EXAM IN MODELING AND SIMULATION (TSRT62)

SAL: ISY:s datorsalar

TID: Monday 27th August 2018, kl. 8.00–12.00

KURS: TSRT62 Modeling and Simulation

PROVKOD: DAT1

INSTITUTION: ISY

ANTAL UPPGIFTER: 5

ANTAL BLAD (inkl försättsblad): 10

ANSVARIG LÄRARE: Claudio Altafini, 013-281373, 073-9931092

BESÖKER SALEN: cirka kl. 9 och kl. 10

KURSADMINISTRATÖR: Ninna Stensgård 013-282225, ninna.stensgard@liu.se

TILLÅTNA HJÄLPMEDEL:

1. *L. Ljung & T. Glad* ”Modellbygge och Simulering”
   (English title ”Modeling and Identification of Dynamical Systems”)
2. *T. Glad & L. Ljung*: ”Reglerteknik. Grundläggande teori”
3. Tabeller (t ex *L. Råde & B. Westergren*: ”Mathematics handbook”,
   C. Nordling & J. Österman: ”Physics handbook”,
   S. Söderkvist: ”Formler & tabeller”)
4. Miniräknare

Normala inläsningsanteckningar i läroböckerna är tillåtet. Notera att kommunikation med andra personer och informationshämtning via nätverket eller Internet *inte* är tillåtet under tentamen.

LANGUAGE: you can write your exam in both English (preferred) or Swedish

LÖSNINGSFÖRSLAG: Finns på kursens websida efter skrivningens slut.

VISNING av tentan äger rum 2018-09-07 kl 12.30-13:00 i Ljungeln, B-huset, ingång 25, A-korridoren, room 2A:514.

PRELIMINÄRA BETYGSGRÄNSER:		
	betyg 3	23 poäng
	betyg 4	33 poäng
	betyg 5	43 poäng

OBS! Lösningar till samtliga uppgifter ska presenteras så att alla steg (utom triviala beräkningar) kan följas. Bristande motiveringar ger poängavdrag.

Lycka till!

COMPUTER TIPS:

- To open Matlab:
  - open a terminal (right-click on the background and choose `open terminal`)
  - type

    ```
    module add prog/matlab
    matlab &
    ```

- Print out the model description and the plots requested
- Remember to write your AID number on each printed page you include
- In the identification exercise using the System Identification toolbox:
  - To print the model description: Right-click on the icon of the model you have computed and then click `Present`. The model description appears then on the matlab main window. Copy it into a file and print it.
  - the SysId plots cannot be directly printed. You have to choose `File` → `Copy figure`, which gives an ordinary matlab plot you can print.
- Printing in Linux:
  - A file called `file.pdf` can be printed out for instance typing in a terminal

    ```
    lp -d printername file.pdf
    ```

    (replace `printername` with the name of the printer in the room you sit in).
  - It is possible to print using `File` → `Print` in a matlab plot, but one must select the printer name writing `-Pprintername` in the `Device option` (again `printername` is the name of your printer).

1. (a) Why is it a good idea to do some preliminary experiments with step inputs before building a model of a system? [2p]

   (b) The ODE

$$\dot{x} = f(x), \qquad f(x) = -3x, \quad x(0) = 1$$

   is simulated using the following implicit Adams method

$$x_{n+1} = x_n + hf(x_{n+1})$$

   For what values of h is the numerical method stable? [2p]

   (c) Stiff systems are difficult to simulate. Why? Rank the following systems according to their stiffness (*Hint: do not forget that you can use matlab for computing e.g. eigenvalues of a matrix*)

$$\text{(i)} \qquad \dot{x} = \begin{bmatrix} 1 & -6 \\ 1 & -4 \end{bmatrix} x$$

$$\text{(ii)} \qquad \dot{x} = \begin{bmatrix} 0 & 1 \\ -0.001 & -1.001 \end{bmatrix} x$$

$$\text{(iii)} \qquad \dot{x} = \begin{bmatrix} -50 & 1 \\ 2450 & -51 \end{bmatrix} x$$

   [4p]

   (d) In oder to simulate a model in Modelica, it is often necessary to deal with systems of DAE. Why is it so? [2p]

2. Determine the parameter b in the model

$$y(t) = bu(t-1) + e(t)$$

(where e is a white noise independent of u) from an identification experiment in which u can be chosen in different ways. The true system is

$$y(t) = u(t-1) + u(t-2) + w(t)$$

where w is a white noise of variance λ_w, independent of u. Estimate b by minimizing the prediction error

$$V_N = \frac{1}{N}\sum_{1}^{N}(\hat{y}(t) - y(t))^2$$

when $N \to \infty$. Consider the following cases:

(a) u is a white noise. [3p]

(b) $u(t) = (-1)^t$, $t = 0, 1, 2, \ldots$ [4p]

(c) $u(t)$ such that the covariance is

$$R_u(\tau) = \begin{cases} 1 & \text{if } \tau = 0,\ \pm 1 \\ 0 & \text{otherwise} \end{cases}$$

[3p]

3. The data for this exercise are in a file called `sysid_data_20180827.mat` located in the directory `/site/edu/rt/tsrt62/exam/`. To load it into your Matlab workspace use any of the following:

   - type in the Matlab window

     `load /site/edu/rt/tsrt62/exam/sysid_data_20180827.mat`

   - copy the file to your current directory and then load it into your Matlab workspace (typing `load sysid_data_20180827.mat` at the Matlab prompt).

   Inside `sysid_data_20180827.mat` you will find the sampled signals u and y (the sample time is $T_s = 0.1$).

   (a) Do the data show any sign of resonances? [2p]

   (b) Construct one or more appropriate black-box models fitting the data, with the constraint that the total number of poles in the input-output transfer function is less or equal to 3 (i.e., $n_a \leq 3$ for ARX and ARMAX, $n_f \leq 3$ for OE and BJ). Report:

      - plot of the fitted model vs. validation data
      - parameter values and uncertainty
      - residual plot
      - Bode plots
      - poles and zeros placement

      Discuss and comment your choices and results. [8p]

4. Consider the hydromechanical system of Fig. 1, where A_i are the cross-sections of the corresponding pipes, m_i are masses, k_i are spring constants, b_2 is a friction coefficient. The bar of length $L_1 + L_2$ works as a lever (small angles only are considered). It is fixed at the bottom by a rotating hitch. It is attached at point j to the shaft of the piston and at point a to a mechanical system driven by the external force F. The liquid is incompressible and without energy losses. No gravity is considered. All components are mass-less except the two masses indicated.

   (a) Show that the part of system between the points a and b (i.e., the part in the shaded area) can be written as a single transformer. [2p]

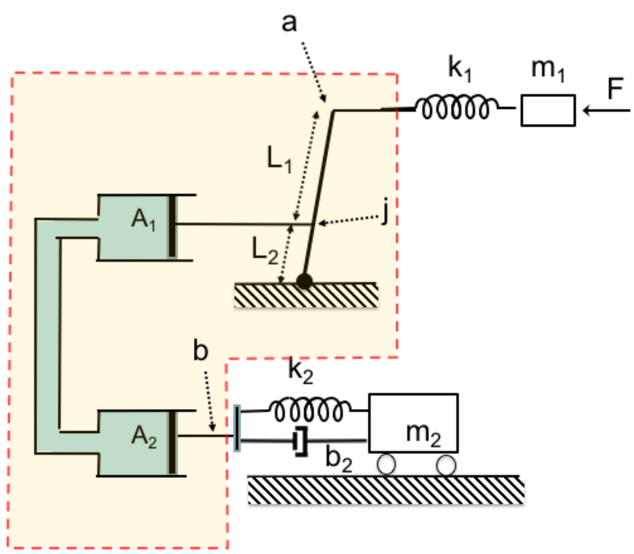

Figure 1: Exercise 4

   (b) Set up a bond graph of the system and mark its causality. [4p]

   (c) Write the state space equations for the system. [4p]

5. Consider the circuit in Fig. 2, composed of a generator, a resistor, a capacitor and an inductor.

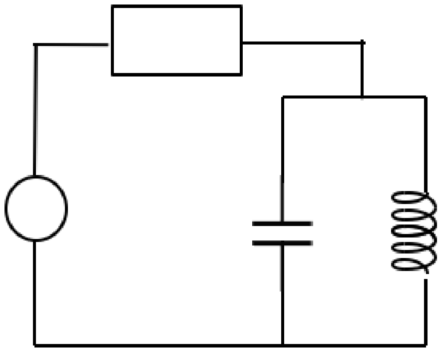

Figure 2: Exercise 5

(a) Assume the generator is a voltage generator. Compute the bond graph and show its causality. [2p]

(b) Determine a state space model of the system. [2p]

(c) Assume instead that the generator is a current generator. How does the causality change? [2p]

(d) In a more refined model of the circuit, all components are non-linear. Denoting $i(t)$ the current at a component, and $u(t)$ its voltage, then consider the following equations

$$\begin{aligned} \text{Resistor:} \quad & u(t) = R_1 i(t) + R_2 i^7(t) \\ \text{Capacitor:} \quad & \frac{du(t)}{dt} = \frac{1}{C_1} i(t) + \frac{1}{C_2} i^3(t) \\ \text{Inductor:} \quad & \frac{di(t)}{dt} = \frac{1}{L_1} u(t) + \frac{1}{L_2} u^5(t) \end{aligned}$$

For each of the two cases above (voltage / current generator) determine the differentiability index. [4p]