CS/ME 469: Machine Learning and Artificial Intelligence for Robotics
Assignment #0: Filtering Algorithms
Code A Due: Oct. 4th   **Code B due:** Oct. 14th   **Writeup (A+B) due:** Oct. 14th

This assignment will focus on the implementation and assessment of a filtering algorithm on a robot dataset. You have been assigned to a specific Gaussian or nonparametric filtering algorithm and one of two robot datasets (see Canvas for assignment). The goal is to implement the algorithm, and assess it (guidelines below). Steps annotated with [*] are graded with a higher weight.

Please revisit the plagiarism and formatting instructions in the syllabus.

Datasets

Both datasets derive from the same robot platform performing a mobile navigation behavior while visually observing landmarks; the same file formats are used for both. Ground truth positions for the landmarks are known, and should be considered during the measurement update. In the first dataset (ds0) the robot is freely roaming, while in the second dataset (ds1) there are walls that partially occlude landmarks.

The datasets are courtesy of the Autonomous Space Robotics Lab at the University of Toronto. Thorough documentation of the robot platform, task and file formats, as well as video, are provided here: http://asrl.utias.utoronto.ca/datasets/mrclam/index.html. Note that there are data files from multiple robots and multiple experimental runs; feel free (but not obligated) to test your algorithm on other datasets as well. (For your reference, ds0 is [MRSLAM_Dataset4, Robot3] and ds1 is [MRCLAM_Dataset9, Robot3].) Note that the files provided on blackboard have been truncated.

Files:

_Odometry.dat: Controls information (translational and rotational speeds)

_Measurement.dat: Measurement information (visually observed landmarks, and other robots)

_Groundtruth.dat: Ground truth robot position (measured via Vicon motion capture – use for *assessment* only)

_Landmark_Groundtruth.dat: Ground truth landmark positions (measured via Vicon motion capture – may be taken as known information for use during filtering)

_Barcodes.dat: Associates the barcode IDs (" Barcode # " in Barcodes.dat, " Subject # " in _Measurement.dat) with landmark IDs (" Subject # " in _Landmark_Groundtruth.dat). *Note that here " Subject # " has mapped to **different** meanings in different files.* (This was not changed, to keep consistent with the website above.)

PART A

1. Design a motion model to estimate the positional (2-D location and heading) changes of a wheeled mobile robot in response to commanded speed (translational and rotational) controls. Clearly define the inputs, outputs and parameters of this model, and report the math. Explain your reasoning, as needed. Is this model linear in its inputs? Why or why not?

2. Test your motion model on generating movement for the following sequence of commands. Report the values of any parameters. (Below, v is translational speed, ω is rotational speed, and t is the duration of the commands.) Report the resulting plot.

$$\left[v=0.5\frac{m}{s}, \quad \omega=0\frac{rad}{s}, \quad t=1s\right]$$

$$\left[v=0\frac{m}{s}, \quad \omega=\frac{-1}{2\pi}\frac{rad}{s}, \quad t=1s\right]$$

$$\left[v=0.5\frac{m}{s}, \quad \omega=0\frac{rad}{s}, \quad t=1s\right]$$

$$\left[v=0\frac{m}{s}, \quad \omega=\frac{1}{2\pi}\frac{rad}{s}, \quad t=1s\right]$$

$$\left[v=0.5\frac{m}{s}, \quad \omega=0\frac{rad}{s}, \quad t=1s\right]$$

3. Test your simulated controller on the robot dataset. Issue the controls commands (in _Odometry.dat) to your controller, and compare this dead-reckoned path (i.e. controls propagation only) to the ground truth path. Report and discuss the resulting plot.

4. Describe, concisely, the operation of your assigned filtering algorithm. Include any key insights, assumptions, requirements. Use equations in your explanation.

5. Design a measurement model for your filter. Report all maths and reasoning; include images for illustration when appropriate.

6. Test your measurement model on predicting the range and heading of the following landmarks when the robot is located at the associate positions. Convert your predictions to global positions, compute the errors and report your results. (Remember, you have access to the ground truth landmark positions to compute the error.)

Position (x,y)	Landmark (Subject #)
(2, 3)	6
(0, 3)	13
(1, -2)	17

PART B

7. Implement the full filter.

8. [*] Compare the performance of your motion model (i.e. dead reckoning) and your full filter on the sequence of commands from step 2, and also on the robot dataset (as in step 3). Report the results, explain any differences (what performs well? what performs poorly? under what conditions? and why?). Ground your explanations in the algorithm maths.

9. [*] Examine the effect (trends? limits?) of uncertainty in the algorithm (i.e. changing the noise parameters). Examine its performance at different parts of the execution (e.g. when missing an expected measurement reading). Report plots and/or tables, and provide explanations.

Code

To be submitted with the report. Development in Matlab, Octave or Python is a requirement. A single executable script file named "run.m" or "run.py" should output, when executed, all of the data (plots, table values) reported in the write-up (as instructed above), with clear presentation and labels. *Code that does not run will receive zero points.* The run.m/run.py file should be easy to read – a sequence of calls to standalone functions, that hide away the meat of code (rather than placing that code in the run function). Clear commenting for all functions and function calls is encouraged. (No need for excessive verbosity, but the quicker and easier we are able to read the code, the better for your grade...) Bundle everything into a zip or tar file, and include also the data files provided on Canvas.

The code submitted for the Part A deadline should output the data plots of steps 2 and 3, and prediction and error computations of step 6 (printing to the terminal is fine). No write-up for these steps is required at the time of the Part A submission. It is okay to improve upon the Part A code for the final (Part B) submission. The code submitted for the Part B deadline should output all of the data plots from **both** sections, as reported in the write-up, and provide a writeup for all steps of the assignment.

Write-up

For each step above, explain thoroughly, and with clean consistent maths, all design decisions (motion model, measurement model, how parameters were set...) and reported assessment results. Remember to label all plot axes, title all plots, provide captions for any figures, include (as appropriate) units for all reported numbers, etc. Language counts; specifically with respect to clarity. If you use other sources (e.g. follow guidelines to linearize a motion model as described in a scholarly article), be sure to cite them.

Hints

- Start simple, plot often and build on working components. For example, first verify that the motion model on its own and the filter prediction step produce similar/identical paths for noise parameters near zero, and only after this include the measurement update step.

- Start early. Successful formulations will require time to develop. If you start only a few days before the deadline, your chances of finishing a high performing implementation in time are *extremely* slim.

- Note the sampling rate of controls versus observations... it might be that multiple controls are executed before an observation is taken (and vice versa). Pay attention to timestamps; take care to synchronize data.

- If you aren't able to achieve step 7, for steps 8-9 still try to report something. If part of your filter works, just run that part for the comparisons (and be sure to acknowledge this clearly). If nothing runs, then at least hypothesize on differences/characteristics you would expect to see, and why.