The robot's controls
  - Observations of nearby features
- Estimate
  - Map
  - Pose or path of the robot

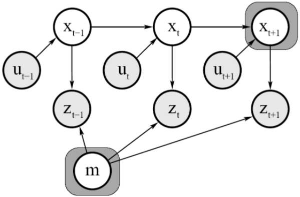
SLAM
Online and full SLAM

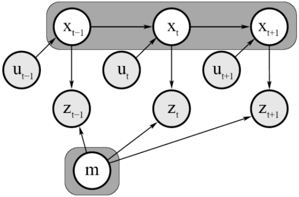
- Online SLAM – estimates map and current position given measures and controls

$$p(x_t, m | z_{1:t}, u_{1:t})$$

- Full SLAM – estimates map and the whole robot path given measures and controls

$$p(x_{1:t}, m | z_{1:t}, u_{1:t})$$





- SLAM techniques: Scan matching, EKF SLAM, Fast-SLAM, Graph-SLAM, SEIFs, Gmapping, LAMA
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