Homework Set #5
Due: Wednesday, November 27, 2013.

Please Read Chapter 3 and 4. Please read related part of Appendix B. Type and run all MATLAB programs provided in those pages.

1. As we are about to start Control Systems Design part of the course, it would be motivating to learn about the impact of Control Engineering in different aspects of our lives. In this problem, you are asked to investigate major achievements of control engineering and its visible or invisible impacts on our daily lives and different areas including production, security, health, environment and space science. The document in the following link is a perfect starting point:

http://ieeecss.org/general/impact-control-technology

Based on this document provide a list of major achievements of control engineering and their direct and indirect impacts in your own words. Then choose one particular achievement that is of interest to you, and investigate this area more in different resources and provide a two paragraph summary, again in your own words. Please also provide the list of references you used.

2. Find the transfer function corresponding to the following state space representation

\[
A = \begin{bmatrix}
-44 & 18 & 2 & 14 \\
-45 & 18 & 2 & 15 \\
-45 & 18 & 1 & 14 \\
-45 & 17 & 2 & 14 \\
\end{bmatrix} \quad B = \begin{bmatrix}
\frac{1}{17} \\
\frac{1}{17} \\
\frac{1}{12} \\
\end{bmatrix} \\
C = \begin{bmatrix}
1 & 0 & -10 & 9 \\
\end{bmatrix} \quad D = 0
\]

Show all your intermediate states of your derivation.

3. This example serves as a simple illustration of the potential of system modelling and control in Health related applications. In the past, Type-1 diabetes patients had to inject themselves with insulin three or four times a day (currently many diabetes patients still do that!). New delayed-action insulin analogues such as insulin Glargine require a single daily dose. A similar procedure to the one described in the Pharmaceutical Drug Absorption case study (in Chapter 3 of the textbook) is used to find a model for the concentration-time evolution of plasma for insulin Glargine. For a specific patient state-space model matrices are given by

\[
A = \begin{bmatrix}
-0.435 & 0.209 & 0.02 \\
0.268 & -0.394 & 0 \\
0.227 & 0 & -0.03 \\
\end{bmatrix} \quad B = \begin{bmatrix}
1 \\
0 \\
0 \\
\end{bmatrix} \quad (1) \\
C = \begin{bmatrix}
0.003 & 0 & 0 \\
\end{bmatrix} \quad D = 0, \quad (2)
\]
where the state vector is given by

\[ x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}. \quad (3) \]

The state variables are

- \( x_1 \): insulin amount in plasma compartment,
- \( x_2 \): insulin amount in liver compartment,
- \( x_3 \): insulin amount in interstitial (in body tissue) compartment.

The system’s input is

- \( u \): external insulin flow,

and the system’s output is

- \( y \): plasma insulin concentration.

(a) Find the transfer function of the system (show the details of your calculation).

(b) Implement this state space model in simulink and obtain the unit step output. Print your output plot. Please submit your simulink file to F:\COURSES\UGRADS\ELEC\ELEC304\HOMEWORK\HOMEWORK5

\[ \text{Figure 1: Carbon Cycle model.} \]
4. This example shows the potential application of the mathematical system modelling tools we learned in this course on environmental issues. Figure 1 shows a schematic description of the global carbon cycle (Li, 2009). In the figure,

- $m_A(t)$: the amount of carbon in gigatons (GtC) present in the atmosphere of the earth,
- $m_V(t)$: the amount in vegetation,
- $m_S(t)$: the amount in soil,
- $m_{SO}(t)$: the amount in Surface Ocean,
- $m_{IDO}(t)$: the amount in Intermediate and Deep Ocean,
- $u_E(t)$: the human generated $CO_2$ emissions (GtC/yr).

From the figure, the atmospheric mass balance in the atmosphere can be expressed as

$$\frac{dm_A(t)}{dt} = u_E(t) - (k_{O1} + k_{L1})m_A(t) + k_{L2}m_V(t) + k_{O2}(t)m_{SO}(t) + k_{L4}m_S(t), \quad (4)$$

where the $k$'s are exchange coefficients (1/yr).

(a) Write the remaining reservoir mass balances, assuming similar linear model. Namely write equations for $\frac{dm_{SO}(t)}{dt}$, $\frac{dm_{IDO}(t)}{dt}$, $\frac{dm_V(t)}{dt}$, $\frac{dm_S(t)}{dt}$.

(b) Express the system in state space form where the output is the amount of carbon in atmosphere.