Homework 4

Assigned on November 22, 2023
Due on December 8, 2023

Maximum Points: 100

Learning Outcomes

After this homework, you should be able to:

(a) understand sources of error in sensors and develop measurement models of sensors based on this understanding;

(b) apply grid-mapping with known poses;

(c) contrast the KF and PF for localizing a robot;

(d) get a feel for the algorithmic tradeoffs between accuracy and computational efficiency;

(e) appreciate correlatedness between robot pose and mapping and its impact on SLAM, by implementing EKF-SLAM;

(f) refine their strategies for developing and debugging algorithms for robotics.

Instructions

- The homework assignment can be attempted in groups of two.
- Each group will register themselves as a group on Canvas under People/Groups/Homework 2.
- The homework submission on Canvas will be set up for group submission, so each group needs to make only one submission.
- **If it appears that a group member has not contributed to a homework assignment, then each member will be graded individually.**

Tasks

Problem 1
CLO2-C4
25 points

Sensor Model. Assume that you're building a sensor model for the robot used in the previous homework assignment that was equipped with a sensor capable of measuring the distance and bearing to landmarks. Furthermore, assume that this sensor is also capable of identifying the landmarks, so that when you receive a range and bearing measurement you know which landmark it corresponds to.

A sensor measurement $z = (r, \theta)^T$ is composed of the measured distance, r, and the measured bearing, , to the landmark l. Both the range and the bearing measurements are subject to zero-mean Gaussian noise with variances σ_r^2 and σ_θ^2, respectively. The range and the bearing measurements are independent of each other. Design a sensor model $p(z|x, l)$ for this type of sensor and explain it.

Problem 2
CLO2-C3
25 points

Grid-based Occupancy Mapping. In this problem, you'll implement occupancy grid mapping for a simple one-dimensional environment, spanning from left to right, e.g. imagine one long lane (1D), using a sequence of measurements from a range sensor. The length of the map or this lane is 2 meters. Divide the map into cells of size 10 cm. Choose a representative point (coordinate) for each cell according to some rule and state your rule. Our robot is placed in the left-most cell and has a range sensor mounted on it that is oriented towards the right, or towards the lane. The robot does not move while building this map.

Assume a very simple model for the sensor: every grid cell with a distance from the robot that is smaller than the measured distance is assumed to be occupied with probability 0.3. Every cell behind the measured distance is occupied with probability 0.6. Every cell located more than 20 cm behind the measured distance should not be updated.

Assume that we have no prior information about the occupancy of any cell. The robot receives the following sequence of measurements, from its range sensor, at different time steps:

$$\{101, 82, 91, 112, 99, 151, 96, 85, 99, 105\}.$$

Using MATLAB, find the belief of the map incorporating all the measurements. Plot the probability values of each cell against your chosen representative points to obtain a PMF. Based on the obtained belief, draw the map.

Problem 3
CLO2-C4
25 points

In Problem 4 of the last homework assignment, you used EKF for landmark-based localization, where the line features in the environment played the role of landmarks. In this problem, you'll solve the same localization problem using particle filter, or in other words apply Monte

Carlo Localization.

Problem 4
CLO2-C3

(Bonus) 20 points

This linked Mathworks example uses pose graph and factor graphs for SLAM, given odometry data and measurement data from April Tag markers being used as landmarks. You'll instead implement the EKF-SLAM algorithm on the same data, to obtain the locations of all landmarks and the trajectory of the robot.

Problem 5
CLO-2/C-4

25 points

Answer the following questions individually:

(a) How many hours did each of you spend on this homework? Answer as accurately as you can, as this will be used to structure next year's class.

(b) Each group member is to specifically state their contribution in this homework assignment.

(c) Do you have any specific advice for students attempting this homework next year?

(d) Each group member is to provide a self-reflection in the form of a note or a concept map. This requires you to reflect on your learning in relation to each of the outcomes stated at the beginning of this document.

Some questions that may help in this regard are: Have I achieved this outcome? What do I currently understand about content related to this outcome? How does it help me understand or build any robot? Do I have unanswered questions? What went wrong? How can I enable myself to achieve this outcome? What could I do to know more or enhance my skills in this context?

Don't forget to indicate your name with your respective paragraph.

Grading:

To obtain maximal score for each question, make sure to elaborate and include all the steps.