CL 686 : Advanced Process Control
Nonlinear System 1 (Group A)

1. **Use your program for Computing Assignment 1 to simulate the system under the following conditions**

   (a) **Measurement Outputs:** X_2 (reactor fluid temperature) and X_3 (reactor cooling jacket fluid temperature)

   $$\mathbf{Y}(k) = \mathbf{C}\mathbf{X}(k) + \mathbf{v}(k) \tag{1}$$

   $$\mathbf{C} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad and \quad \mathbf{v}(k) = \begin{bmatrix} v_1(k) \\ v_2(k) \end{bmatrix} \tag{2}$$

   where $v_1(k)$ is a zero mean normally distributed random number with $\sigma_{v_1} = 0.2$ and $v_2(k)$ is a zero mean normally distributed random number with $\sigma_{v_1} = 0.25$.

   (b) **Steady state inputs:**

   $$\mathbf{U}_s = \begin{bmatrix} 120 & 30 \end{bmatrix}^T \quad ; \quad D_s = 1 \tag{3}$$

   (c) **Equilibrium/ Steady State Operating Point**

   $$\mathbf{X}_s \equiv \begin{bmatrix} 0.0192 & 384.0056 & 371.2721 \end{bmatrix}^T \tag{4}$$

   (d) **Random noise in disturbance input D:**

   $$D(k) = D_s + d(k) \tag{5}$$

   where $d(k)$ is a zero mean normally distributed random number with $\sigma_d = 0.015$.

   (e) **Sapling interval (h) and simulation time**:

   $$T = 0.1 \text{ min} \quad \text{and} \quad t_f = 100 \text{ min}$$

   (f) **Manipulated input simulation:** Random Binary Input

   $$RBS\_Period = \begin{bmatrix} 25 & 30 \end{bmatrix}^T \quad \text{and} \quad RBS\_amplitude = \begin{bmatrix} 10 & 4 \end{bmatrix}^T$$

2. Identify two 3'rd order MISO ARX models using the simulation data over time interval time $0 \leq t \leq 75$ and construct a MIMO state space model of the

   $$\begin{aligned} \mathbf{x}(k+1) &= \mathbf{\Phi}\mathbf{x}(k) + \mathbf{\Gamma}\mathbf{u}(k) + \mathbf{L}\mathbf{e}(k) && (6) \\ \mathbf{y}(k) &= \mathbf{C}\mathbf{x}(k) + \mathbf{e}(k) && (7) \end{aligned}$$

   as explained in the generic assignment description.

3. Use simulation data over interval $75 \leq t \leq 100$ to validate the model as follows

(a) **One step predictions**

$$\widehat{\mathbf{y}}(k) = \mathbf{C}\widehat{\mathbf{x}}(k) \tag{8}$$

$$\mathbf{e}(k) = \mathbf{y}(k) - \widehat{\mathbf{y}}(k) \tag{9}$$

$$\widehat{\mathbf{x}}(k+1) = \Phi\widehat{\mathbf{x}}(k) + \Gamma\mathbf{u}(k) + \mathbf{L}\mathbf{e}(k) \tag{10}$$

(b) **Model Simulation**

$$\widetilde{\mathbf{x}}(k+1) = \Phi\widetilde{\mathbf{x}}(k) + \Gamma\mathbf{u}(k) \tag{11}$$

$$\widetilde{\mathbf{y}}(k) = \mathbf{C}\widetilde{\mathbf{x}}(k) \tag{12}$$

4. Plot $y_i(k)$ v/s time, $\widehat{y}_i(k)$ v/s time and $\widetilde{y}_i(k)$ v/s time in same figure for i = 1, 2

5. Compare step responses of linearized discrete time model with identified discrete time model using *step* command in Matlab control system toolbox. (You need to create discrete time state space objects using *ss* command in Matlab to use *step* command).