16-735 Project Progress Presentation

Coffee delivery mission

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NSH 3211
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What we have done – Building Map

- Getting familiar to program at NOMADIC robot
  - Wireless access
  - Ultrasonic sensor data understanding
  - Convex mirror camera data understanding
  - Motion command understanding

- Workspace definition (NSH A floor) and landmark(pink box) positioning

- Sonar data collection and mapping at measured workspace

- Taking pictures for every reference points

- Calibration of camera data

- Image processing for landmark detection (angle and range with respect to robot configuration)
What we have done – Building Map

- Workspace definition (NSH A floor) and landmark(pink box) positioning
- Sonar data collection *(filtered)* and mapping at measured workspace
What we have done – Building Map

- Taking pictures for every reference points
What we have done – Landmark Calibration

- Taking pictures for every distance and then comparing with image
What we have done – Landmark detection

- Unknown mirror geometry: building approximation of the relation between pixel distance in the image and the real distance using least square 3-order polynomial
What we have done – Landmark detection

Problem: low resolution causes big error in distance detection

Possible solution: change design to use full camera data
– raising camera position / changing convex mirror curvature

Landmark resolution for distances over 100 pixels
What we have done – Landmark detection

Position and Orientation can be uniquely determined with THREE NEAR LANDMARKS
- No information of range from camera but bearing
What we have done – Position correction

- Using the known position of the closest landmark and the approximated distance and angle, we corrected the actual robot position with a calculated position.

Problem: position data from camera not accurate and at least two landmarks needed for angle detection.
What we have to do

- Search algorithm (not decided yet)
  - D* on occupancy grid
  - Voronoi graph search

- Completing image processing with more landmarks and maybe changing robot design

- Kalman filtering using landmark – position and orientation calibration

Demo

- Delivering coffee from start position to goal position.
- But it may face unexpected obstacles.
- Since we have other connectivity, robot decides to go another way to reach goal.
Medelson- Progress

• Variance of sensor data
  – Odometry is at about 0.5% off
  – Need to find a better measuring instrument for the LADAR

• Started coding kalman filter
  – Basing off of previous code in java
    • Trying to decide if I should use the second LADAR.
      – May turn it on and off depending on state of the robot
        » Useful for turning and when just leaving a station
        » Not useful when people are following it
    • If both LADARs are used at the same time, code needs to be modified
This week

• Gathering LADAR data for variance estimation
  – Can't just use any spec sheets for the lasers. They're quite old
  – Also use for steady-state error in the data
• Hopefully finish coding the filter
• Try the filtering on the data with a reasonably still environment- empty lab so that it has a chance at working pre-tuning
• Tuning!
• Fixing up GUI work for approximate path design
Navigating in MazeWorld

Ross A Knepper

16-735 Motion Planning
Mid-Semester Project Presentation
Problem Statement

• You are a Nomad Scout robot in a maze of twisty little cardboard passages, all alike.
• Known:
  – Maze
  – Start and goal
• Unknown:
  – Position, once moved
• Need to use sonar readings to reduce uncertainty ...
... Use a Kalman Filter

- Assumes all error sources are Gaussian.
- Uses a System Model to propagate state through time.
- Uses a Measurement Model to adjust state to correct for errors caused by inaccurate vehicle model or physical disturbance.
- Tolerates sensor noise.
Reducing Error with a Kalman Filter

• With a Kalman Filter, you predict what the sensors will read based on state estimate.

• Then use the innovation between actual and predicted readings to correct state estimate.
State and Measurements

• State vector: \([x \ y \ \theta \ V \ \omega]^T\).
• State measurement: \([x \ y \ \theta \ V_R \ V_L]^T\).
• Sonar measurement:
  \([r_0 \ r_1 \ r_2 \ r_3 \ r_4 \ r_5 \ r_6 \ r_7 \ r_8 \ r_9 \ r_{10} \ r_{11} \ r_{12} \ r_{13} \ r_{14} \ r_{15}]^T\).
System Model

- Update state $\hat{x}_{k+1} = \phi_k(\hat{x}_k)$ and state covariance $P_{k+1} = \Phi_F P_k \Phi_F^T + \Gamma_k Q_k \Gamma_k^T$ to account for time passing.
- $Q_k$ is the system covariance matrix.

$$\begin{bmatrix} x_{k+1} \\ \dot{x}_{k+1} \end{bmatrix} \approx \begin{bmatrix} \Phi \end{bmatrix} \begin{bmatrix} x_k \\ \dot{x}_k \end{bmatrix} \approx \begin{bmatrix} 1 & 0 & 0 & c\theta \Delta t & 0 \\ 0 & 1 & 0 & s\theta \Delta t & 0 \\ 0 & 0 & 1 & 0 & \Delta t \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\Phi_F \approx I + F \Delta t$$

$$\begin{bmatrix} 1 & 0 & -V_s \theta \Delta t & c\theta \Delta t & 0 \\ 0 & 1 & V_c \theta \Delta t & s\theta \Delta t & 0 \\ 0 & 0 & 1 & 0 & \Delta t \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$
State Measurement Model

- $z_e = [V_R \ V_L]$

- $H_e = \frac{\partial z_e}{\partial \tilde{x}} = \begin{bmatrix} 0 & 0 & 0 & 1 & L/2 \\ 0 & 0 & 0 & 1 & -L/2 \end{bmatrix}$

- $R_k = \begin{bmatrix} \alpha & |VR| & 0 \\ 0 & \alpha & |VL| \end{bmatrix}$

\[
H_k = \frac{\partial h}{\partial x}(\hat{x}_k) \quad F_k = \frac{\partial f}{\partial x}(\hat{x}_k)
\]

\[
K_k = P_k^{-1} H_k^T \left[ H_k P_k^{-1} H_k^T + R_k \right]^{-1}
\]

\[
\hat{x}_k^+ = \hat{x}_k^- + K_k [z_k^- - h(\hat{x}_k^-)]
\]

\[
P_k^+ = [I - K_k H_k] P_k^-
\]
Sonar Measurement Model

- $z_s = [r_0 \ r_1 \ \ldots \ r_{15}]$.
- $h(x) = \ldots$
- $R_k = \begin{bmatrix} \beta & \ldots & 0 \\ \ldots & \ldots & \ldots \\ 0 & \ldots & \beta \end{bmatrix}$

$$H_k = \frac{\partial h}{\partial x}(\hat{x}_k^{-}) \quad F_k = \frac{\partial f}{\partial x}(\hat{x}_k^{-})$$

$$K_k = P_k^- H_k^T [H_k P_k^- H_k^T + R_k]^{-1}$$

$$\hat{x}_k^+ = x_k^- + K_k [z_k - h(x_k^-)]$$

$$P_k^+ = [I - K_k H_k] P_k^-$$