EXAM IN MODELING AND SIMULATION (TSRT62)

SAL: ISY:s datorsalar

TID: Thursday 10th January 2019, 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 2019-01-22 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) Mention 3 possible reasons for non-identifiability (i.e. failure in identifying the parameters) of a model. [2p]

   (b) Alice and Bob must solve a black-box system identification problem. Alice uses a program that can solve only systems of linear equations, while Bob has a program based on Gauss-Newton method. Which classes of models among ARMAX, ARX, OE, and BJ, can Alice, respectively, Bob use with their software program? [2p]

   (c) Compute the spectrum of the system

$$y(t) = G(p)u(t) + e(t), \qquad G(p) = \frac{p+\alpha}{p+\beta}$$

   where α, $\beta > 0$, $u(t)$ and $e(t)$ are uncorrelated white noises of variances, resp. 1 and 2. [2p]

   (d) For the system

$$\begin{aligned} \dot{x}(t) &= -3x(t) - u^2(t) \\ y(t) &= x^2 \end{aligned}$$

   compute the static relationship (på svenska: statiska sambandet) between u and y. [2p]

   (e) The system

$$\dot{x} = \begin{bmatrix} -1 & 0 \\ 0 & -4 \end{bmatrix} x$$

   must be simulated with the Euler method $x_{n+1} = x_n + hf(x_n)$. For what values of h is the method stable? [2p]

2. Consider the following "true" system

$$y(t) = 0.5u(t-1) + 0.7u(t-2) + v(t)$$

where $v(t)$ is a zero-mean white noise of variance λ_v. We use the prediction error minimization criterion with cost function

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

to fit the model

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

for $k = 1, 2, \ldots, \infty$, assuming that the input is generated by the following equation

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

where $w(t)$ is a zero-mean white noise of variance $\lambda_w = 0.5$, uncorrelated from $v(t)$. Compute the value to which b converges when $N \to \infty$, for all values of k. [10p]

3. The data for this exercise are in a file called `sysid_data_20190110.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_20190110.mat
     ```

   - copy the file to your current directory and then load it into your Matlab workspace (typing `load sysid_data_20190110.mat` at the Matlab prompt).

   Inside `sysid_data_20190110.mat` you will find the sampled signals u and y (the sample time is $T_s = 1$).

   (a) What is the best model you can find if you are allowed to use a maximum of 4 poles and 4 zeros overall (i.e., for instance for BJ: $n_f + n_d \leq 4$ and $n_b + n_c \leq 4$, and similarly for the other classes)? For your best model 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. [5p]

   (b) Show that the fitting can be improved if you choose a nonlinear model. Explain your choice. [5p]

4. Consider the system of Fig. 1

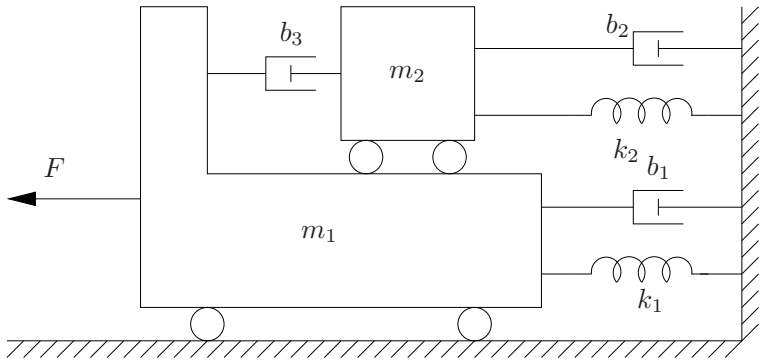

Figure 1: Exercise 4

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

(b) Write the state space equations for the system. [5p]

(c) Which of the 3 linear dampers can be replaced by a nonlinear non-invertible friction element without compromising the achievement of a state space model? [1p]

5. Consider the following DAE

$$\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix} \dot{z} + \begin{bmatrix} 0 & -a \\ 1 & a \end{bmatrix} z = \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

where $a \neq 0$.

(a) Is the system uniquely solvable? What are the poles of the system? [3p]

(b) Write the system in the "standard form I" (*Hint: use* $w_1 = z_1$ *and* $w_2 = z_1 + az_2$) [3p]

(c) What is the index of the system? [2p]

(d) Assume now $a = 0$. Explain why the system is not uniquely solvable. [2p]