EE5103/ME5403 Computer Control Systems: Homework #3
(Due date: 17/10/2021)

Q1. (10 Marks)
Consider the system given by the transfer function

$$H(z) = \frac{z + 0.8}{z^2 - 1.5z + 0.5}$$

Use polynomial design to determine a controller in the form of

$$R(q)u(k) = T(q)u_c(k) - S(q)y(k)$$

such that the closed-loop system has the characteristic polynomial

$$A_m(z) = z^2 - 1.8z + 0.9$$

Let the polynomial $A_o(z)$ have as low order as possible and place all of its poles in the origin. Design the controller such that the steady-state gain from the command signal $u_c(k)$ to the output $y(k)$ is one. Consider the following two cases:

a) The process zero is canceled.

(4 Marks)

b) The process zero is not canceled.

(4 Marks)

Simulate the step responses of the two cases (letting $u_c(k) = 1$), and plot out the corresponding output and input signals. Discuss the differences between the two controllers. Which one should be preferred?

(2 Marks)

Q2. (10 Marks)
Given the discrete-time system

$$x(k+1) = \begin{pmatrix} 0.5 & 1 \\ 0.5 & 0.8 \end{pmatrix} x(k) + \begin{pmatrix} 0.2 \\ 0.1 \end{pmatrix} u(k) + \begin{pmatrix} 1 \\ 0 \end{pmatrix} v(k)$$

$$y(k) = \begin{pmatrix} 1 & 0 \end{pmatrix} x(k)$$

where v is a constant disturbance.

a) Assume that only the output can be measured, derive the transfer function of the process. Use the transfer function approach to determine a controller such that the influence of v can be eliminated in steady state.

(8 Marks)

b) Compare the design with that of Prob.2 in Homework #2. Which one is simpler?

(2 Marks)

Q3. (10 Marks)

Assume that the process is described by the transfer function

$$H(z) = \frac{z - 0.5}{z^2 - 1}$$

The reference model is specified as

$$H_m(z) = \frac{1}{z^2}$$

a) Design a controller in the form of

$$R(q)u(k) = T(q)u_c(k) - S(q)y(k)$$

to make the closed-loop transfer function match the reference model as close as possible. Also try to make the controller reject constant disturbance.

(5 Marks)

b) Design a two-degree-of-freedom controller in the form of

$$u(k) = u_{fb}(k) + u_{ff}(k)$$

where the feedback control signal $u_{fb}(k)$ is generated by the feedback controller

$$U_{fb}(z) = -\frac{S(z)}{R(z)}Y(z)$$

and the feed-forward control signal $u_{ff}(k)$ is produced by the feed-forward controller

$$U_{ff}(z) = H_{ff}(z)U_c(z)$$

Design the feedback controller and feed-forward controller properly to follow the same reference model and to reject constant disturbance.

(5 Marks)

Q4. (10 Marks)

A nonlinear process is described by the input-output model

$$y(k+1) = cy(k) + y^2(k-1) + u(k-1)$$

where c is a constant parameter.

a) Design a one-step-ahead controller to make the output of the system, $y(k)$, follow any arbitrary desired output, $r(k)$.

(7 Marks)

b) Discuss the condition on the parameter c such that perfect tracking is attainable.

(3 Marks)