

Exercise 0: General Information and Preliminaries

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The lecture course on Modelling and System Identification (MSI) shall enable the students to create models that help to predict the behaviour of systems. Here, we are particularly interested in dynamic system models, i.e. systems evolving in time. With good system models, one can not only predict the future (like in weather forecasting), but also control or optimize the behaviour of a technical system, via feedback control or smart input design. Having a good model gives us access to powerful engineering tools. This course focuses on the process to obtain such models. It builds on knowledge from three fields: Systems Theory, Statistics, and Optimization.

Organization of the Course

The course combines lectures and exercise sessions, supplemented by written materials for independent study and a mandatory team project.

Exercise sheets include both pen-and-paper problems and programming tasks using Python. During exercise sessions, students receive guidance on solving the problems, and solutions are discussed together. The course is taught in English, and all course-related communication is conducted in via the course homepage:

<https://www.syscop.de/teaching/ws2026/modelling-and-system-identification>

Lectures The lectures take place on Mondays, 08:15–09:55, in Building 101, HS 026, and Wednesdays, 08:15–09:55, in Building 101, HS 036.

Lecture recordings from past years for self-study, along with a detailed course plan, are available on the course webpage. Please check the webpage regularly, as the schedule may change during the semester.

Exercises (voluntary, not graded) Exercise sheets are uploaded to the course webpage every Monday. You have one week to complete each sheet and are encouraged to work in groups of up to three students. Exercises are voluntary and ungraded, but regular participation is recommended.

For feedback from the tutors, submit your pen-and-paper solutions by email to syscop.msi@gmail.com before the deadline specified on the sheet. Programming solutions must be submitted via GitHub. Further instructions on group registration and repository access will be provided on the course webpage.

Exercise sessions take place in two groups:

- Group 1: Wednesday, 14:00–16:00, Building 51, SR 00 031
- Group 2: Thursday, 10:00–12:00, Building 101, SR 01-009/13

During the exercise sessions, solutions are discussed and feedback is provided. There is also time for questions on the current exercise sheet.

Studienleistung, Microexams, Project (mandatory) To fulfill the requirements of the Studienleistung, at least 60 of the 120 available points must be obtained from three microexams (60 points in total) and a project (60 points).

Each microexam lasts 45 minutes and is worth 20 points, comprising ten multiple-choice questions and up to two exercise-based questions. Possible types of the exercise-based questions will be marked with an asterisk (*) on the exercise sheets.

Project (mandatory): The project is worth 60 points and must be completed in teams of up to three students, preferably in the same teams as for the exercises. Teams may choose a topic from the suggestions published on the course webpage or discuss their own idea with the tutors.

The project announcement and further instructions will be published on the course webpage. The submission deadline is 31st January.

A project description of 1–2 pages is required, and all team members should be prepared to explain their work, answer questions, and make requested changes to their code.

Final Written Exam The final course grade is determined solely by the final written exam at the end of the semester.

The final exam is closed-book. You may bring a pen, paper, a calculator, and two double-sided A4 sheets with handwritten formulae of your choice.

The 6 ECTS credits are awarded upon passing the final written exam, provided the requirements for the Studienleistung have been met.

Linear Algebra Basics A voluntary mini-exercise to refresh the knowledge of some matrix properties.

1. ON PAPER: Consider the following linear system :

$$\begin{cases} a + b + 5c = 15 \\ 2a + b + c = 10 \\ 2b + 3c = -50 \end{cases}$$

Please bring it to the form $\Phi\theta = y$, where $\theta = [a, b, c]^\top$

(a) Specify the matrix Φ and the vector y , and give their dimensions.

(b) Compute the rank of Φ . Is it invertible? What does this mean for the solution $\theta = \Phi^{-1}y$?

2. ON PAPER: Consider the function $f(x) : \mathbb{R}^2 \mapsto \mathbb{R}^2$ with $x = [x_1, x_2]^\top \in \mathbb{R}^2$

$$f(x) = \begin{bmatrix} 5 \log(x_1) - x_2^2 \\ 2x_1 + e^{3x_2} \end{bmatrix}$$

and its Jacobian matrix $J \in \mathbb{R}^{2 \times 2}$, defined as

$$J(x) = \frac{\partial f}{\partial x}(x) = \begin{bmatrix} \frac{\partial f}{\partial x_1}(x) & \frac{\partial f}{\partial x_2}(x) \end{bmatrix} = \begin{bmatrix} \frac{\partial f_1}{\partial x_1}(x) & \frac{\partial f_1}{\partial x_2}(x) \\ \frac{\partial f_2}{\partial x_1}(x) & \frac{\partial f_2}{\partial x_2}(x) \end{bmatrix}.$$

Given the point $\bar{x} = [1, 2]^\top$, is $J(\bar{x})$ invertible?

3. ON PAPER: Show that for any $A \in \mathbb{R}^{n \times m}$ holds that $A^\top A$ is symmetric and positive semi-definite (PSD). *Hint: A matrix B is PSD, if for any $x \in \mathbb{R}^m$ holds that $x^\top Bx \geq 0$.*

Getting started with Python Clone the Github repository (link on the website), and consider the python script **task4.py** to fill in the gaps in the TODO sections.

1. Plot the data read from the file **position.npy** using the function **plt.plot()**.
2. Compute the average value of the position from the data. Plot it in a figure with the data. Useful commands are **np.sum()** and **np.mean()**.

This sheet is not mandatory and does not give points.