SC4070 — Control Systems Lab

Course Information for Academic Year 2011/2012, Q3

Course year	Msc programs
Term	third quarter (Feb 6th to the end of March)
ECTS credits	4 (112 hours)
Prerequisites	some experience with Matlab, Simulink
Lectures	4 lectures in February:
	Mon 6th, Wed 8th, Mon 13th, Mon 20th
	1 lab demo:
	Wed February 15th
Lab sessions[1]	week 8, 10 and 11: Room 5B-0-30,
	Mekelweg 2
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Examination	written report, final presentation
	evaluating results of the lab sessions
WWW page	http://www.dcsc.tudelft.nl/~sc4070
Blackboard	search course SC4070 on
	http://blackboard.tudelft.nl

[1]There are three sessions of about 4 hours each. The exact days and times will be scheduled during the first lectures.

General Information

This course, provided by the Delft Center for Systems and Control, TU Delft, is intended for two target groups of MSc (graduate-level) students:

1) Students who already have basic knowledge of control theory (at the BSc-level as taught, for instance, at Electrical, Mechanical or Aerospace Engineering and Applied Maths). For these students, the main benefit from this course will be the hands-on experience with the design and implementation of a computer-controlled system on a real laboratory-scale process. Relatively abstract parts of control theory will become clear and tangible.

2) Students who are familiar with the basic principles of feedback, but have not followed any courses on control theory (for instance Informatics, Civil Engineering, Policy and Management). These students will have the opportunity to learn the essentials of control in a concrete manner through solving a control design problem with a real laboratory-scale process. The necessary theory will be given in introductory lectures.

Both target groups will be working together with the same lab setups. The lab projects are carried out in groups of three students (more details are given further in this text). The assessment is thus uniformly made.

Course Subject

Practically all modern control systems are based on digital computers and specialized micro-controllers. By using digital control, better performance and improved functionality can be obtained than with analog systems.

The goal of this course is to gain hands-on experience with the design and implementation of a computer-controlled system. We will use a discrete-time approach, in which the system to be controlled is modeled both by discretizing an available continuous-time physical model and by using system identification. A systematic, MATLAB-supported design methodology is followed, using a state estimator (observer) and a state-feedback controller.

In the first two weeks, four lectures are given in order to refresh the theoretical and methodological background. Furthermore, a lab demo will introduce the students to the available experimental setups. Then, the students work in groups of three in the lab, with a setup of their choice (inverted pendulum, 'helicopter' model, inverted wedge, or the 'container crane' model). The mathematical model of the process to be controlled is provided. The assignment is

to be stated in terms of the control objective. The results will be summarized in a report and a final presentation will be given. The grade is determined on the basis of lab participation, the report and the presentation (i.e., there is no written exam).

Keywords: Computer-controlled systems, analysis of discrete-time systems, practical design of sampled-data controllers, implementation of controllers in MATLAB and Simulink.

Instructional Objectives

After successfully completing the course, you should be able to:

- perform system identification or parameter estimation of the setup at hand,
- develop a model of a (nonlinear) dynamic system in Simulink, linearize (trim) and discretize the model,
- select properly the sampling period, given specifications for the closed-loop performance,
- design a discrete-time controller and observer, using effectively the Control Systems Toolbox of MATLAB,
- implement the controller in Simulink and interface it to the physical process with the help of the Real-Time toolbox,
- evaluate the performance of the closed loop and modify the design parameters if necessary.

Course Material

The material includes electronic copies of the transparencies used in the lectures, MATLAB demos and examples.

Books *Computer Controlled Systems* 3^{rd}*ed.* by K.J. Åström and B. Wittenmark (Prentice Hall, 1997) can be consulted, mainly Chapters 1 through 9 are of interest for this course. A number of supplements (errata list, solutions manual, etc.) are available from the course WWW page and also from the authors at http://www.control.lth.se.
Feedback Control of Dynamic Systems 5^{th}*ed.* by Franklin, Powell, and Emami-Naeini. Prentice Hall, 2006.

Slides in PostScript and PDF formats are available for download from the course WWW page. You may want to print the transparencies before each lecture and use them for your notes.

MATLAB scripts and demos can be downloaded from the course WWW page. These will help you to gain more insight both in the theoretical matter and the implementation.

Course Method

The main ingredients of this course are lectures, homework preparation, practical laboratory sessions, reporting and presentation.

Lectures. There are four lectures in the first two weeks of the quarter, two lectures per week. The purpose of the lectures is to refresh the relevant theory and methodology.

Lab demo. Will be given in the first two weeks and will introduce the experimental setups to the students.

Laboratory sessions are the most essential part of this course. The purpose is to gain hands-on experience with the control of a real physical process. The lab sessions have the following structure:

1. Choose your two partners and the laboratory setup (first week of education, week 6) **The work is done in groups of three: email names, student id and email addresses to the Instructor** .
2. Implement a Simulink model of the setup as your home preparation. Prepare also an experiment to identify the parameters of the system and test the experiment on the Simulink model (week 6 and 7).
3. Calibrate the model to approximately match the process. Carry out identification experiments, collect data (lab session).
4. Estimate model parameters through system identification (lab session).
5. Design a controller for the simulation model as your home preparation.
6. Test and fine-tune the controller on the process (lab session).
7. Write the final report (max 10 pages), prepare the presentation.
8. Present the results (presentations will take place in week 12 of quarter 3 – week of Mar. 19th).
9. Write report (week 12 and week 13). Deadline: **hand in a printed copy by Friday March 30th, 2011.**

One lab session takes four hours, the exact days and times will be scheduled during the first two lectures, taking into account your preferences and constraints. If the schedule permits, you may, of course, spend in the lab as much time as you wish. Let us stress that it makes little sense to come to the lab sessions unprepared. For this course it holds perhaps more than for other ones that what you get out of it is directly proportional to what you yourself put in.

Matlab and Simulink. One of the objectives is to learn to use MATLAB, Simulink and the Control Systems Toolbox for computer-assisted design, analysis and implementation of control systems. It is important that you can use this software for your home preparation for the lab sessions. Matlab and Simulink including the Control Systems Toolbox is available via blackboard. If you have no home PC available you can use the computers located in the labs, discuss this with the lecturer. Make sure that the Matlab or Simulink models that you create on your home PC are compatible with the Matlab version installed at the lab-machines (R2008B).

Final grade. There is no written exam. The grade is determined on the basis of lab participation, of your report (one report per group), and of the final presentation. Both the report and the presentation are in English.

The main criteria for the report are completeness and clarity. On the basis of the report, any educated reader should be able to reproduce your results with the laboratory setup. All choices made (such as the selection of the sampling period, design parameters, etc.) must be properly motivated. Evaluate critically the results obtained. Deliver the MATLAB / Simulink files you developed per e-mail to the Lab Assistants. **The report is max 10 pages, and must be delivered on paper. Please indicate exact contributions of each of the students in the group on the report.**

The presentation should take 20 minutes in total, 15 minutes the presentation itself and 5 minutes for questions both by fellow students and the lecturers. It is important that each member of the group gives a part of the presentation (approximately 7 minutes). A beamer will be available.

The suggested (approximate) distribution of the study load over the term is given in the following table.

Week	6	7	8	10	11	12	13	Total
Lectures	4	4						8
Home prep.	10	10	10	10	6			46
Laboratory			5	5	5			15
Presentation					8	3		11
Report						8	12	20
Total	14	14	15	15	19	11	12	100

Questions? You are welcome to ask questions and discuss problems before or after each lecture or during the laboratory sessions. Please, make an appointment with

- the lecturer for theoretical questions or questions on models;
- the lab assistants for questions on models or on lab experiments.