Class Project for Control Theory (AI3206)

Submission Deadline: 20th May, 2023.

This project has two broad purposes: (i) do a full-fledged controller design using root locus technique, and (ii) learn to simulate dynamical systems using Python.

We want to control the angle of attack of an F-16 aircraft. The *linearized* model relating the angle of attack (this is the *output*), θ, to elevator deflection (this is the *input*), δ, can be *approximated* as,

$$G(s) = \frac{\theta(s)}{\delta(s)} = \frac{(s+23)}{(s^2+s-1.19)} \qquad (1)$$

Question 1: Is the open loop system stable or unstable? Why?

Rather than using pen-and-paper to answer this question, you may choose to plot the *pole-zero plot* using Python. You may choose to use the function *control.TransferFunction* from Python library called *control* to define the system and then use *control.pzmap* to plot the pole-zero plot.

Question 2: Obtain the response of the open loop system to unit step input using Python.

You may choose to use the function *control.forced_response* to simulate the system. Just a suggestion, don't simulate for more than 5 seconds.

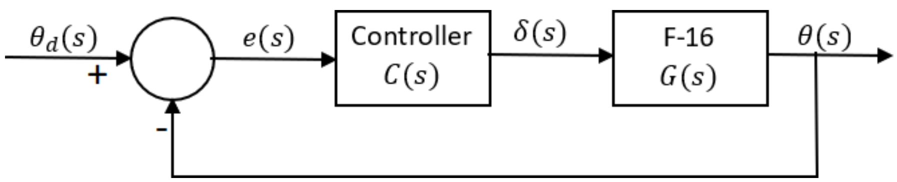

Figure 1: Closed loop control of angle of attack of F-16 where $G(s)$ is given by equation (1).

Question 3: Consider the closed loop control system shown in Figure 1. Let's represent the controller as,

$$C(s) = \frac{\mathcal{C}(s)}{s^N} \qquad (2)$$

where $\mathcal{C}(s)$ is a *Type-0 system* and $N = 0,1,2,\ldots$ Let $\mathcal{C}(s)$ be such that the closed loop system is stable. Then, what is the *minimum* value of N such that the closed loop system has *zero steady state error* for a step input? Hint: Use equation 10 of lecture 13 notes.

Question 4: Design controller $C(s)$ of Figure 1 such that *(i)* the steady state error is zero for a step input, *(ii)* settling time for 2% settling accuracy is 0.05 seconds, and *(iii)* percent overshoot is not greater than 20%. To account for the settling time requirement you may assume that the 2% settling time of a prototype 2nd order system is given by $\frac{4}{\xi\omega_n}$. Hint: You may follow the steps of lecture 20 and 21 notes.

Question 5: Simulate the response of the closed loop system to unit step input using Python.

You may choose to use the function *control.feedback* and *control.series* to obtain the closed loop transfer function rather than doing all the calculations using pen-and-paper.

Question 6: Based on your simulation for Question 5, did the controller fulfill all the design requirements? If not, can you explain possible reasons why this happened?

Drawing the pole-zero plot may help. You should also remember that both poles and zeros determine the transient response.

(You can skip this question if your controller fulfills all the design requirements.)

Question 7: How would you change the *overshoot requirement during the design process* such that the final closed loop system satisfy all the design requirements mentioned in Question 4? Accordingly, redo controller design until all the design requirements mentioned in Question 4 are satisfied.

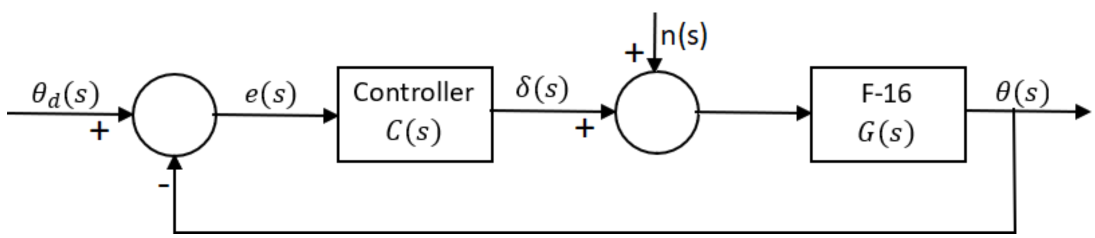

Figure 2: Closed loop control system in presence of noise n.

Question 8: Finally, we want to test the performance of the controller that we have designed in presence of noise. Use Python to obtain the time response of the closed loop system when the noise on Figure 2 is given by $n(t) = sin(200t)$ and the set point signal θ_d is as shown in the following graph,