ME 227
Spring 2019
Project Final Report
Due in class or by 4:30pm on Thursday, May 16

Having now successfully designed, simulated and implemented controllers on an automated vehicle, your last step in the project is to reflect on and write up your results. We want the final report to be clear and capture some of your conclusions but also be concise and easy to produce. Here is how to produce a great final report.

The report should begin with a brief description of your longitudinal and steering controllers (about a page unless you have done something requiring lengthier explanation). You should also present the speed and acceleration profile you developed as a function of the distance, s, and briefly describe how you obtained it.

After that, the report should contain about 1-1.5 pages of text on each of the following two comparisons. In addition to the text, you should include plots of whatever simulation and experimental results are needed to convince the reader of the points you are making in the text. The text should be short but clear and well-edited to capture your main points.

(1) Lookahead controller – simulation, experiment and error sources. Compare the lateral error you observed in experiment with the value predicted by your simulation. How closely do they compare? Did you meet the desired error spec in experiment? Come up with ***two hypotheses*** about effects that could explain some of the difference you see and test these hypotheses in simulation. ***Each of your hypotheses should come from a different category of error sources*** as described below ***and consist of a single change*** (so one parameter change, one input delay, one signal with noise, etc.).

Error source categories you may consider:

Parameter error – Our simulation depends upon a number of vehicle parameters. Think about what parameters the model requires and which of those parameters might be uncertain or vary. If you change a parameter in simulation, does it produce the same "signature" of the differences you see between simulation and experiment? Would reasonable values of parameter error produce the results you see in experiment?

Unmodeled dynamics and delay – We assume that we can produce steering, braking or acceleration immediately in our simulation. In reality, there are additional dynamics associated with these inputs (moving the wheels of the car, pushing fluid to the brakes or pulling additional air and fuel into the engine). If you look at your experimental data, you can get an idea of how long it takes these systems to achieve the desired action and add dynamics to your simulation model to capture this. For example, you can add simple first order dynamics between a desired value of the longitudinal force and the actual value by making the longitudinal force a state and describing the dynamics by:

$$\dot{F_x} = \frac{1}{\tau_{Fx}}(F_{xdes} - F_x)$$

You can similarly do this for the steering. If you match the time constant roughly with your simulation you can evaluate whether or not these unmodeled dynamics have a significant impact on the system's tracking performance.

Sensor noise – You can see from your measurements that there is a certain amount of variability in the signals we use for control. One way to describe this is as sensor noise. With sensor noise, the controller gets a version of the states with some additional noise added on top. While many of you used a purely random variable for this in your initial design, most of the time the noise has a limited frequency range. You can get this effect by passing your random variable through a simple filter such as:

$$\dot{w} = \frac{1}{\tau_w}(v - w)$$

where w represents the noise you add and v represents the random variable. If you play around a bit with the magnitude and variance of v and the filter time constant, you should be able to get something that resembles what you see in experiment.

Process noise – Sometimes what looks like sensor noise is a real measurement. For instance, the "noise" on an accelerometer is generally real acceleration of the vehicle that we are not capturing in our simple model on flat ground. To add this into the simulation, you can simply add noise to the state equations in your model instead of adding it to the measurement you send to your controller.

(2) Controller comparison. Compare the performance between your controller (with gains you got to work experimentally) and the lookahead controller. Which controller did you prefer? What differences did you see in tracking or input noise (as seen in the steering wheel motion)? Offer a convincing explanation for this difference in terms of different pole placement between the controllers or different noise properties of the signals being used as feedback.

That's it. We want you to focus on these particular comparisons and questions. If you observed something else super interesting, by all means include it. However, we don't want a blow-by-blow description of how you got the controller to work. We were there so we remember.