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Advanced Process Control - Tutorial 3 **WS 10/11**

State Estimation - Dealing with noise and model errors

Quickies

1. Does "the system is unobservable" mean that a system observer will always fail?
2. Why is a Luenberger Observer a powerful estimator in a closed loop system?
3. Your task is to design a Luenberger Observer for a given full observable system. Can you place the eigenvalues of the observer arbitrarely or are there any restrictions?
4. What is the basic principle of a Kalman Filter?
5. What are the design parameter of a Kalman Filter?

Exercise - State Estimation

Consider the continuously stirred tank reactor (CSTR) with a reaction from tutorial 1:

$$A \xrightarrow{k_{AB}} B \underset{k_{CB}}{\overset{k_{BC}}{\rightleftharpoons}} C. \tag{1}$$

Assume that the total volume entering is equal to the volume leaving the system: $\dot{V}_{in} = \dot{V}_{out} = \dot{V} = const$. The input of the system is the concentration of component A at the reactor inlet (c_{A0}) , the measured output the concentration of component B (c_B). The component balances are:

$$\frac{d}{dt}c_A = \frac{\dot{V}}{V_R}(c_{A0} - c_A) - k_{AB}c_A \tag{2}$$

$$\frac{d}{dt}c_B = -\frac{\dot{V}}{V_R}c_B + k_{AB}c_A + k_{CB}c_C - k_{BC}c_B \tag{3}$$

$$\frac{d}{dt}c_C = -\frac{\dot{V}}{V_R}c_C + k_{BC}c_B - k_{CB}c_C \tag{4}$$

with $c_{A0} = 1$, $k_{AB} = 1.5$, $k_{BC} = 3$, $k_{CB} = 2$, $\dot{V} = 1$ and $V_R = 10$.

The measurement as well as the system is not free of noise. The task is to design a Luenberger observer as well as a Kalman Filter and to compare the performances.

1. Observer Design
   Design both a Luenberger observer and a Kalman Filter for the given system. Construct the feedback matrix K of the Luenberger observer by pole placement and the Kalman Filter Gain by choosing appropriate covariance matrices Q, R, and $P(0)$. Play with the design parameters and comment observations. The initial state values are $x_0 = [0.2, 0.2, 0.2]$. Please download the zip-file "model.zip" and extract it in your APC folder. You don't have to care about the folder "model", but please open `A1_Linear_System_Luenberger.m` and `A2_Linear_System_Kalman.m` In these m-files everything is implemented, you only have to play with the design variables. If you have questions concerning the implementation, feel free to ask.

2. Observer Design with plant model mismatch
   In this part the task is to design an observer where the observer model differs from the plant model. Try to find some proper eigenvalues for the Luenberger observer and covariance matrices Q, R, and $P(0)$ for the Kalman Filter. What can be observed? Try to explain it! x_0 remains the same. Please open `A3_Linear_System_Plant_Model_Mismatch.m` and play with the design variables.