EXAM IN MODELING AND SIMULATION (TSRT62)

SAL: ISY:s datorsalar

TID: Thursday 26th August 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 2019-09-11 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) Compute the equilibrium points of the system

$$\dot{x}_1 = 2x_1 - x_1 x_2$$
$$\dot{x}_2 = 2x_1^2 - x_2$$

[2p]

(b) Given the true system

$$y(t) = \frac{N(q)}{D(q)} u(t) + e(t)$$

where $N(q)$ and $D(q)$ are polynomials and $e(t)$ is a white noise, which classes of black-box models can give an unbiased predictor?

[2p]

(c) The system

$$\ddot{y} + 2\dot{y} + 5y = -\dot{u} + u$$

has the step response shown in Fig. 1. Compute the step response

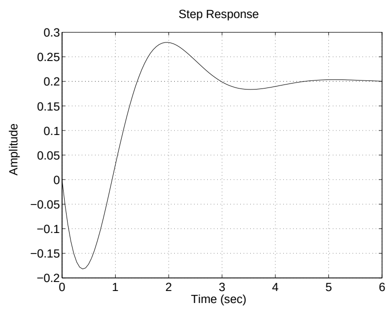


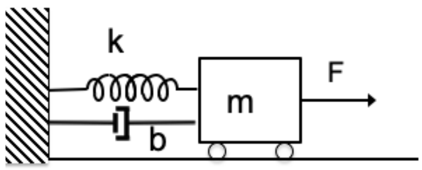
Figure 1:

of the following system

$$4\ddot{y} + 4\dot{y} + 5y = -6\dot{u} + 3u$$

without doing any simulation. Motivate your answer. [3p]

(d) Compute an electrical circuit that has the same bond graph as the following mechanical system.



Show also the bond graph and briefly list the corrrespondences between mechanical and electrical elements in it. [3p]

2. A "true" system is given by

$$y(t) = u(t-1) + 0.7u(t-2) + e(t),$$

where $e(t)$ is a measurement noise and $u(t)$ has covariance

$$R_u(k) = \frac{1}{2^k}, \quad k \geq 0.$$

In order to describe the system, we use the FIR model

$$y(t) = b_1 u(t-1) + b_2 u(t-2) + w(t)$$

where $w(t)$ is a white noise (uncorrelated with everything else). Compute the asymptotic estimate of the $b = [b_1 \ b_2]$ parameters using the prediction error minimization method in the following cases:

(a) The noise $e(t)$ is such that

$$R_e(k) = \frac{1}{3^k}, \quad k \geq 0,$$

and is uncorrelated with the input signal $u(t)$. [5p]

(b) The noise $e(t)$ has the same covariance function as above, but is now correlated with $u(t)$ according to the following cross-correlation function

$$R_{ue}(k) = \frac{1}{5^k}, \quad k \geq 0.$$

[5p]

3. The data for this exercise are in a file called `sysid_data_20190826.mat` located in the directory `/courses/TSRT62/exam/`. To load it into your Matlab workspace use any of the following:

   - type in the Matlab window

     ```
     load /courses/TSRT62/exam/sysid_data_20190826.mat
     ```

   - copy the file to your current directory and then load it into your Matlab workspace (typing `load sysid_data_20190826.mat` at the Matlab prompt).

   Inside `sysid_data_20190826.mat` you will find the sampled signals u and y (the sample time is $T_s = 0.1$).

   (a) Compute the frequency function. Is there any sign of resonances?

   [2p]

   (b) Use the data to construct one or more appropriate black-box models. For your best model report:
   - plot of the fitted model vs. validation data
   - parameter values and uncertainty
   - residual plot
   - Bode plot
   - poles and zeros placement

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

4. Consider the mechanical system shown in Fig. 4. A rotating mass of moment of inertia J_1 and driven by the external torque τ is attached via a flexible axel to a cogwheel of moment of inertia J_2 and radius r. The flexibility of the axle can be modeled as a torsional spring with spring constant k_1. The cogwheel drives a shaft sliding on a rail, shaft of mass m and with viscous (assume linear) friction of coefficient b. The end of the shaft is attached to a spring of spring constant k_2 attached to the wall.

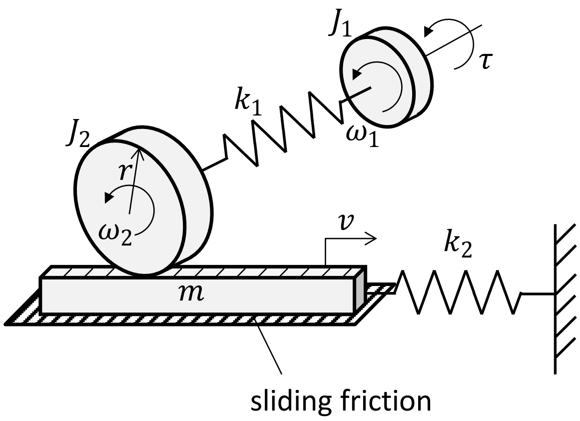


Figure 2: System of Exercise 4.

(a) Compute the bond graph of the system. Show that the causality is not conflict-free. Is the conflict eliminable though some simplification? [5p]

(b) Compute a state space model for the system. *[Note: extra complications occurs when you have causality conflicts.]* [5p]

5. Consider the following DAE:

$$\begin{aligned} \dot{x}_1 &= 1 + x_2 && (1) \\ \dot{x}_3 &= 0 && (2) \\ x_1 x_3 - x_2(2 + x_3) + t &= 0 && (3) \end{aligned}$$

(a) Compute the differentiability index [6p]

(b) Is there any difference in the index if we replace (3) with the following:

$$x_1 x_3 - 2x_2 + t = 0 \qquad (4)$$

Explain your answer. [2p]

(c) Is it possible to transform the DAE system (1)-(3) into an ODE system (possibly of lower dimension, eliminating some variables), plus *explicit* algebraic expressions for the variables that can be eliminated? [2p]