Exercises for Course on Modeling and System Identification (MSI)
Albert-Ludwigs-Universität Freiburg – Winter Term 2018-2019

Exercise 0: General Information and Preliminaries

(to be returned on Oct 26, 2018, 10:15 in SR 00-010/014, or before in building 102, 1st floor, 'Anbau')

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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. We will recall necessary concepts from these three fields on demand during the course, and ask a few basic questions on these fields already in this first sheet.

Organization of the Course

The course is based on two pillars, lectures and exercises, and accompanied by written material for self-study. Course language is English and all course communication is via the course homepage:

`https://www.syscop.de/teaching/ws2018/modeling-and-system-identification`

Lectures are on Wednesdays 14:10 to 15:55h and Fridays 10:00 to 11:45h and take place in SR 00-010/014 in building 101 unless otherwise stated. About one third of all lecture slots is cancelled or modified in order to ensure that the regular lecture duration corresponds to only three semester week hours.

Exercises start only 25th of October, and take place Thursday 16:00 to 18:00 and Friday 14:00 to 16:00 building 082, room 029 (computer pool). A third slot will be arranged for if required. This will be communicated through the course website. During the first half of the exercise session corrected exerecises are handed out and discussed. Afterwards there is room for questions on the current exerciese. We noticed in the past that students who actively participate in the exercises also obtain the highest grades in the exams.

Written material that accompanies the lecture course comprises two scripts and one book:

- The latest version of the script for this course can always be found on the course homepage.
- A script by Johan Schoukens (Vrije Universiteit Brussel, Belgium) that will be made available on the course homepage but can also be found at `http://syscop.de/files/2015ws/msi/Schoukens_sysid_2013.pdf`.
- The textbook *Ljung, L. (1999). System Identification: Theory for the User. Prentice Hall.* This book is available in the faculty library as a hard copy and a main reference for this course.

Final Evaluation, Exercises and Microexams

The final grade of the course is based solely on a final written exam at the end of the semester. The **final exam** is a closed book exam, only pencil, paper, and a calculator, and two double-sided A4 pages of self-chosen formulae are allowed. In order to be eligible for the final exam, one has to have passed two criteria by having obtained at least

- at least 60 overall points.

- at least 30% of the points in each exercise (with a maximum of 2 exceptions)
- Three microexams written during some of the lecture slots give a maximum of 10 points each. The dates of the microexams are:
  November 21, 2018 – December 19, 2018 – January 30, 2019.

Tasks for Exercise 0

1. (linear algebra) Consider the matrices $A \in \mathbb{R}^{m \times n}$, $X \in \mathbb{R}^{n \times n}$, with X symmetric. Prove that the matrix $B = AXA^\top$ is symmetric.
2. (statistics) Write down the probability density function $p(x)$ for a random variable X that takes values $x \in \mathbb{R}$, and which is normally distributed with mean $\mu \in \mathbb{R}$ and variance $\sigma^2 \in \mathbb{R}$. Include the normalization constant that ensures that $\int_{-\infty}^{\infty} p(x)\mathrm{d}x = 1$.
3. (optimization) Compute the minimizer of the convex function $f : (0, \infty) \to \mathbb{R}, x \mapsto f(x) = \frac{1}{x^2} + 2x^2$.
4. (systems theory) Write down the linear ordinary differential equation (ODE) that describes how the temperature $y(t)$ [K] inside a closed water bottle evolves as a function of the ambient temperature $u(t)$ [K] outside the bottle. The heat capacity of the bottle is given by C [J/K] and the total heat transfer coefficient between inside and outside the bottle by k [J/K/s], i.e. the total heat flux in [J/s] from inside to outside the bottle is given by $k \cdot (u(t) - y(t))$.

This sheet gives in total 4 points