Laboratory 4
EKF Localization

CSC 232 / ECE 232 / CSC 432 / ECE 437 - Autonomous Mobile Robots

March 14th, 2016 - March 30th, 2016

Academic Honesty

The following laboratory exercises and and the laboratory report must be performed in accordance with the University of Rochester's Academic Honesty Policy. You may discuss the laboratory exercises with others, however all of the code, data, and material contained within the report must be your own in accordance with the laboratory instructions. Please type or write "I affirm that I have not given or received any unauthorized help on this assignment, and that all work is my own." at the beginning of the laboratory report. Please contact Professor Howard at thomas.howard@rochester.edu if you have any questions about the academic honesty policy for this laboratory.

Report Due Date

This document describes a two week long laboratory due on March 30th, 2016. The laboratory report shall be written in LaTeX, Word, Pages, or the text editor of your choice and submitted as a PDF with a tarball containing the source code through the course website on Blackboard. The laboratory report shall contain a description of the activities taken in each step of the laboratory and answer all questions posed at the end of this document.

Overview

Laboratory 4 will build upon the code that you developed in Laboratory 1, 2, and 3 to enhance the robot with localization capabilities. By the end of this laboratory, you should be able to:

- Implement a measurement models based on the beam model and a known map
- Draw indicators in your GUI that show the estimated location of the cone landmark
- Implement the EKF localization algorithm on the TurtleBot robot

Requirements

This laboratory has two parts. First, you will implement the landmark measurement model using information from your beam model and a known map. Second, you will implement the EKF localization algorithm detailed in Table 7.2 of Probabilistic Robotics. Lastly, you will run a series of tests to evaluate the performance of your EKF localization in the Questions section.

Landmark Measurement Model

In Chapter 6 of Probabilistic Robotics a method of modeling feature-based sensors called the *Landmark Measurement Model* is discussed. In this laboratory we will implement a simplified form of this model that looks for a landmark (a cone) at a known location. The physical environment that you will use is a simplified form of the one you used in Laboratory 3, which is illustrated in Figure 1, where X is the experimentally determined radius of the cone you computed in Laboratory 3.

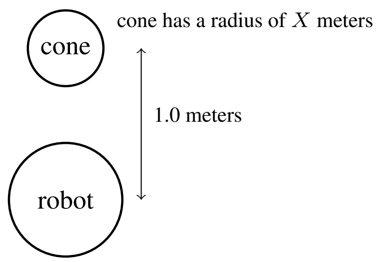

Figure 1: A diagram showing the simulated and physical test environments

To find the center of the cone, which is the global position of the first and only landmark $(m_{1,x}, m_{1,y})$, can be found by checking the returns from the simulated beam model for returns that are both approximately in the predicted location and in the form of a partially observed circle. The center can be found by fitting a circle to the data, or by projecting the radius along the line that connects the nearest return with the robot's position. For the uncertainty of the landmark measurement model, use the following value for Q_t.

$$Q_t = \begin{bmatrix} 0.001 & 0 & 0 \\ 0 & 0.001 & 0 \\ 0 & 0 & 0.001 \end{bmatrix} \quad (1)$$

Extended Kalman Filter Localization

In Chapter 7, the Extended Kalman Filter Localization algorithm is presented and the implementation for a differential drive mobile robot is outlined in Table 7.2 on page 204. You will implemented the EKF Localization assuming values for the uncertainty in the velocity motion model $\alpha_1, \alpha_2, \ldots, \alpha_6 = 0.01$. Note that you will have to implement methods to multiple, transpose, and invert matrices. For 2×2 and 3×3 matrices, matrix inversions can be computed in closed form.

System Architecture

An illustration of the message passing between the three programs is illustrated in Figure 2. The *localization* module you will implement in this laboratory will accept commanded velocity and laserscan messages and generate the geometry_msgs::PoseWithCovariance message. Note that this message is the three-dimensional (6-DOF) generalization of the two-dimensional (3-DOF) case that we are considering in this laboratory.

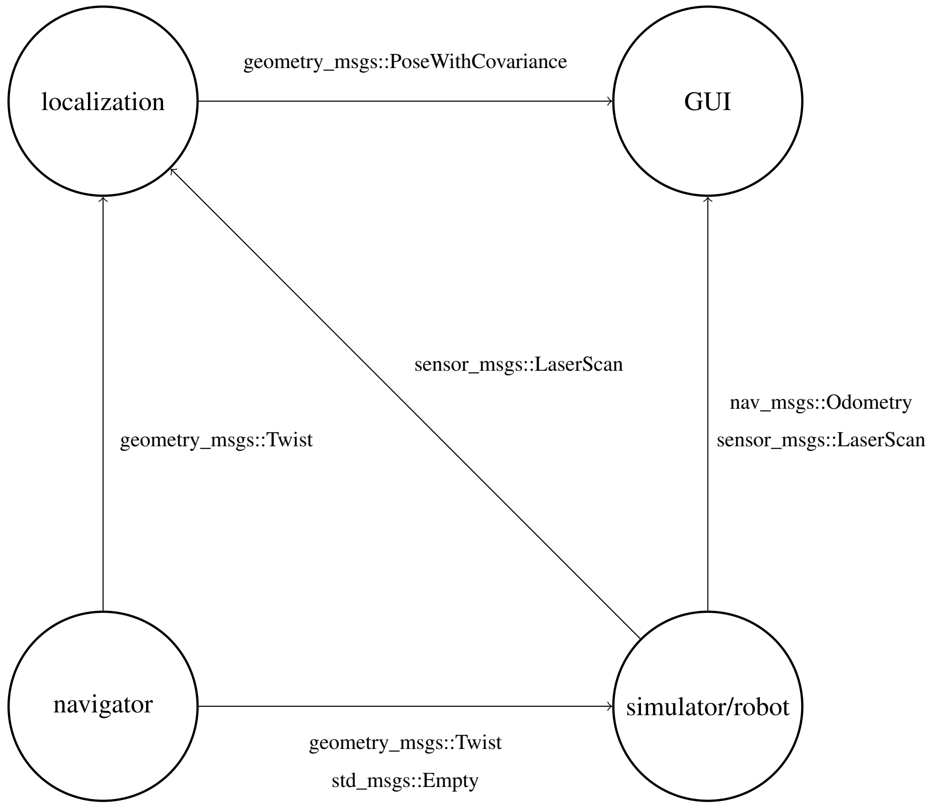

Figure 2: A diagram of the message passing between the *navigator*, *simulator*, *localization*, and *GUI* programs in Laboratory 4

Code Checklist

- ☐ ***localization* function to calculate the landmark measurement for a known environment**
- ☐ ***localization* function to estimate the pose of the robot using the EKF localization algorithm**
- ☐ ***localization* functions to multiple, invert, and transpose matrices**
- ☐ ***GUI* geometry_msgs::PoseWithCovariance subscriber to accept the estimated pose**
- ☐ ***GUI* function to draw the estimated pose of the robot**
- ☐ ***GUI* function to draw the actual pose of the robot (from simulator)**

Questions

1. Using your simulator, test your EKF localization algorithm by collecting 30.0 seconds of data recorded at 10.0 Hz when assuming:

$$v(t) = -0.5sin(2t)\frac{m}{sec} \tag{2}$$

$$\omega(t) = 0.1\frac{rad}{sec} \tag{3}$$

   Plot the mean of the belief computed by your EKF localization algorithm in Matlab.

2. Now test your EKF localization algorithm with a physical setup in the laboratory that reflects the same environment as in Figure 1. Again, collect 30.0 seconds of data recorded at 10.0 Hz and plot the mean of the belief

computed by your EKF localization algorithm in Matlab.

3. Now using the physical platform, repeat the previous experiment on the TurtleBot robot. Plot the mean of the belief computed by your EKF localization algorithm in Matlab.

4. Discuss the similarities and differences you observed between the simulated and physical experiments.