INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics and Control
Assignment #4

Due: Saturday, April 24, 2021

Exercises

1. An operator introduces a step change in the flow rate F_i to a particular process at 9:05 A.M., changing the flow from 500 to 540 l / min. The first significant change in the process temperature T (initially at 50$^\circ C$) occurs 9:09 AM. Subsequently, response in temperature is quite rapid, slowing down gradually until it appears to reach a steady-state value of 55.7 $^\circ C$. The operator notes in the logbook that there is no change after 9:34 A.M. What approximate TF might be used to relate temperature to flow rate for this process in the absence of more accurate information? What should the operator do next time to obtain a better estimate?

2. Consider a process whose TF is given by $G(s) = \dfrac{(2s+1)e^{-3s}}{(20s+1)(15s+1)(4s+1)(0.5s+1)}$

   (a) Simulate the step response of this system and fit an FOPTD model using Krishnaswamy and Sundaresan's method (of two points)

   (b) From the transfer function, directly obtain the FOPTD and SOPTD approximations using Skogestad's half-rule method

   (c) Fit an SOPTD model using the frequency-domain (magnitude and phase) least-squares approximation method.

   (d) Compare the step responses of the models obtained in parts (a)-(c) with that of the original one. Tabulate your observations.

3. It is desired to develop an empirical model for a process. The exercise will provide insights into the data generation and subsequent model identification.

   (a) Assume that the process is $G(s) = \dfrac{4(-s+1)e^{-2s}}{(6s+1)(8s+1)}$. Set up the SIMULINK diagram for the sampled-data system consisting of a ZOH, the process and the sampler in series. Choose $T_s = 0.8$ s.

   (b) Design a pseudo-random binary signal (PRBS) input sequence. Use the `idinput` routine for this purpose. Generate $N = 2555$ long sequence with $B = 0.2$ and amplitudes between -2 and 2. Simulate the process using this input to the ZOH. Add measurement noise (of variance 1.2) at the output to obtain the measurement $y[k]$. Partition the data into **training** and **test** data sets.

   [For the remainder of this exercise, you shall assume that no process knowledge is available.]

(c) Estimate the non-parametric, i.e., response-based models to obtain estimates of delay, steady-state gain and qualitative guess of the process order.

(d) Next assume an appropriate model for the system,

$$y^\star[k] + \sum_{i=1}^{n} a_i y^\star[k-i] = \sum_{j=d}^{m} b_j u[k-j] \tag{1}$$

where the values of d, m and n have to be chosen as per your analysis of impulse and step responses (you are **not allowed** to use any knowledge of the process). Assuming white-noise errors in the measurements, estimate the parameters of (1) using the `oe` routine.

(e) Assess the goodness of the model estimated in (3d) for underfit using the residual analysis. Use the `resid` routine for this purpose. Is the model satisfactory? If no, refine the model structure (by increasing the output and/or input orders) until the model passes this test satisfactorily. Subsequently, examine the errors in parameter estimates (using the `present` routine) and compare the gains of this model and the one obtained in (3c).

(f) Report the final **discrete-time** model after cross-validation with the **test** data.