INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics and Control
Assignment 1

Due: Tuesday, February 23, 2021 11:55 PM

Exercise

1. Consider a household storage geyser that provides hot fluid stream to the user by heating the incoming cold water. Do / answer each of the following:
   (a) Classify the process as a continuous / batch / fed-batch process.
   (b) Identify the controlled variables, manipulated variables, and disturbance variables.
   (c) Propose a feedback control method and sketch the schematic diagram.
   (d) Suggest a feed-forward control method and sketch the schematic diagram.

2. An input-output dynamical system is governed by

$$\frac{d^2y}{dt^2} + a_1\frac{dy}{dt} + a_0 y(t) = b_0 u(t), \qquad a_1 = 8,\ a_0 = 15,\ b_0 = 3$$

   (a) Re-write the ODE in terms of deviations from steady-state, $\tilde{u}(t) = u(t) - u(0)$, $\tilde{y}(t) = y(t) - y(0)$, where $u(0)$ and $y(0)$ are the steady-state input and output, respectively.
   (b) AahaOohu wishes to increase the steady-state value of output by 2 units. To realize this objective, he decides to change the input by a fixed value. Determine the amount of change in input that is required.
   (c) Due to uncertainties in a_0 and b_0, AahaOohu wishes to deploy a feedback strategy by changing the input proportional to the error $\tilde{u}(t) = K_c e(t)$, where $e(t) = 2 - \tilde{y}(t)$. Will the control objective be achieved for any finite value of $K_c > 0$?
   (d) In a different scheme of feedback control, AahaOohu changes the rate of input as $\dot{\tilde{u}}(t) = K_c\dot{e}(t) + K_I e(t)$. Will the control objective be achieved for any value of K_c and K_I?

3. Consider the following model of 2-stage absorption model:

$$\frac{dw}{dt} = -\frac{L + Va}{M}w + \frac{Va}{M}z$$
$$\frac{dz}{dt} = \frac{L}{M}w - \frac{L + Va}{M}z + \frac{V}{M}z_f$$

   where w and z are liquid concentrations on stage 1 and 2, respectively. L and V are the liquid and vapour molar flow rates, z_f si the concentration of the vapour stream entering the column.

   The steady-state input values are $L = 80$ gmol inert liquid/min and $V = 100$ gmol inert vapour/min. The parameter values are $M = 20$ gmol inert liquid, $a = 0.5$ and $z_f = 0.1$ gmol solute / gmol inert vapour.

   Do / answer each of the following:

(a) Find the steady-state values of w and z.

(b) Obtain a linearized state-space model around the normal steady-state operation assuming that L and V are the inputs.

(c) Find the eigenvalues of the system. What are the expected "slowest" and "fastest" initial condition directions of the system?

(d) Set up the non-linear system in MATLAB. Solve for steady-state and obtain a linearized model using the linear analysis tools in MATLAB/SIMULINK.

(e) Plot and compare the step responses of the non-linear system with that of the linearized model for two different magnitudes of steps (i) 5% and (ii) 15% change in the flow rate.

4. Answer the following

(a) Find the Laplace Transform of the signal $x(t) = \begin{cases} t-2 & 0 \le t < 3 \\ 1 & 3 \le t < 4 \\ -\cos(3\pi(t-4)) & 4 \le t < 5 \\ e^{-2(t-5)}\cos(5\pi(t-5)) & t \ge 5 \end{cases}.$

(b) Find the inverse Laplace transform of $X(s) = \dfrac{(s-2)}{s(\tau^2 s^2 + 2\zeta\tau s + 1)}$, where $\tau > 0$. Consider three different cases: (i) $\zeta > 1$, (ii) $\zeta = 1$ and (iii) $0 \le \zeta < 1$