[December 13, 2021] **CHEM-E7190 (Exam)**

Exercise 01. The linearisation of a state-space and instrument process model around some steady-state operating point (x_{SS}, u_{SS}) leads to the following linear and time-invariant (LTI) dynamics and measurement equations:

$$\dot{x}(t) = \begin{bmatrix} 0 & -6 \\ 1 & -5 \end{bmatrix} x(t) + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u(t) \tag{1a}$$

$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} x(t) + \begin{bmatrix} 0 \end{bmatrix} u(t) \tag{1b}$$

(10%) Briefly define what is the meaning of Eq. (1a) and Eq. (1b). For each equation, use simple words and max two short sentences;

(10%) Briefly define what the process variables $\dot{x}(t)$, $x(t)$, $u(t)$, and $y(t)$ are and determine how many (their dimension) of each are used in Eq. (1). For each variable, use simple words and max two short sentences;

(10%) Identify all the matrices involved in the model (state-state, input-state, state-output, and input-output matrix) and determine their size.

Exercise 02. We are interested in controlling the process system above using a state-feedback approach. For the task, we must firstly verify that the system is both controllable and observable and then design a state feedback controller and a state observer that operate together with the system.

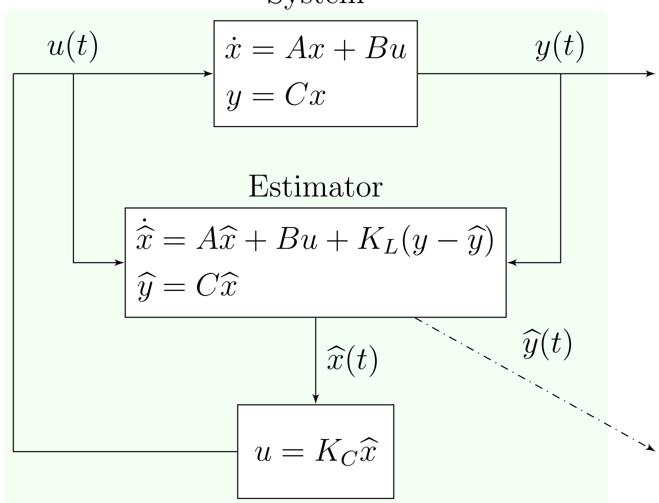
(10%) Define the notion of controllability and what a feedback controller does. Use simple words and max three short sentences;

(10%) Define the notion of observability and what a state observer does. Use simple words and max three short sentences;

(10%) Define the controllability matrix and compute it for the system in Eq. (1). Can you determine from the controllability matrix that you computed whether the system if controllable?

(10%) Define the observability matrix and compute it for the system in Eq. (1). Can you determine from the observability matrix thst you computed whether the system if observable?

The block-diagram representing the system-observer-controller is below



The observer is given by

$$\dot{\widehat{x}}(t) = A\widehat{x}(t) + Bu(t) + K_L(y(t) - \widehat{y}(t)); \tag{2a}$$
$$\widehat{y}(t) = C\widehat{x}(t). \tag{2b}$$

The controller is given by

$$u(t) = K_C\widehat{x}(t). \tag{3}$$

(10%) Briefly define what is the meaning of Eq. (2a), Eq. (2b), and Eq. (3). For each equation, use simple words and max four short sentences;

(10%) Briefly define what the process variables $\dot{\widehat{x}}(t)$, $\widehat{y}(t)$ are and determine how many (their dimension) of each are used in the model in Eq. (1). For each variable, use simple words and max two short sentences;

(10%) Define all new matrices involved (K_L and K_C) and determine their size.