Exercises for Course on Modeling and System Identification (MSI)
Albert-Ludwigs-Universität Freiburg – Winter Term 2016-2017

Exercise 0: General Information and Preliminaries

(to be returned on Oct 24, 2015, 8:00 in SR 00-010/014,
or before in building 102, 1st floor, Chair of Systems Control and Optimization)

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The lecture course on Modelling and System Identification (MSI) aims at enabling 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:

`http://www.syscop.de/teaching/ws2016/modeling-and-system-identification`

Lectures are on Mondays from 8:15-10:00 and Fridays from 10:15 to 12:00 and take place in SR 00-010/014 in building 101 unless otherwise stated. **Exercises** take place (starting 25th of October)

- Tuesday 12:00 to 14:00, building 082, room 029,
- Wednesday 12:00 to 14:00, building 082, room 029,
- Thursday 14:00 to 16:00, building 074, room 019 (IMTEK pool).

Each Monday an exercise sheet is distributed, and the solutions must be returned by teams of 1 to 3 people, **on paper**, the next Monday, 8:00. Please state the names of all team members on the papers you hand in.

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 excellent 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 is the 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 course, one has to have obtained at minimum 50% of the total points in the exercise sheets that are distributed each week. There will also be 3 microexams during the semester that might earn you bonus points on the exercises. The exact dates of the microexams will be communicated at a later point in time.

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 that will count as bonus points for Exercise 1