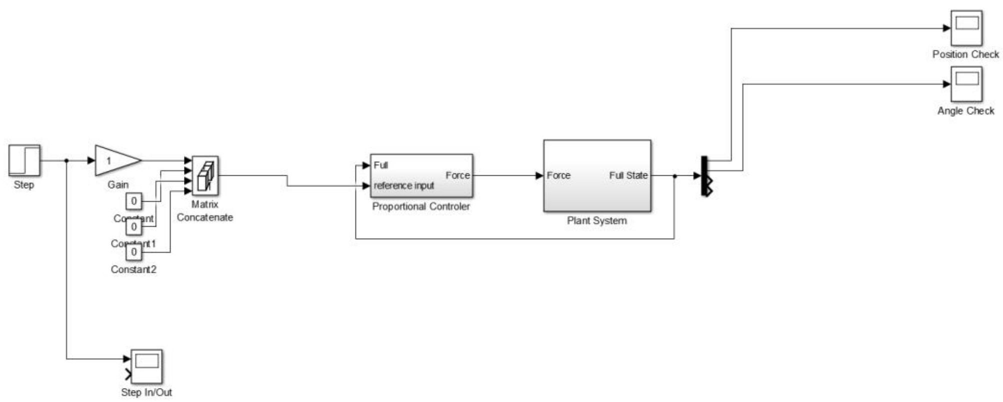
Lukas Gemar, ES158, Lab 4 II

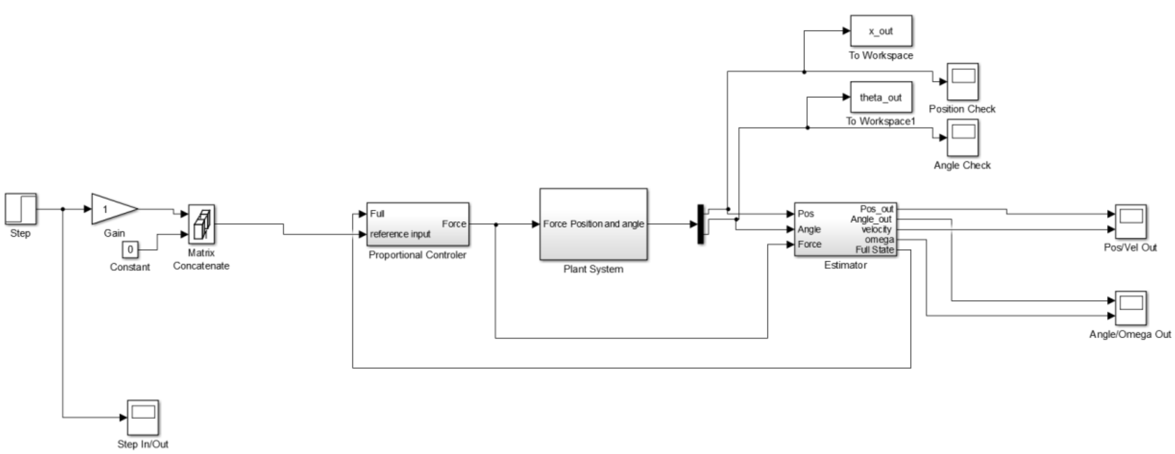
State Feedback Controller

System Diagrams

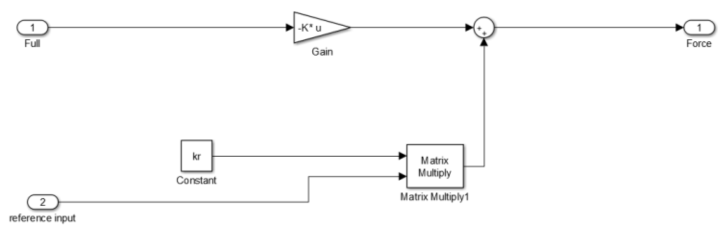
State Feedback Controller (without estimator)



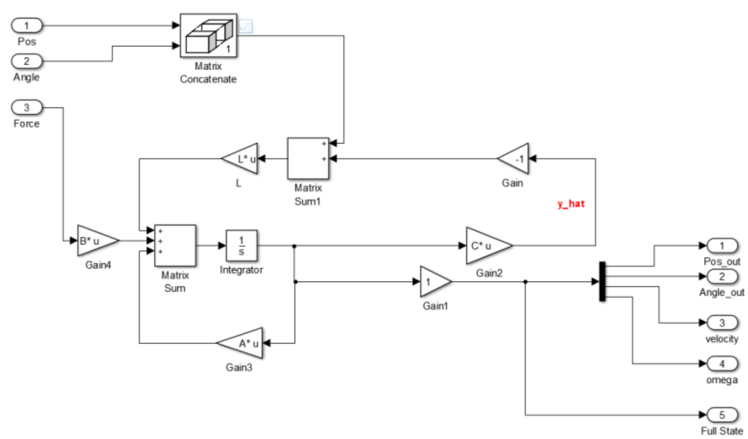
State Feedback Controller (with estimator)



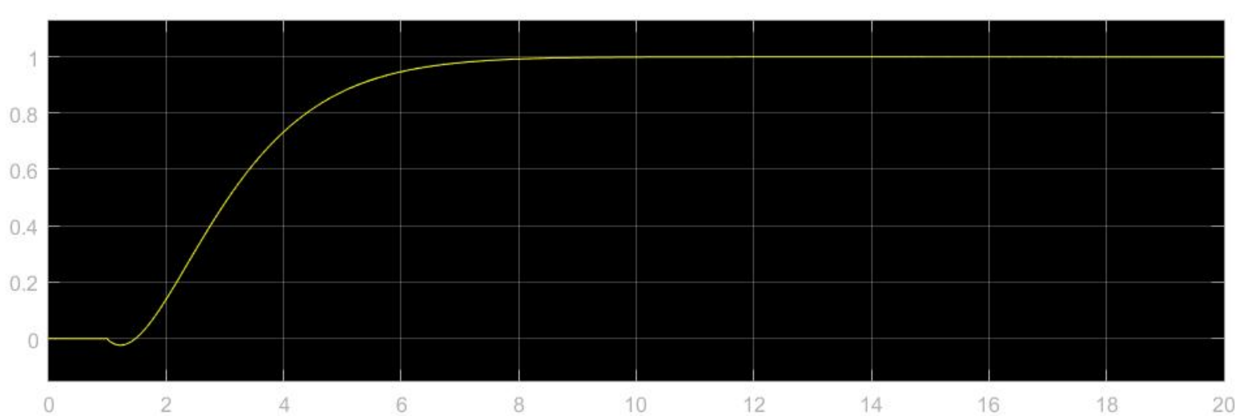
Proportional Controller



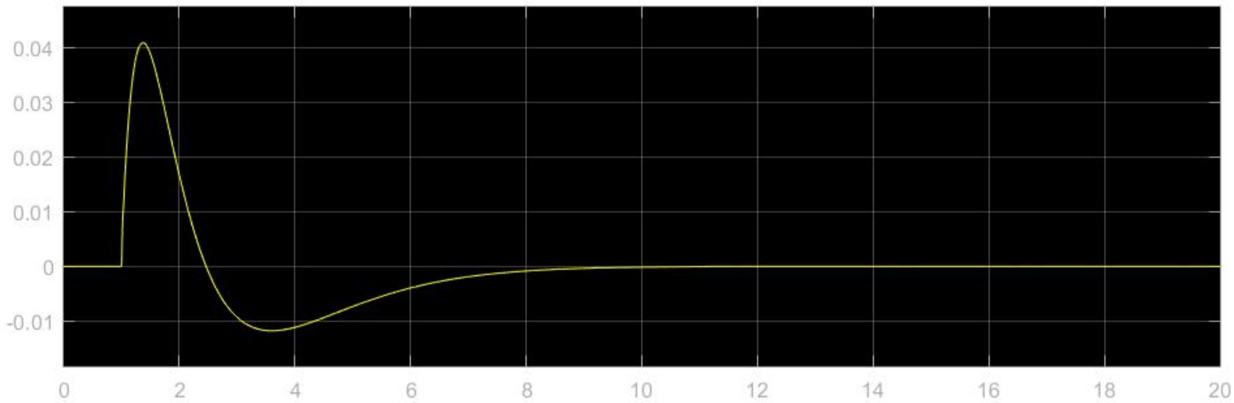
Estimator



Step Response: Position



Step Response: Angle



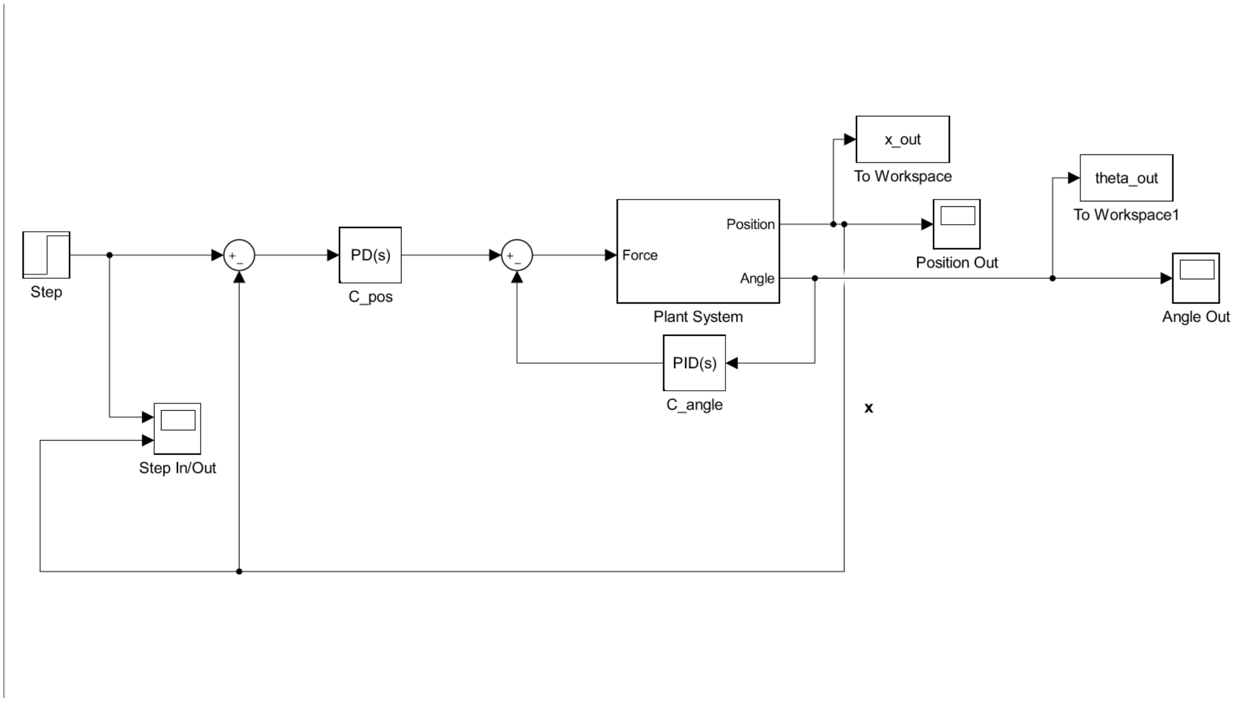
Design and Optimization

The primary parameter that I designed was the K in the controller u = -K * x + k_r * r. First, I designed K by placing the eigenvalues of the A-B*K matrix in the left hand plane (LHP) at values similar to the eigenvalues of the original system defined by A.

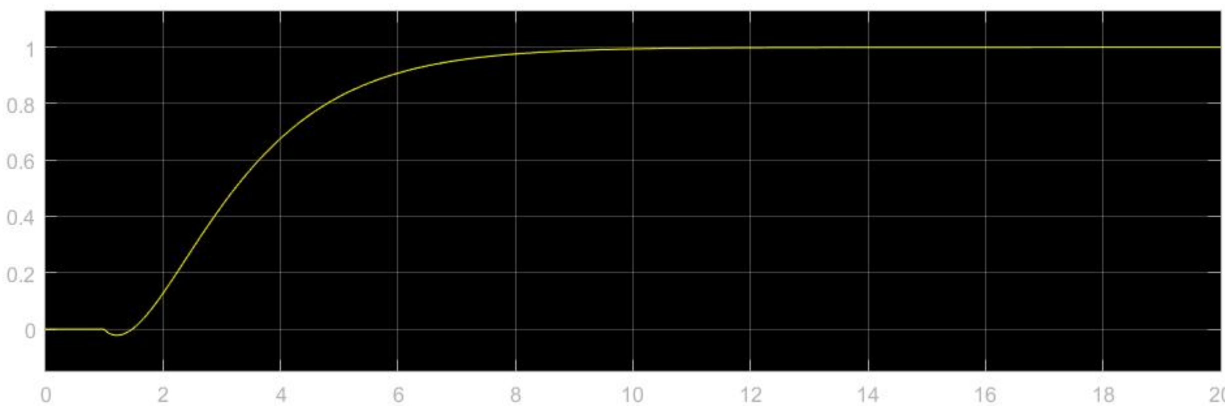
To optimize the system I programmatically looped through various placements of the poles of the A-B*K matrix by defining a range of pole locations. I set the lower and upper limits of the search for poles by trying various pole locations by hand and testing the scores of those locations. Once I determined the bounds for the search, I looped through the values of the poles and saved the scores of all of those locations. I set the poles of A-B*k to be the set of poles that maximized the score.

PID Controller

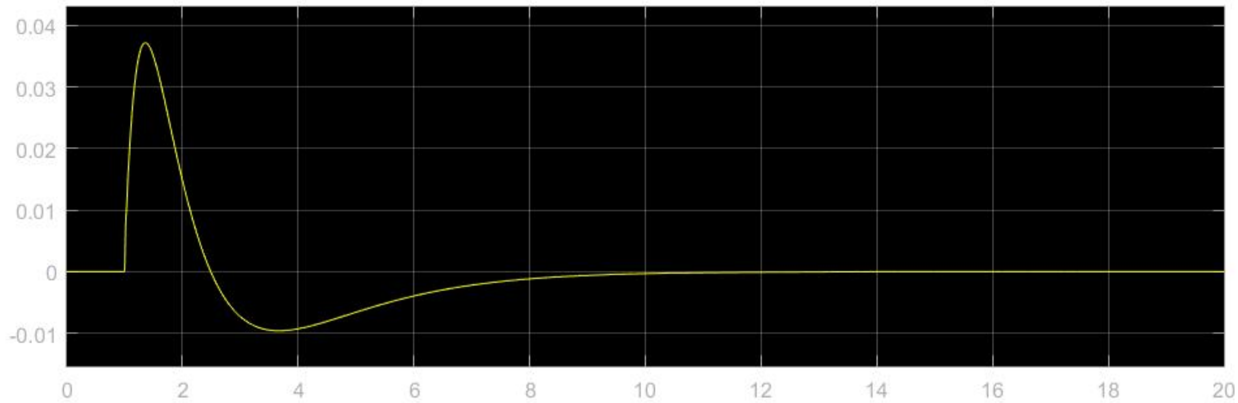
System Diagram



Step Response: Position

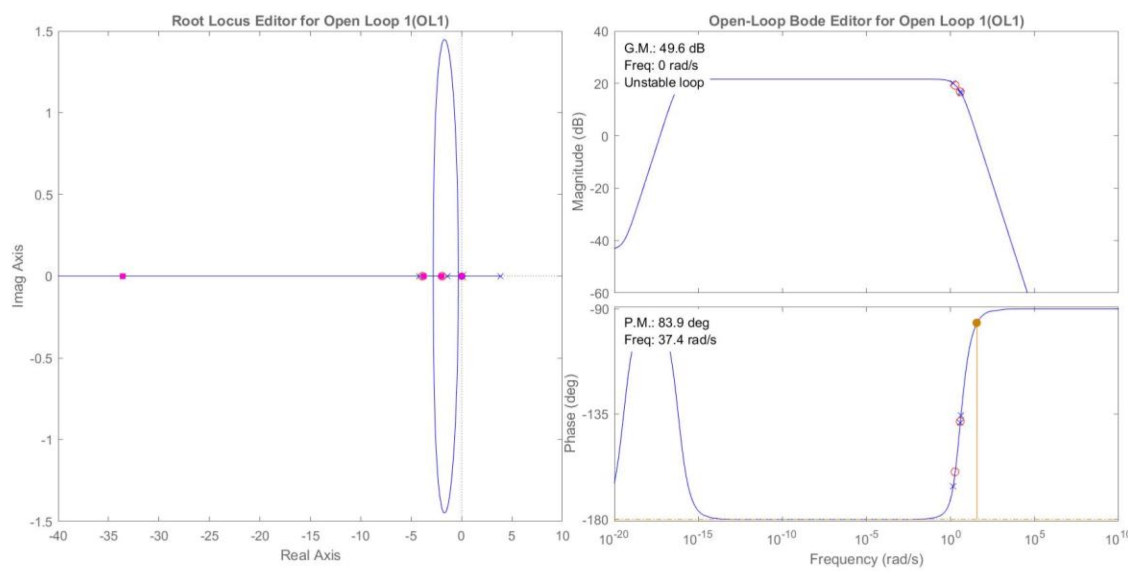


Step Response: Angle

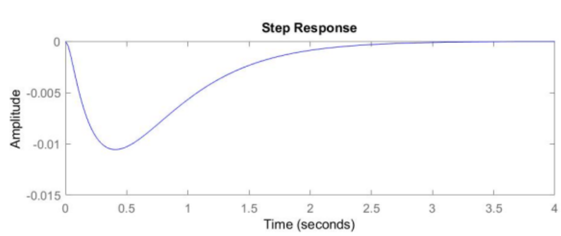


Design and Optimization

To design the PID controller for the inverted pendulum system, I first designed a PID controller for the angle. To design this PID, I used the root-locus plot to place the poles and zeros of the angle controller, C_angle for the plant P_angle. The frequency design is shown below:



Given this frequency design of C_angle, the step response of the plant for the angle (P_angle) is shown in the graph below:

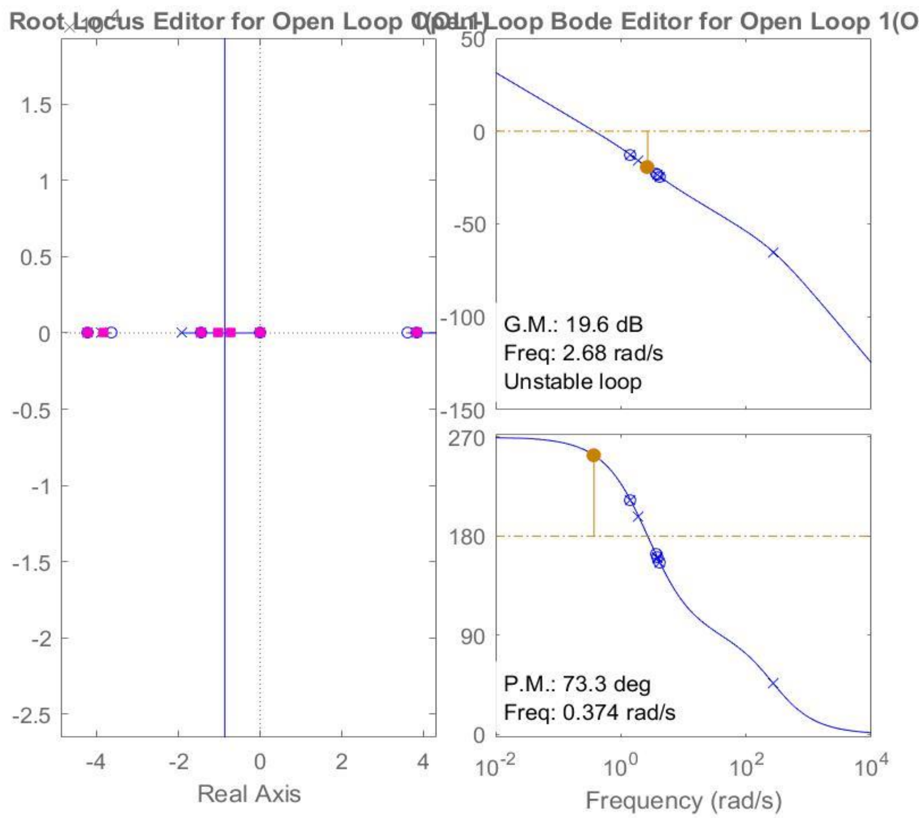


After finding a controller C_angle that could control the angle of the inverted pendulum, I used the PID approach to design a position controller, C_pos. I found that the transfer function from the input force to position – after the PID controller was in place for angle – was given by the equation,

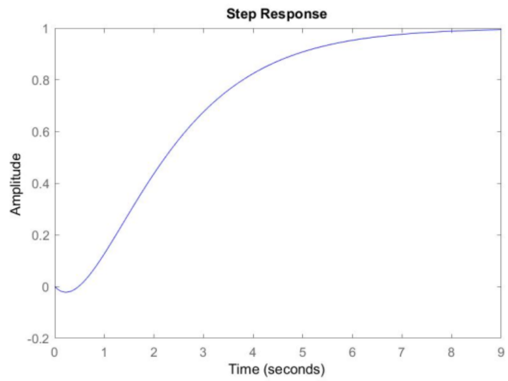
```
x_over_u = P_pos / (1 + P_angle * C_angle);
```

where x_over_u is the transfer function from the input force to the position, P_pos is the plant for the position, P_angle is the plant for the angle, and C_angle is the controller for the angle.

Similar to my design approach for the C_angle controller, I designed the set of parameters for the PID controller by using the root-locus plot. The frequency space design is shown in the graph below:



I found that simply using a proportional controller was sufficient for controlling the position. The step response is shown below:



I optimized the pair of controllers for position and angle by programmatically searching through a set of options for the zeros of the C_angle controller, gain for the C_angle controller, and gain for the C_pos controller. The final set of parameters that I used was the set that produced the maximum score for the controller.

Final Results

Controller	Overshoot, OS_x	Settling Time ST_x	Maximum Angle, M_{theta}	Score
State Feedback	0	15.43	0.0095	119.40
PID	0	9.21	0.0372	117.96