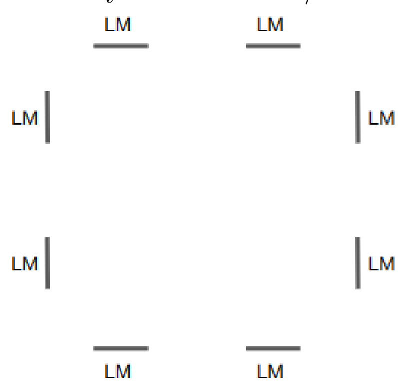
Homework 3 - CSE 276 - Introduction to Robotics

Due: Thursday, 14 November 2024, before midnight

The objective of homework 3 is to implement a version of the Simultaneous Localization and Mapping (SLAM) technique and evaluate its performance.

1. Set up an environment in a 10ft $\times$ 10ft area with landmarks (LM) as the figure exemplifies. There should be two landmarks on each side. The landmarks could be markers as used in HW2 or natural objects. If you use markers, you can use a different ID for each landmark. Measure the position of your landmarks/walls

   Provide a sketch of your ground-truth map in the top-down view layout as part of the report. If you want to scale down the square area, the minimum side should be 8 ft.

2. Implement the KALMAN filter-based SLAM system as described in the lecture notes. Use the off-the-shelf software to detect the landmarks. You can drive slowly enough to make the system matrices as simple as possible. Still, an EKF-based Kalman filter is likely to be more successful.

3. Start from a pose inside the square and drive through your environment to build up a map. The robot does not know the start pose. i) Initially drive the robot in a square path (say n x n ft in size). ii) Drive through the environment using an 8-point octagon trajectory (side length m ft). Assume you know nothing about the location of the landmarks regarding the robot. You thus have to estimate the position of the landmarks and the robot's trajectory as part of the homework. You **cannot** assume a-priori that you have 8 landmarks! The Kalman filter does not know how many landmarks there are.

4. Compare the two maps. What are the main differences, if any? Given that the robot started from an unknown pose and created the map, you will need to measure the start pose and transform the map into the world frame to compare with the measured ground-truth map. If you drive multiple times around the trajectory, is there a change in your results? Measure the average error of landmarks between the measured map from point 1 and the map estimated by the algorithm.

5. Provide a report that describes i) Your algorithm, ii) The results obtained with a square motion, iii) the 8-point motion, iv) Comment on the results obtained. How did you select the size of the square n / 8-point m? What trade-offs did you consider? v) A link to your unlisted YouTube video of the robot doing the SLAM.

6. For the algorithm part, the following should be included. i) What is the state x and measurement vector z? ii) How did you get the system matrix F, control matrix G, and measurement matrix H? iii) How did you initialize the state $x_{0|0}$ and state covariance $\Sigma_{0|0}$? iv) How did you determine the system noise and measurement noise? v) How do you handle a new landmark for the first time being detected, a landmark going out of the field of view, and a previously detected landmark reappearing?

7. For the result part, i) provide a plot of the trajectory estimated by the algorithm (not your eyes) along with the map of landmarks you built. The landmark plot should include the position covariance for each landmark, ii) Measure the average error of landmarks between the measured ground-truth map from point 1 and the map estimated by the algorithm. iii) Describe if the map improves if you drive multiple times.

8. Provide a zip file with the code.