CSE 668: Localization and SLAM

You can write this assignment in pure Python. The data from class can be accesses using `rospy`, which will allow you to read the messages form a ros bag file by calling `import rosbag` in your code. Please submit a single PDF file (with text and figures) and a tar/zip archive with the source code and an additional python file `result.py` that defines the data structure with the answer and a comment describing how it was created. I want to be able to run the file and have the in my plotting program.

1) **Sensor modeling** Modeling sensors is one of the key steps in enabling robots to reason about the external world. In this problem you will simulate a small gird localization problem with different sensor noise.

Assume that the sensor returns a single distance measurement as the robot is turning, i.e. moving at a constant speed of $1m/s$ along a circle with radius $r = 0.5m$ Use Bayes filter to determine the angle and distance to a wall from noisy sensor measurements.

Assume you have a simple sensor model, i.e. some additive noise with $\sigma = 0.25$. The sensor returns measurements in meters every $0.2s$.

- Draw a diagram of the robot, turning in front of a wall, and describe the state space.
- Look at the data ranges, what is an appropriate state-space for this estimation problem?
- Write a function `beam` that returns the $P(Z|range)$, i.e. the beam model for the sensor.
- Write a function `observe`that returns $P(z|x)$ based on the sensor model.
- Write a prediction function (`motion`) $P(X_{t+0.2}|X_t)$ that takes the current estimate $P(X_t)$ produce the next estimate $P(X_{t+0.2})$ on the state space.
- Use the `motion` and `observe` function to write a Bayes filter to estimate the distance and angle to wall given the following observations in the data file `ranges.dat`.
- Plot the estimate at those 6 time-steps.
- What is the most likely states at time $t = 1$?

2) **Sensor modeling - 2** Run the same plots with a more complicated sensor, i.e. one that returns uniform samples from the valid range %20 of the time, and the previous noise model otherwise. Data from this sensor is in `ranges2.dat`.

3) **Working with robot data** Plot the odometery and landmarks on a single plot. Sub-sample the messages in the bag file so that you get a reasonable number of time steps. These samples should line up with visibility of Markers (they don't need to be uniform). You will use these subsample messages for the next two problems. Please create a plot of the trajectory data and plot the landmarks as they are seen from the robot. Without running localization or SLAM, these data should make sense and give you an idea of what the results should look like.

4) **Localization: Monte Carlo or EKF** Implement either a Mote Carlo Localization filter (try a few different particle set sizes) OR implement an EKF localization scheme. In either case, please submit the the resulting estimated trajectory as a numpy array with (x,y,theta) for each time, and clearly state in the comment file which method you used and what the time discretization and localization parameters were. I will consolidate them in a single plot. In order to complete this part, you will need to use the PDF file of the known map.

5) **SLAM** Implement EKF SLAM with *known* data association. Instead of using the map to localize, you will try to build the map as you go. How does the map compare to the known map? Getting SLAM to work can be tricky. For partial credit, please analyze the behavior and fingure out when/where/why it fails.

6) **Project.** I would like you to start thinking about your class project. If you have not discussed with me yet, please send me a one paragraph description of what you would like to do. Be as specific about the goals and outcomes as possible. Find a relevant paper, cite it, and describe how it is relevant. (If I gave you a paper to start with, please examine a relevant reference). In a second paragraph please describe the technical approach of the paper and how it relates to your project idea.

This part of the assignment is not so much about writing (only two paragraphs) but about clarifying project goals. The project does not need to be perfectly planned out at this point, but I would like you think about the scope and outcomes.