MODULE 7 SOLUTIONS - ECE 147B

1. The first problem considers two additional designs of the satellite dish network introduced in the module. Design (1) is to have relatively aggressive pole locations, and design (2) is to have significantly more sedate locations. The pole locations for design (1) should be fairly close to the origin, and a valid choice would be z=0 and z=0.02. Figure (a) shows the response of the angle plotted over the control input. As expected, the angle of the satellite stays very close to the origin even in the presence of the wind signal.

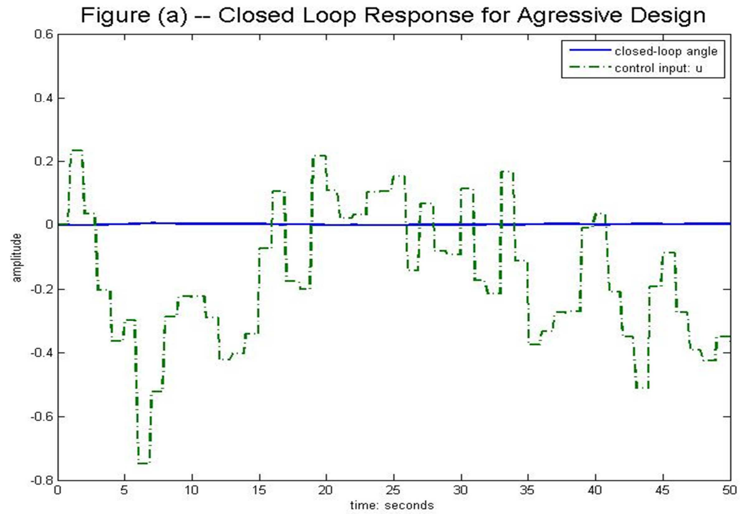
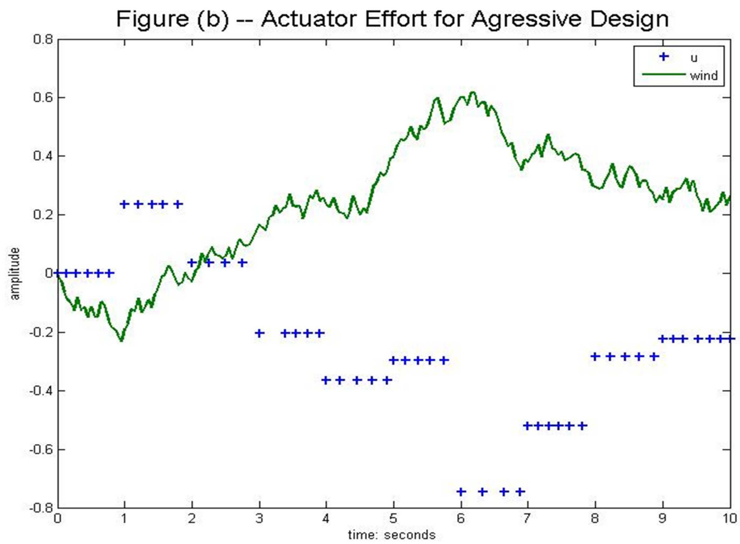


Figure (b) below shows the actuator effort plotted against the wind signal for the first 10 seconds of the simulation. As expected, the controller works in the opposite direction as the wind is pushing to align the satellite.



Design (2) must have poles far away from the origin, and one example of a valid choice is z=0.7 and z=0.9. Figure (c) shows the response of the angle plotted against the control output. Here we see that the angle has a minor oscillation on the presence of the wind, and since the controller is not as aggressive as the previous design it is not able to keep it quite as stabilized exactly on equilibrium.

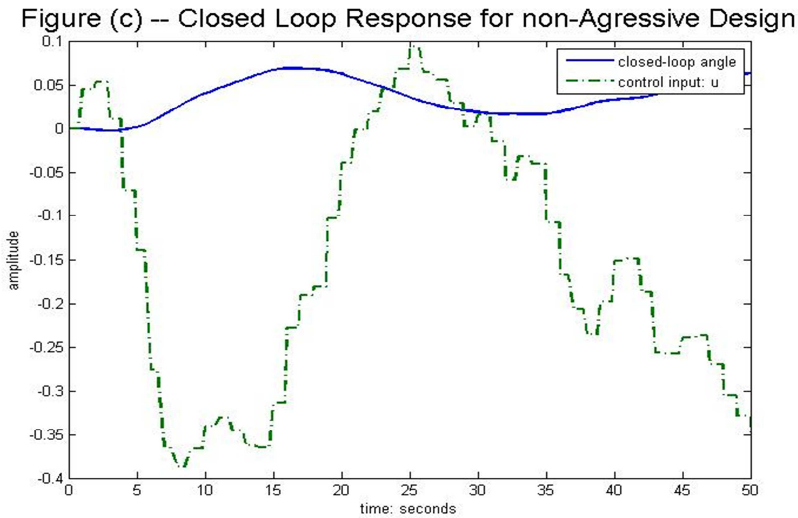
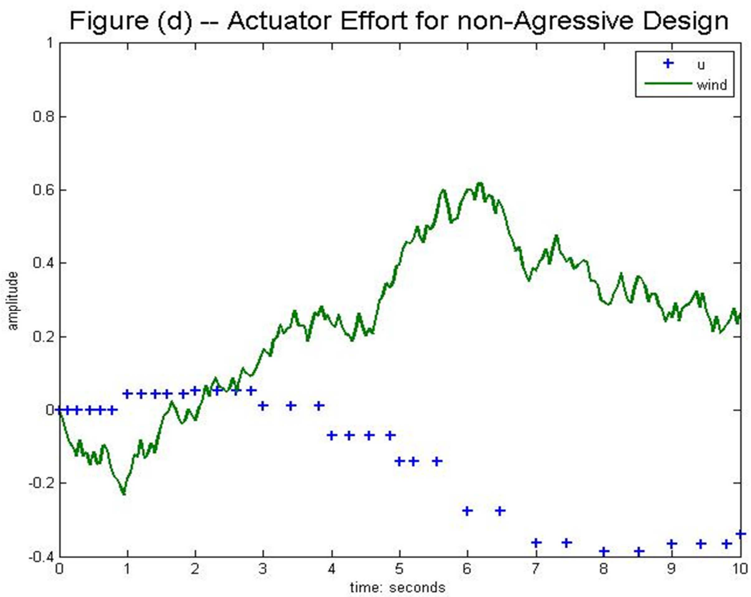


Figure (d) below shows the actuator effort plotted against the input wind signal.

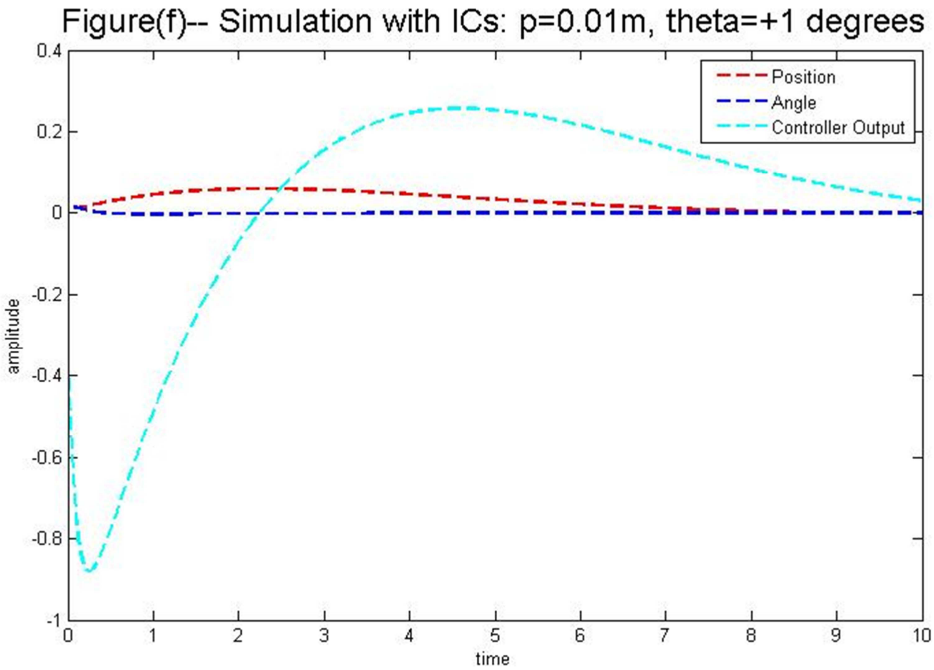


Comparing figures (d) to (b) we see that the aggressive design requires a maximum close to 0.8 volts, whereas the non-aggressive design only requires a maximum of 0.4 volts. The aggressive nature of figure (b) allows the control signal to better track the wind signal, which is why the angle of the more aggressive design has less error. Ultimately, there is some trade-off between acceptable error in the presence of a disturbance and actuator effort.

2. This problem considers the design of the controller for an inverted pendulum, very similar to that seen in LAB3. The first step is to convert the continuous-time state-space model to a discrete model using the ZOH equivalence, and calculate the state-feedback gain K for the given pole locations: 0.75, 0.84, 0.99 +- 0.01i. The resulting K matrix is:

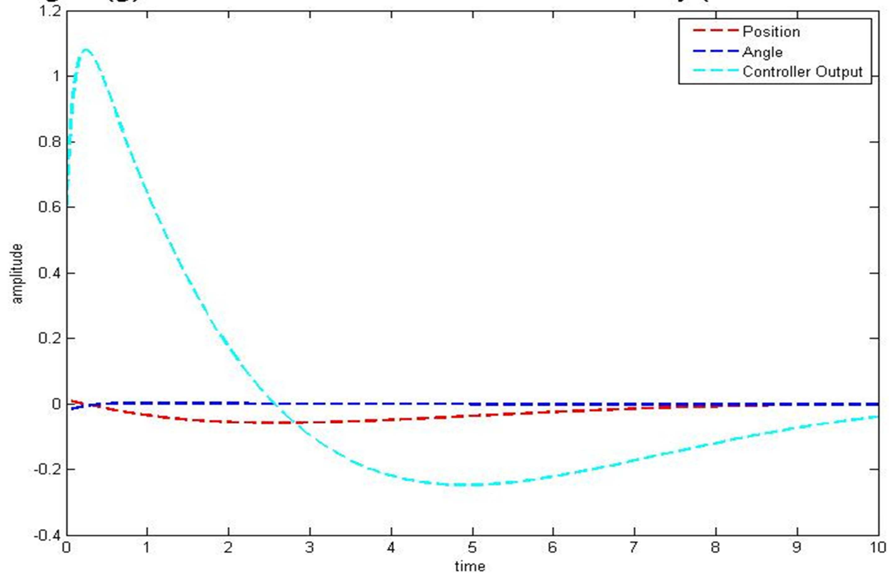
$$K = [-19.65 - 3.37 - 0.24 - 20.78] \qquad (1)$$

The simulation seen below in figure (f) showcases the response of the system to initial conditions p=0.01 and theta =1 degrees.



Here we see the response of the system is fine. The position and angles are able to stabilize after a few seconds, and the actuator output does not exceed the maximum value of one volt. Next, another initial condition of the **same size** is examined. This means that both p and theta must have the same magnitude as the simulation seen in (f). One acceptable initial condition could be to simply give the velocity states a very small offset. Setting the position velocity state to -0.1 m/s yields the simulation shown on the next page on figure (g). This controller now (barley) exceeds our requirement of <1 volt actuator output and must be redesigned.

Figure(g)-- Simulation with increased initial velocity (same controller)



Redesigning the controller so that the complex poles are brought in away from the unit circle slightly while bringing the two real poles very close to z=1 results in a new K matrix:

$$K = [-38.5 - 6.37 - 2.15 - 22.78] \quad (2)$$

The resulting simulation is shown below, and clearly now the response is both faster and no longer exceeds the required 1 voltage output of the actuator.

Figure(h)-- Simulation with increased initial velocity (new controller)