

Course: ELEC-E8103 Modelling, Estimation, and Dynamic Systems

EXAMINATION 16.12.2015

The examination will start from 16.12.2015 12:00 to 21:00. Please submit your solutions to the exam section of the course page in mycourses.aalto.fi before the deadline. The exam will be carried out in student's own computer at home. The exam should be done individually, and **NO discussion is allowed.**

Submission of the exam papers

You should submit your solutions to the Exam section of the Aalto University Mycourses page: <https://mycourses.aalto.fi/course/view.php?id=5231§ion=4>. Your submission should include a single zip file named as "surname_studentNumber_Exam.zip", consisting of a pdf file named "surname_studentNumber_Exam.pdf", and the following MATLAB files: "problem1.m", "problem1.mdl", "parameters.m", "problem2.m", and "sys01.sid", "sys02.sid", "sys03.sid", "sys04.sid", and "sys05.sid" for problem 3.

The hard deadline for submission of the exam solutions is 16.12.2015 at 21:00.

Hints

The physical laws in the exam are already discussed in the exercise sessions of the course, especially sessions 2 and 6.

Exam Questions:**1. (17 points)**

The Fig. 1 shows a simplified version of a car suspension system. The input u is the displacement of the road with respect to a reference (you may say unevenness of the road) and y is the displacement of the body of the car.

a) Derive the dynamic model of the system in the form of differential equations.

(2 points)

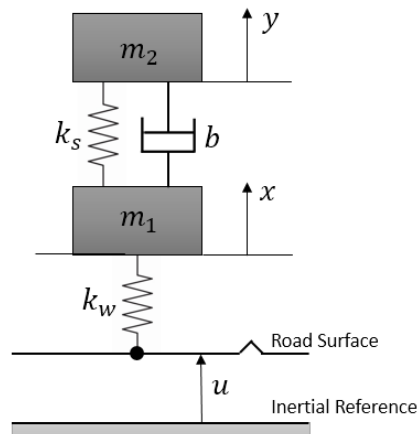


Figure 1 – Suspension system

b) Obtain the transfer function $Y(s)/U(s)$ of the system.

(3 points)

c) Write the equations of motion (derived in part “1-a”) in the state-space form. Use the following vector X as the state vector.

$$X = [x \quad \dot{x} \quad y \quad \dot{y}]^T$$

(2 points)

d) Write a MATLAB script named “problem1.m”. Plot the position of the car and the wheel after the car hits a unit bump (i.e., r is a unit step) using MATLAB. Assume the following values for the system parameters.

$$m_1 = 10 \text{ kg}$$

$$m_2 = 350 \text{ kg}$$

$$k_w = 500,000 \text{ N/m}$$

$$k_s = 10,000 \text{ N/m}$$

Select the value of b that makes the car comfortable for the passengers the most. State your reasons about the chosen value.

(5 points)

- e) Simulate the system in Simulink. Save the Simulink model as “problem1.mdl”. Use the inputs given in part “1-d”. Plot x and y for the chosen parameter b .

You should include all the used parameters in the Simulink model in a separate file. After executing this file, all needed parameters should be stored to MATLAB workspace. Save the mentioned script -including the parameters for your simulation- as “parameters.m”.

(5 points)

2. (8 points)

Load the data file “data2.mat”. Consider x and y as training input and output, and xv and yv as validation input and output.

Write a script called “problem2.m”. The script should perform the following tasks:

- a) Draw the scatter plot of (x,y) data. Estimate the parameters k_i in the following model using optimization algorithms for the given data. (You are not allowed to use MATLAB curve fitting toolbox for this question)

$$y = e^{(k_1 - k_2 x)}$$

(3 points)

- b) Plot the estimated function for $x \in [1,6]$ on the same scatter plot of data together with the validation data. Calculate SSE and R^2 for the training data. Calculate SSE for the validation data.

(2 points)

- c) Estimate a polynomial model for the given data using MATLAB polynomial estimation functions, “polyfit” and “polyval”. What polynomial order do you choose for the given data? Why?

(3 points)

3. (25 points)

Copy the files “runExam.m”, and “modeldata.mat” in your MATLAB current folder. Run the “runExam.m” script.

The following text should appear in your command window.

>> runExam

Please Enter the numeric part of your student number!:

Now, you should type your student number and press *Enter*. If your student number ends with an alphabetical letter, you should just type the numerical part of your student number, e.g. if your student number is 12345W, you should type 12345.

Then your data will be stored to MATLAB workspace. Data has been collected from five different dynamic systems. Input-output datasets are (u_1, y_1) , (u_2, y_2) , (u_3, y_3) , (u_4, y_4) , and (u_5, y_5) .

Identify polynomial models of the mentioned systems using MATLAB System Identification Toolbox. You should explicitly select a model as your final answer for each input-output dataset.

You should explain the identification path in your final document. The identification path includes the following issues:

- What were the reason(s) for rejection of a specific model structure in your path?
- What were the reason(s) for selection of a specific model structure in your path?
- What are the alternative model(s) for the data if you think there are any?

You should validate your answers to the above-mentioned questions using required plots. You should include all validation test results for your final selected model for each system in your document.

Save the final identification session for each dynamic system as “sys01.sid” for (u_1, y_1) , “sys02.sid” for (u_2, y_2) , “sys03.sid” for (u_3, y_3) , “sys04.sid” for (u_4, y_4) , and “sys05.sid” for (u_5, y_5) .

The points will be given based on the resulted model structures and their orders, as well as the justification of the identification path.

(5 points for identification of each system, 25 points in total)