EXAM IN MODELING AND SIMULATION (TSRT62)

SAL: ISY:s datorsalar

TID: Friday 5th January 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 2018-01-19 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) Explain briefly what a stiff system of ODEs is and why it is difficult to simulate it. [2p]

   (b) Is it easier to compute the parameters of an ARX model or of an OE model? Why? [2p]

   (c) The following system

$$\begin{aligned}\dot{x}_1 &= -x_1 + 0.4x_2 \\ \dot{x}_2 &= x_1 - 4096x_2 + 512u\end{aligned}$$

   is simulated from the initial condition $x(0) = [0\ 0]^T$ and is driven by a high frequency input u. Compute a simplified version of the system which approximates its behavior. [2p]

   (d) What is the stability region of the Euler backwards method

$$x_n = x_{n-1} + hf_n$$

   What does it mean for the system

$$\dot{x} = -10x$$

   And for the following one?

$$\dot{x} = 10x$$

   [4p]

2. A physical system is described by

$$y(t) = G(q)u(t) + w(t) \tag{1}$$

   where w is a white noise of variance $\lambda_w = 2$.

   (a) Assume

$$G(q) = 0.5q^{-1} + 0.3q^{-2} \tag{2}$$

   and that the model used for the estimation is the following

$$y(t) = b_1u(t-1) + b_2u(t-2) + e(t) \tag{3}$$

with $e(t)$ a white noise. Compute the value of the parameters $\theta = [b_1\ b_2]$ that for $N \to \infty$ minimizes the prediction error square

$$V_N(\theta) = \frac{1}{N}\sum_{t=1}^{N}(y(t) - \hat{y}(t|\theta))^2 \tag{4}$$

when $u(t)$ is a white noise of variance $\lambda_u = 3$ uncorrelated with w and e. Compute also the variance of the parameter estimation. [3p]

(b) Consider the same $G(q)$ in (2) and the model (3). Describe what happens when minimizing (4) if the input $u(t)$ is a signal uncorrelated with w and e and with the following covariance

$$R_u(\tau) = \begin{cases} 1 & \text{if } \tau = 0 \\ 1 & \text{if } |\tau| = 1 \\ 0 & \text{if } |\tau| > 1 \end{cases}$$

[3p]

(c) Assume the true system is

$$G(q) = \frac{0.5 + 0.3q^{-1}}{1 + 0.2q^{-1} + 0.4q^{-2}} \tag{5}$$

$u(t)$ is a white noise (uncorrelated with w) and the OE model for the estimation is

$$y(t) = \frac{b_1 + b_2q^{-1}}{1 + f_1q^{-1} + f_2q^{-2}}u(t) + e(t)$$

where $e(t)$ is a white noise (uncorrelated with u). Estimate the value of the parameter vector $\theta = [b_1\ b_2\ f_1\ f_2]$ when $N \to \infty$. [*Hint: in this case it is easier to use eq. 12:46 (Swedish book; eq. 11.60 on the English book)*] [2p]

(d) Consider the true system (5), and the static model

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

where u is a constant signal and $e(t)$ is a white noise. Compute the value of the parameter b when $N \to \infty$. [*Same hint as above*]

[2p]

3. The data for this exercise are in a file called `sysid_data_20180105.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_20180105.mat`

   - copy the file to your current directory and then load it into your Matlab workspace (typing `load sysid_data_20180105.mat` at the Matlab prompt).

   Inside `sysid_data_20180105.mat` you will find the sampled signals u and y (the sample time is $T_s = 0.1$).

   Assume that the transfer function from noise to output has the Bode plot shown in Fig. 1.

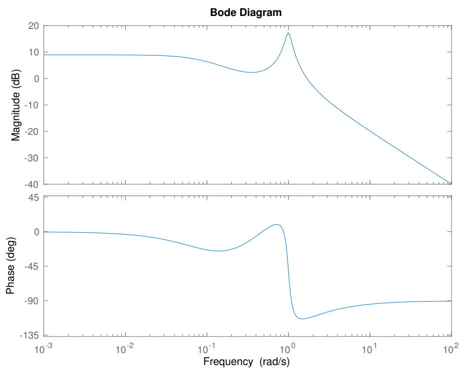

Figure 1: Exercise 3. Transfer function from noise to output.

   Construct one or more appropriate black-box models fitting the data and compatible with this transfer function, reporting

   - 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. *[Hint: since the noise-output transfer function is available, also the "noise spectrum" function of the SysId GUI main panel (button below "zeros and poles") can be used to evaluate the models.]* [10p]

4. Consider the hydromechanical system of Fig. 2, where A_i are the sections of the corresponding pipes/tanks, m_i the masses, k_i the spring constants, b_i the friction coefficients, and F is the input (external force). Assume pistons 1 and 2 are massless (piston 3 has mass m_3). Let ρ be the density of the fluid and h the height of the fluid in the tank of section A_4.

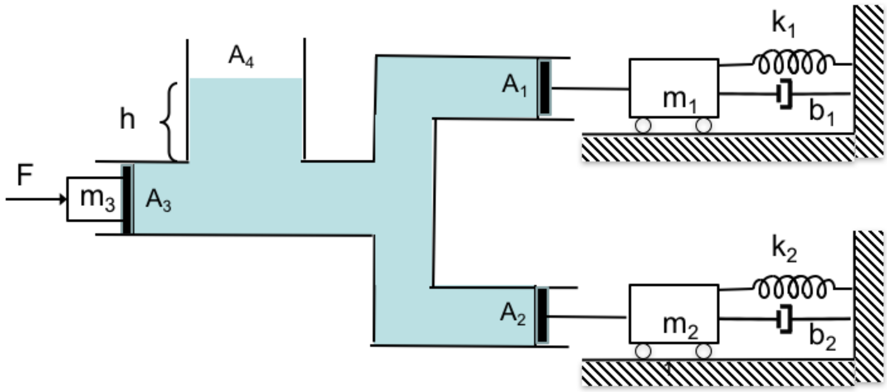

Figure 2: Exercise 4

(a) Set up a bond graph of the system and mark its causality. [5p]

(b) Translate the bond graph into state space equations, taking the height h as output of the system. [5p]

5. Consider the circuit in Fig. 3 where the two generators are current generators.

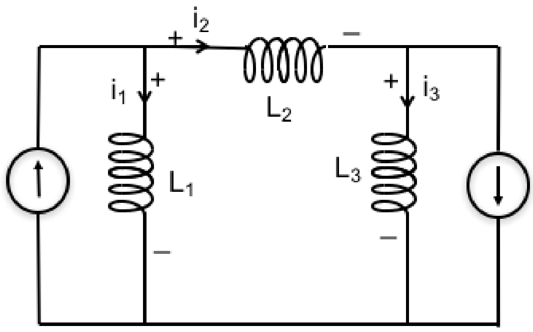

Figure 3: Exercise 5

(a) Show that the bond graph has a causality conflict. [2p]

(b) Show that the system can be represented as a DAE. Compute the index of the DAE. [5p]

(c) What happens if one current generator is replaced by a voltage generator? Is the circuit still representable with a DAE of the same index? [3p]