CSCE 439/839: Robotics: Algorithms and Applications Spring 2022
Homework 2

Started: Weds, February 16
Due: Weds, March 9

Instructions: This homework is an individual assignment, collaboration is not allowed. If you discuss any problems with others, please note this on the assignment as described in the syllabus. Also note any materials outside of lecture notes, course textbooks, and datasheets that you used. Show your work and describe your reasoning to get partial credit if your solution is incorrect.

You should also make sure that you properly label and **describe** any figures or plots that you include in your writeup. You will not receive full credit if you do not explain these. In addition, you should refer to your code where needed to answer the questions (e.g. say "See file mynode/launch/test.launch for this problem, which ...").

You must turn in a pdf of your assignment on Canvas **as a single zip file**. Make sure to answer questions in complete sentences and explain answers as needed. **You must also turn in your code for all parts of this problem on Canvas.** Failing to electronically turn in your code will result in a 10 point penalty on this assignment. Points may also be deducted for coding errors, poor style, or poor commenting.

If you use any code from an online or other source you must cite the source in the comments. Otherwise it is considered plagiarism, which we check for!!

Name:

Problem 1. *(5 pts)*[1] *(To be completed at end of assignment) Approximately how many* **hours** *did the total assignment take? Which sub-problem took longest and how many hours did it take? Are there any questions that need clarification?*

Problem 2. *ROS: In this problem, you will create a ROS node that will compute statistics for the Huskers' Football team. For these questions, refer to the hw2 code (*`rawStats.py` *and* `offensivePlay.msg`*).*

a). *(5 pts) Create a new ros package called* `hw2stats`*. Describe how you create this ros package for this node and where you place the files. What topic does this node publish on?*

[1] Each HW counts equally in your overall grade, even if homeworks have different point totals. This one is out of 80 points for 439 and 80+20 points for 839.

b). *(5 pts) Create a new node, called* `offensiveStats` *(C++ or Python) that subscribes to messages of type* `offensivePlay`*. Write the code in this node to compute the pass completion percentage (number completed passes (*`passCompleted` *true and* `isPass` *true) divided by total number of passes attempted) and the pass drop percentage (number of incomplete passes (*`passCompleted` *false and* `isPass` *true) divided by the total number of passes attempted). Describe the steps required to create the node and subscribe to the message.*

c). *(5 pts) Create a new message type that contains the pass completion and drop percentage as well as the total passing yards (yards when* `passCompleted` *is true) and rushing yards (yards when* `pass` *is false) for this game. Describe the process for creating a new message. How do you ensure that this message (and others) are compiled when you run* `catkin_make`*?*

d). *(5 pts) Write the code to create a publisher, populate, and send the above message. Make sure to comment your code.*

e). *(5 pts) What command would you use to plot the total rushing yards completed? Give the command, the proper arguments, and include the plot.*

f). *(5 pts) Without changing the* `rawStats` *node, launch a new pair of nodes that publish raw stats on the topic* `\plays\opponentOffensivePlay` *and also generates the offensive stats for the opponent. Hint: look into "remap" in the ros documentation.*

g). *(5 pts) Create a launch file that will launch all four nodes.*

Problem 3. *Sensing*

a). *(5 pts) What is the difference between precision and accuracy? Which is more important if you are trying to follow an object using a range finder (like we did in Lab2)? Make sure to say why and support it with examples.*

b). *(5 pts)* **839 Only:** *Describe how you could obtain dead-reckoned position information from an accelerometer that is tracking the acceleration of a robot. What would the largest position error be after moving 50m if the accelerometer has a 5% error.*

Problem 4. *PID*

a). *(5 pts) Write the equations for a PID controller and explain the impact of each of the P, I, and D terms.*

b). *(5 pts) In a controller running at 20Hz with P=10, I=0.1, and D=4 (without any loop time compensation), what would you set the parameters to if the loop rate was decreased to 10Hz and you wanted to maintain a similar level of performance? Why?*

c). *(5 pts)* **839 Only:** *List and explain 2 different problems that can occur with PID controllers and how you can mitigate these problems in a PID controller.*

Problem 5. *Kalman Filter: In this problem you should use the* `rocketShip.py` *code. Your goal is to develop a Kalman filter that will estimate the position, velocity, and acceleration of the rocket at a given time. You are given a control input in terms of acceleration on the topic* `control/acceleration` *and sensed values for the acceleration and velocity on* `sensors/acceleration` *and* `sensors/velocity`*, respectively. For your debugging purposes, you also have ground truth information, but you should not incorporate this into your filter design.*

a). *(5 pts) Write the linear equations that define the process and measurement in the matrix notation used in class.*

b). *(5 pts) Write the Kalman Equations (process and measurement update equations) for this system using the actual numbers and variables in the matrices (e.g. do not just say $x = A...$, write the vector elements of x).*

c). *(5 pts) Implement your Kalman filter to estimate the position, velocity, and acceleration of the rocket. Discuss your implementation and challenges you faced. You can use C++ or python and any matrix libraries (although this isn't required), but you should write your own Kalman code and not use a Kalman library. Hint: You can temporarily comment out the* `gauss` *calls in the code to eliminate noise. That way you can make sure your filter works correctly without noise. Just make sure to add back in the noise for evaluation and parameter turning.*

d). *(5 pts) How did you tune the parameters of your Kalman filter (R and Q)? Discuss the impact of changing the values of these parameters and support it with plots showing different responses. Hint: You can base your tuning on the actual process and sensing noise which are added with the* `gauss` *function in the source or you can tune it heuristically. Regardless, make sure to clearly explain.*

e). *(5 pts) Approximately how long can you stay within 50 units of the ground truth position with your estimate? Include data from multiple runs to support your answer.*

f). *(10 pts)* **839 Only:** *If you do not use the control input in your equations how much better/worse does it perform? Discuss why this is the case and support this with data and plots.*

Do not forget to fill in the amount of time you spent on this assignment in Question 1.