AUTOMATIC CONTROL, BASIC COURSE (FRTF05)

Course Syllabus, Fall 2019

Higher education credits: 7.5 ECTS (one eighth of a year of full-time studies).
Grading scale: Fail, 3, 4, 5.
Level: G2 (Secondary basic level).
Language of instruction: English.
Course coordinator: Richard Pates, Dep. of Automatic Control, Lund University, Sweden.
Recommended prerequisites: Calculus in One Variable, Calculus in Several Variables, Linear Algebra, Linear Systems or Systems and Transforms.
Assessment: Written exam, three laboratory exercises.
Further information: The course is given at Beihang University (BUAA) in Beijing, China.
Home page:

`http://www.control.lth.se/education/engineering-program/frtf05-automatic-control-basic-course-china/`

Aim

The aim of the course is to give knowledge about the basic principles of feedback control. The course will give insight into what can be achieved with control—the possibilities and limitations. The course mainly covers linear continuous-time systems.

Knowledge and understanding

For a passing grade the student must

- be able to define the fundamental concepts of control.
- be able to linearize nonlinear dynamical models.
- be able to compute the relations between dynamical models in the form of transient responses, transfer functions, differential equations on state-space form, and frequency responses described with Bode or Nyquist diagrams.
- be able to analyze dynamical systems with respect to stability, robustness, stationary characteristics, controllability, and observability.
- be able to implement controllers using discretization of analog controllers.

Skills and abilities

For a passing grade the student must

- be able to design controllers from given specifications on robustness and performance based on models on state-space form, transfer function form, Bode diagrams or Nyquist diagrams.
- be able to design controllers based on cascade connections, feedforward, and delay compensation.
- be able to evaluate controllers by analysing transient and frequency responses, and via laboratory experiments on real processes.

Judgement and approach

For a passing grade the student must

- understand relationships and limitations when simplified models are used to describe complex dynamical systems.
- show ability for teamwork and collaboration at laboratory exercises.

Lectures and Problem Solving Sessions

Lectures are given by Anders Robertsson (L1-L5) and Richard Pates (L5 onwards). Exercise sessions are given by Anders Robertsson (E1-E3), Gautham Nayak Seetanadi (E4-E9) and Richard Pates (E10-E13). Labs are supervised by Gautham Nayak Seetanadi.

Richard Pates will also produce 'flipped classroom' material for L8-L12, which will be supported on site by Gautham Nayak Seetanadi.

Lectures and Exercises on Tuesdays and Wednesdays will be given at Old Main Building 407. Lectures and Exercises on Thursdays will be given at Old Main Building **Middle** 404.

Week	**Date**	**Time**	**Activity**	**Topics**
44	Oct 29 (Tue)	15:00-16:35	L1	Introduction. The PID controller.
	Oct 29 (Tue)	16:40-18:15	L2	Process models.
	Oct 31 (Thu)	14:00-15:35	E1	Process models. Linearisation.
45	Nov 5 (Tue)	15:00-16:35	L3	Impulse and step response analysis.
	Nov 5 (Tue)	16:40-18:15	E2	System representations. Block diagrams.
	Nov 6 (Wed)	14:00-15:35	L4	Frequency analysis.
	Nov 6 (Wed)	15:50-17:25	E3	Poles and zeros. Impulse and step responses.
	Nov 7 (Thu)	14:00-15:35	L5	Feedback and stability.
46	Nov 12 (Tue)	15:00-16:35	L6	The Nyquist stability criterion and stability margins.
	Nov 12 (Tue)	16:40-18:15	E4+E5	Frequency response. Bode and Nyquist diagrams. Preparation for Lab 2.
	Nov 14 (Thu)	14:00-15:35	L7	The sensitivity function and stationary errors.
47	Nov 19 (Tue)	15:00-16:35	L8	State feedback.
	Nov 19 (Tue)	16:40-18:15	E6	The Nyquist stability criterion and stability margins.
	Nov 20 (Wed)	14:00-15:35	L9	State estimation.
	Nov 20 (Wed)	15:50-17:25	E7	Stationary errors and controllability.
	Nov 21 (Thu)	14:00-15:35	L10	Output feedback and pole-zero cancellation.
48	Nov 26 (Tue)	15:00-16:35	L11	Lead-lag compensation
	Nov 26 (Tue)	16:40-18:15	E8+E9	Observability. State Estimation.
	Nov 28 (Thu)	14:00-15:35	L12	PID Control
49	Dec 3 (Tue)	15:00-16:35	L13	Controller structures and implementation
	Dec 3 (Tue)	16:40-18:15	E10+E11	Lead-lag compensation. Frequency analysis. PID design.
	Dec 4 (Wed)	14:00-15:35	L14	Synthesis example. Course Round-up.
	Dec 4 (Wed)	15:50-17:25	E12+E13	Controller structures. Synthesis.
	Dec 5 (Thu)	14:00-15:35	Old Exam	

Each lecture has a separate chapter in the lecture notes by Tore Hägglund, see 'Literature'.

Laboratory exercises

The course contains three mandatory laboratory exercises (3h15min each). Each laboratory exercise will be given at two occasions. It is mandatory to sign up for one occasion per exercise through the course homepage. The location for the labs will be updated soon.

Activity	Date	Time	Topics
Lab 1	Nov 6 (Wed)	19:00-22:15	Empirical PID control.
	Nov 7 (Thu)	19:00-22:15	
Lab 2	Nov 20 (Wed)	19:00-22:15	Modeling and calculation of PID controller.
	Nov 21 (Thu)	19:00-22:15	
Lab 3	Nov 27 (Wed)	19:00-22:15	State feedback and observer design.
	Nov 28 (Thu)	19:00-22:15	

You will work in groups of two or three students. For the labs you should ideally work in mixed Swedish, Chinese groups.

The manuals for Labs 2 and 3 contain preparatory exercises that must be solved before the laboratory exercise. At the start of Lab 2, a quiz with two review questions are given. You must give correct answers to both questions in order to proceed with the laboratory exercise. Sign-up lists for the laboratory exercises will be available on the course web page.

Literature

The course is based on the following compendiums:

- Tore Hägglund: *Automatic Control, Basic Course – Lecture Notes.* Department of Automatic Control, Lund University, 2018.
- *Automatic Control, Basic Course – Collection of Exercises.* Department of Automatic Control, Lund University, 2014.
- *Automatic Control, Basic Course – Laboratory Manuals.* Department of Automatic Control, Lund University, 2012.
- *Automatic Control, Basic Course – Collection of Formulae.* Department of Automatic Control, Lund University, 2012.

As reference textbook, we recommend

- Karl Johan Åström & Richard Murray: *Feedback Systems: An Introduction to Scientists and Engineers.* Princeton University Press. Second edition (2016) is available for free download at:

  `http://www.cds.caltech.edu/~murray/amwiki`

Examination

The mandatory parts of the course are

- the three laboratory exercises,
- the written exam.

The final grade is based only on the result from the written exam.

You may bring the collection of formulae[1] and a pocket calculator (without any control software) to the exam.

The exam for the Swedish students will be held in January 2020

The exam for the Chinese students will be held in December 2019

The corrected exams will be available for inspection at the Department of Automatic Control in Lund. Inspection date will be announced online.

Recommended Exercise Problems

S = Solved at exercise session. H = Recommended to be solved at home.

E1	S:	1.1, 1.2, 1.7
	H:	1.5a-c, 1.6, 1.9
E2	S:	2.1, 2.14ab, 2.15,
	H:	2.2ab, 2.16ab
E3	S:	2.5, 2.9, 2.11, 2.13
	H:	2.6
E4	S:	3.1, 3.2, 3.4bd, 3.5b, 3.7
	H:	3.4ac, 3.5a, 3.6
E5	S:	4.1, Prep exercises 3.1,3.5 in Lab 2, 4.9
	H:	6.3, 6.4
E6	S:	4.13, 4.15, 4.17, 4.18
	H:	4.12, 4.14, 4.19
E7	S:	4.11, 4.2, 4.6, 4.7, 4.4
	H:	4.3, 4.5
E8	S:	5.5, 5.8, 5.10, 5.11
	H:	5.2, 5.6
E9	S:	5.3, 5.12, 5.9
	H:	5.13
E10	S:	6.11, 6.12, 6.13, 6.14
	H:	6.15
E11	S:	6.5, 6.2, 6.7, 6.8
	H:	6.6, 6.9
E12	S:	7.1, 7.6, 7.8, 7.9
	H:	7.2, 7.5
E13	S:	8.1
	H:	8.2

Personnel

Name	**Duration of visit**	**Responsibilities**
Anders Robertsson	Weeks 44-45	L1-L5, E1-E3, Lab 1
Richard Pates	Weeks 45-46, 49	L6-L14, E10-E13, Old Exam.
Gautham Nayak Seetanadi	Weeks 47-48	E4-E9, Lab 2, Lab 3.

[1] clean, no own notes

Contact Information

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