
Final exercise 30.11.2020

The final exercise starts on 30.11.2020 09:00 and **ends on 04.12.2020 23:59**. Please submit your solutions to [the final exercise section of the course page in mycourses.aalto.fi](#) before the deadline. The final exercise should be done individually, and **no discussion is allowed**.

Your submission should include one zip file, “surname_studentNumber_Final.zip”, consisting of a pdf file, “surname_studentNumber_Final.pdf”, and seven MATLAB files, “problem1.m”, “problem1Simulink.mdl”, “constants.m”, “estimate_price.m”, “sys01.sid”, “sys02.sid”, and “sys03.sid”.

1. (20 points)

Consider the magnetic suspension system shown in Fig. 1. The magnetic coil is fixed on the floor (position $z = 0$), and the ferromagnetic bar with mass m is suspended in air. The magnet is controlled with current $i(t)$, and the objective is to predict the position of the magnet, $z(t)$. The positive direction is assumed to be upwards. The magnet is connected to a fixed frame by a spring and a damper with coefficients k and b , respectively. z_k is the neutral position of the bottom of the spring without any mass attached. Assume the following relationship between the magnetic force, magnet position z , and current i :

$$F(z, i) = p \left(\frac{i}{z + \epsilon_0} \right)^2,$$

where $p = 1.5 \times 10^{-5}$, and $\epsilon_0 = 0.5$ mm. Note that magnetic force $F(z, i)$ is directed downwards, and the weight is not negligible and directed downwards as well.

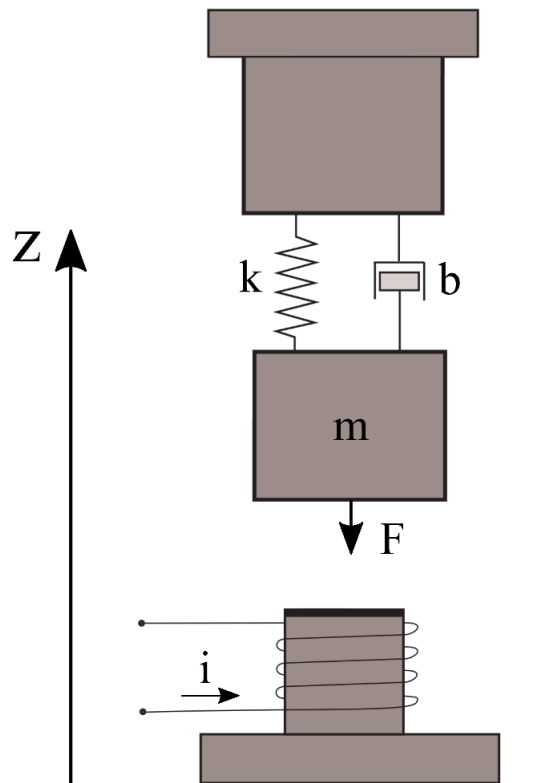


Figure 1 – Magnetic suspension system.

- a) Based on the description of the system, structure the problem. You are supposed to answer the following questions: What signal(s) are the output(s) of the system? What signal(s) are the input(s) of the system? What are the constants of the system? What are the internal time-varying variables of the system? (1 point)
- b) Set up the basic equations of the system. You are supposed to derive the underlying differential equations of the system motion using first principles. What are the states of the system? Is the system linear or nonlinear? (5 points)
- c) Solve the differential equations using MATLAB ode solvers, e.g., ode45. Implement a MATLAB script named “problem1.m”. In “problem1.m”, you are supposed to establish the underlying differential equations of the system, solve the equations with MATLAB ode solvers, and plot the response of the system (including all of the states) to the following input current:

$$i(t) = 10 \sin(10t).$$

Simulation time is [0 10] seconds. Use the following system parameters:

$$z_k = 0.2 \text{ m}$$

$$m = 0.1 \text{ kg}$$

$$k = 10 \text{ N/m}$$

$$b = 10 \text{ Ns/m}$$

$$z(t = 0) = 0.1 \text{ m}$$

$$\dot{z}(t = 0) = 0 \text{ m/s}$$

$$g = 9.81 \text{ m/s}^2$$

(6 points)

- d) Simulate the system in Simulink. Save the Simulink model as “problem1Simulink.mdl”. Plot the response of the system (states) to the input current given in (c). Include all the constants used in the Simulink model in a separate file, constants.m. After executing this file, all the constants should be stored to MATLAB workspace. (5 points)
- e) Find the input current, $i_{eq}(t)$, required to maintain the system at a stationary point, $z_{eq} = 0.08 \text{ m}$ and $\dot{z}_{eq} = 0 \text{ m/s}$, using the system parameters given in (c). This value can be obtained either by trial and error or by solving the steady-state equation analytically. Plot the response of the system to this input current. (3 points)

Include all the plots in your report.

2. (19 points)

The goal of this task is to implement a computer program that can estimate the sale price of a residential property based on a database. Suppose you are a data analyst working for a consulting company and your client is a real-estate agent. The real-estate agent provides you with the database of 200 properties, which were sold last month, stored in “data2.xlsx”. Your task is to design a program in MATLAB that can be used by the real-estate agent for pricing new residential properties.

The database includes all relevant information about the residential properties: sold price (euros), the area of living space (m^2), the construction year, the number of rooms, the floor number, and the house location defined by x and y coordinates (km). Your program should take the parameters of a new residential property and suggest its price. Specifically, your program should be in the format of a function named “estimate_price.m” as below,

```
function price_house = estimate_price(house_params)
```

where **price_house** (scalar) is the estimated price for a new residential property, and **house_params** (vector) includes the specifications of the new residential property that you want to price. For example, **house_params** should be in the following format, **house_params** = [45 1978 1 1 0.2 0.3], for the first residential property in Table 1 below.

Note that the downtown of the city is located at the following location,

$$P_{\text{Downtown}} = \begin{cases} x = 1.43 \text{ (km)} \\ y = 0.63 \text{ (km)} \end{cases}$$

The downtown is considered to be the center of a city, e.g., the neighborhood of Kamppi in Helsinki. Being close to the downtown is generally considered as a positive point for a property.

Estimate the price for the following test cases by your program and **include the estimated prices in your final report**:

	Living area (m^2)	Construction year	Number of rooms	Floor number	x (km)	y (km)
House No. 1	45	1978	1	1	0.2	0.3
House No. 2	56	2000	2	2	0.6	1.6
House No. 3	72	2016	3	6	1.4	0.65

Table 1 – Residential properties of test cases.

Your solution should have the following substances:

1. **Accuracy:** your program should estimate the price of the residential properties reasonably. We will test your program with our standard solution and the test cases provided in the document.
2. **Validity:** you are supposed to validate your solution with the data and appropriate methods, which were discussed in Lectures 5-6. **In the report, explain your validation procedure in sufficient detail and include the appropriate plots and measures. The code, which produces the relevant plot and measures, should be implemented inside the aforementioned function.**

The points for this task will be given based on the **accuracy of your estimations** for the test cases as well as your **justification of the solution**.

3. (21 points)

The goal of this question is to identify dynamic systems using input-output data. 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, type your student number and press Enter. If your student number ends with an alphabetical letter, you should 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 were collected from three different dynamic systems. Input-output datasets are (u_1, y_1) , (u_2, y_2) , and (u_3, y_3) . The sampling frequency for all of the datasets was 1 Hz. Identify polynomial models of these systems using MATLAB System Identification Toolbox. You should explicitly select a model as your final answer for each input-output dataset. You are supposed to answer the following questions for each system:

- What is the model structure you have selected?
- Present the resulted plots and information related to validation procedure **only for your selected model structure**. (Hint: For instance, present residual analysis plots, poles and zeros plot, variance analysis information, etc.)
- What are the alternative system(s) for the data if you think there are any?

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

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

(7 points for identification of each system, 21 points in total)