Features

Chapter 6
Last week: Sensors

- Different sensor technologies
  - Distance, velocity, acceleration
  - Light, sound, magnetic field, ...
- Precision, accuracy, bandwidth, dynamic range and resolution
- No single sensor for any application
- Running example: robot navigation
Last Friday: Dijkstra on Sparki

- Please implement till next Friday
- This Friday: moving the robot from waypoint to waypoint
- Brute-force implementation of Dijkstra or google (30 lines of code)
How much data does a laser scanner produce?

What to do with so much data? (Cameras are even worse!)

Hokuyo URG
What kind of high-level information could we possibly extract to aid in robot navigation?
Ideas

• Detect *walls* to constrain pose estimate
• Detect *corners* to recognize places (“loop closure”)
• Estimate speed by observing how the environment changes
• ...

Sensor data needs to be broken down into *features*. All sensors provide data that contains features.
What features could we extract from Sparki?

• Accelerometer
• Magnetometer
• Rate gyroscope
• Floor sensor
• Ultrasound sensor
• IR receiver
• Light sensor
Other features

- Being picked up, falling of the table, ...
- N, S, E, W
- Rotating / not rotating
- Cross on the floor, ...
- Lines, corners, ...
- In kitchen, in living room, ...
- Light on / light off

Writing code to extract such features often is hard. Reliability of detection will be treated with later...
Today

- Extracting line and corner features
- Least-squares
- RANSAC
- Split-and-merge algorithm

Obvious applications to mapping and navigation, but very, very general algorithms
Lines

\[ \rho_i \cos(\theta_i - \alpha) - r = d_i. \]

\[ S_{r,\alpha} = \sum_i d_i^2 = \sum_i (\rho_i \cos(\theta_i - \alpha) - r)^2 \]

How to find the optimal parameters alpha and r?
"Least-squares"

\[ S_{r,\alpha} = \sum_{i} d_i^2 = \sum_{i} (\rho_i \cos(\theta_i - \alpha) - r)^2 \]

\[ \frac{\partial S}{\partial \alpha} = 0 \quad \frac{\partial S}{\partial r} = 0 \]

\[ \alpha = \frac{1}{2} \arctan \left( \frac{\frac{1}{N} \sum \rho_i^2 \sin 2\theta_i - \frac{2}{N^2} \sum \sum \rho_i \rho_j \cos \theta_i \sin \theta_j}{\frac{1}{N} \sum \rho_i^2 \cos 2\theta_i - \frac{1}{N^2} \sum \sum \rho_i \rho_j \cos (\theta_i + \theta_j)} \right) \]

\[ r = \frac{\sum \rho_i \cos(\theta_i - \alpha)}{N} \]

Matlab demo
Problems

- Big problems with noise
- Computational complexity quite high $O(N^2)$
- Cannot deal with multiple lines at once
- Solution: appropriate segmentation

Ultrasound data from Sparki (the “line” was perfect)
Random Sample and Consensus (RANSAC)

1. Sample random line from two points
2. Calculate number of “inliers”
3. Check if better than previous
   1. Yes: store
   2. No: discard
4. Repeat X times

Inliers are points sufficiently close to a line
Split-and-Merge Algorithm

1. Select point with highest error
2. Split dataset at this location
Other applications of RANSAC

• Image stitching (iPhone panorama function)
• Map alignment
• Data clustering
• Any regression
• ...
Summary

• Features are a smart way to reduce data coming from sensors
• Features are task-relevant high-level information
  – Location of lines
  – Location of corners
  – Location of objects
  – ...
• Least-squares gives optimal solutions
• RANSAC deals with outliers
• Feature extraction is an optimization problem with a probabilistic outcome