Introduction to localization and mapping for robots

COMP 4500 Mobile Robotics I
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Three Types of Robot Architectures

Hierarchical

Reactive

Hybrid

From Murphy 2000
Minerva’s Architecture Diagram

User Interface

Task Planner

Map Builder

Localization

Path Planner

Collision Avoidance
Robot localization example
Multi-Robot Mapping and Exploration

Carnegie Mellon
October 1999
Mapping Mines
Closing loops

From https://blog.cometlabs.io/teaching-robots-presence-what-you-need-to-know-about-slam-9bf0ca037553
Google Gar/Waymo
Navlab, CMU, 1997
The SLAM Problem

A robot is exploring an unknown, static environment.

**Given:**

- The robot’s controls
- Observations of nearby features

**Estimate:**

- Map of features
- Path of the robot
Structure of the Landmark-based SLAM-Problem
SLAM Applications

Indoors

Space

Undersea

Underground
Representations

• Grid maps or scans

[Lu & Milios, 97; Gutmann, 98; Thrun 98; Burgard, 99; Konolige & Gutmann, 00; Thrun, 00; Arras, 99; Haehnel, 01;…]

• Landmark-based

[Leonard et al., 98; Castelanos et al., 99; Dissanayake et al., 2001; Montemerlo et al., 2002;…]
Why is SLAM a hard problem?

**SLAM**: robot path and map are both *unknown*

Robot path error correlates errors in the map
Why is SLAM a hard problem?

- In the real world, the mapping between observations and landmarks is unknown.
- Picking wrong data associations can have catastrophic consequences.
- Pose error correlates data associations.
SLAM:
Simultaneous Localization and Mapping

• Full SLAM: Estimates entire path and map!

\[ p(x_{1:t}, m | z_{1:t}, u_{1:t}) \]

• Online SLAM: Integrations typically done one at a time

\[ p(x_t, m | z_{1:t}, u_{1:t}) = \int \int \ldots \int p(x_{1:t}, m | z_{1:t}, u_{1:t}) \, dx_1 \, dx_2 \ldots dx_{t-1} \]

Estimates most recent pose and map!
Graphical Model of Online SLAM:

\[ p(x_t, m | z_{1:t}, u_{1:t}) = \int \int \cdots \int p(x_{1:t}, m | z_{1:t}, u_{1:t}) \, dx_1 \, dx_2 \cdots dx_{t-1} \]
Graphical Model of Full SLAM:

\[ p(x_{1:t}, m \mid z_{1:t}, u_{1:t}) \]
Want to learn more?

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