Introduction

The final lab report tests your understanding of all EECS 16B Labs, with an emphasis on conceptual and analytical understanding. It also allows you to look at these labs from a bigger picture and reflect on your design process and choices. You may use your homeworks, pre-labs, labs, lab notes, presentation slides, and any other resources we provided throughout the semester to help you. Many of these questions have also been asked in lab checkoffs. **However, all of your answers and explanations must be in your own words; you are not allowed to directly copy from those resources.**

The report is to be done with your lab group using LaTeX or Google Docs/Microsoft Word. **At the top of the report, please include the names and emails of all your group members, as well as the group ID you use for checkoffs.** Make sure to complete the following for each section header (Sections 2-6):

- First, give a summary in your own words of what you have done in the lab this semester.
- Then, answer all of the questions listed under the section header. Remember to fully and clearly explain your answers. Some questions also require you to upload your work.

Under Section 8, please detail each group member's contributions to the lab report. **If we find a highly disproportionate amount of work distribution among the group, we will adjust grades accordingly to penalize non-contributors.** Also, cite any sources you used that were not provided with the course materials.

The final lab report is due on Monday, May 2 at 11:59 PM. Only one group member submits the lab report to Gradescope and you must add all of your group members into the same submission.

1 Midterm Lab Report Review

Describe the connection of each of the following labs with the S1XT33N car project:

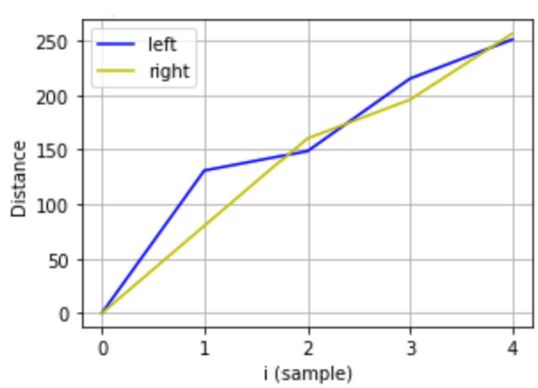
1. Introduction to Simulation
2. Analog and Digital Interfaces
3. Motion
4. Sensing Part 1
5. Sensing Part 2

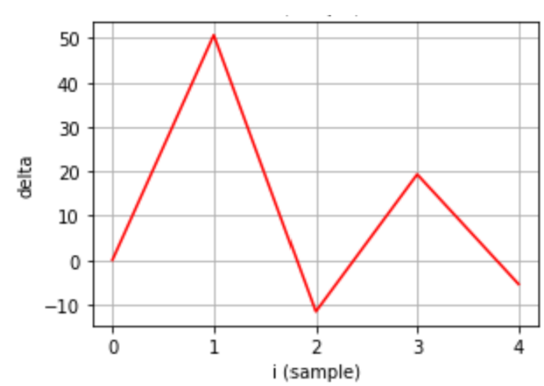
2 System ID

1. How did you choose the region to collect finer data on (data_fine.txt)? Why is it important to choose such a region to run least-squares regression on?
2. What do θ and β represent physically, not mathematically?
3. Why do we have separate θ and β values for the left and right wheels?
4. Why do we set v^* to the midpoint of our overlapping wheel velocity range, instead of closer to the boundaries? What would happen if we operated our car at a velocity outside of the overlapping velocity range?
5. Explain how using each of the following methods as our model can produce a better fit for the data we collected than our current linear model of the car: a) higher-order functions and b) piecewise-linear functions. You may not manipulate the data set in any way (i.e. remove outliers, collect more data points, etc.).

3 Controls Part 1

1. What are the open-loop model equations for our PWM input, $u[i]$?
2. What is the purpose of the jolts? Why might the left and right jolts be different?
3. Why does open-loop control fail? Why do we need to implement closed-loop control in order to have the car travel straight?
4. What are the closed-loop model equations for our PWM input, $u[i]$? Explain the purpose of each term.
5. Derive the system eigenvalue. Under what condition is the system stable (in theory)?
6. When testing out different f-values in practice, how do you know if the system eigenvalue has gone from positive to negative based on the car's behavior?
7. What effect does setting both f-values to 0 have on the car's control scheme? How is this different from non-zero f-values? Why are non-zero f-values necessary?
8. Why can't we use negative f-values for both wheels? If we wanted to use negative f-values for both wheels, how should we change our closed-loop model equations such that our car goes straight and corrects any errors in its trajectory?
9. What does a zero `delta_ss` value tell you about your car's trajectory? What about a non-zero `delta_ss` value? What kind of error is it supposed to correct when we add it to our control scheme? (**Hint**: Think about the difference between the trajectories for a zero versus a non-zero `delta_ss` value.)
10. Draw the trajectory of the car whose distances and delta over time are plotted below. The blue line represents d_l and the yellow line represents d_r on the distances plot. Please clearly indicate the direction of your car's movement in your drawing.





4 Controls Part 2

1. How did you change the closed-loop model equations to allow the car to turn? Write the equations below and explain how they change for turning left, turning right, and going straight.
2. Describe how the trajectory of the car would look if we added a constant δ_{ref} instead of a δ_{ref} that changes as a function of the timestep.
3. Why do we divide v^* by $m = 5$ for the turning expressions?
4. How is using `STRAIGHT_CORRECTION` different from `delta_ss` in Controls Part 1?

5 Classification

1. What are some characteristics of a good set of four words for classification? Provide at least two features.
2. What are length, prelength, and threshold for our data processing? Include both the definitions and the values you chose.
3. Why do we process our data so that the words are aligned before we run SVD/PCA on it?
4. Why do we need to use SVD/PCA to represent our data set?
5. Why do we use the V^T vectors for our lab instead of the vectors inside of the U matrix returned by SVD?
6. Why can we simply take the dot product when projecting our recorded data vector onto the principal component vectors?
7. Describe all the steps in the procedure we use to take a recorded data point and identify which word it is.
8. How many PCA vectors would we need to represent a data set that, when graphed, looks like a thin, straight line? How many would we need if the data set looks like a circle when plotted? How many would we need if the data set looks like a cylinder with a large base area and small height when plotted?
9. If we keep increasing the number of PCA vectors, how does the increase in accuracy with each subsequent PCA vector change?
10. What is `EUCLIDEAN_THRESHOLD`? What is `LOUDNESS_THRESHOLD`?

6 Integration/Final Demo

1. Briefly discuss what you learned throughout the S1XT33N car project and in the labs. What was your favorite part? Least favorite part? Please answer this question individually.
2. What was the most difficult bug you encountered this semester? How did you resolve the bug? What did you learn from the debugging experience?

7 Feedback

Please provide any feedback you have about 16B lab or anything we can do to better support you.

8 Collaborators and Sources

Please detail each group member's contributions to the lab report. Also, cite any sources you used that were not provided with the course materials.