AER372 Control Systems

Syllabus and Course Information, Winter 2016

Objective

This course is an introduction to feedback control. Topics include the modelling of physical systems, the analysis of their dynamic behavior (dynamic response and stability), and the design of feedback controllers to achieve a desired closed-loop system behavior.

The objective of this course is to provide a solid foundation of the concepts and methods of classical control theory so that students will have the ability to design and analyze linear feedback systems involving a single input and single output. Additionally, state-space methods are introduced so that students will have the background for future, more detailed studies of this topic.

Instructor

Prof. Angela Schoellig, schoellig@utias.utoronto.ca, Institute for Aerospace Studies (UTIAS), phone 416-667-7518

Teaching Assistants

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Schedule

- Lecture: Mon 15:00–17:00, BA1210; Wed 13:00–15:00, BA1210.
- Lab: Thu (alternating, see schedule below) 15:00–18:00, BA3114 (Labs 1–3) and MC402 (Lab 4).
- Office hours: after class and by appointment (please send an e-mail to the TAs or Prof. Schoellig); additional office hours will be offered before the term tests and final exam.

Website

We will use Blackboard for course administration:

`http://portal.utoronto.ca/`.

Reference Material

We will use the course textbook:

*Feedback Control of Dynamic Systems (**Seventh** Edition)* by G. F. Franklin, J. David Powell, and A. Emami-Naeini, Prentice Hall, 2014.

Hand-written class notes will be made available on Blackboard; notes will typically be available for download before the lecture.

A standard software tool for control systems design and analysis is Matlab/Simulink. We will use Matlab/Simulink for labs and exercises. The software is available to students through ECF. *Check it out!*

Additional recommended reference material is

> *Course Notes on Classical Control* by B.A. Francis, Electrical and Computer Engineering Department, University of Toronto, `http://www.scg.utoronto.ca/~francis/main.pdf`

and

> *Control Tutorials for Matlab – University of Michigan*, `http://ctms.engin.umich.edu`.

Course Topics and Syllabus

#	Date	Topic	Reading
1	Mon Jan 4	**Introduction**: Control Systems Examples	
2	Wed Jan 6	System Modeling, Linearization	1, 2
3	Mon Jan 11	**Dynamic Response**: Laplace Transform	3.1, A.1
4	Wed Jan 13	Laplace Transform (continued), Transfer Functions, Block Diagrams	3.2
5	Mon Jan 18	Poles and Zeros, Control Specifications, First-Order Systems	3.3, 3.4
6	Wed Jan 20	Second-Order Systems, Time Domain Specifications, Effect of Zeros	3.5, 3.6
7	Mon Jan 25	**Feedback Properties**: Stability, Basic Equations of Control	4.1
8	Wed Jan 27	Simple Controllers, Steady-State Error Analysis	4.2
–	Mon Feb 1	*Repetition and Practice Problems (Lectures #1 to #8)*	
–	Wed Feb 3	*Term Test 1 (covers Lectures #1 to #8)*	
9	Mon Feb 8	Dynamic Error Analysis, PID Control	4.3
10	Wed Feb 10	**Root Locus Design**: Root Locus Plot	5.1
–	Feb 15, 17	*Reading Week*	
11	Mon Feb 22	Root Locus Sketching Guidelines	5.2
12	Wed Feb 24	Root Locus Examples, Non-minimum-Phase Systems	5.3
13	Mon Feb 29	**Frequency-Response Analysis**: Frequency Response, Bode plots	6.1
14	Wed Mar 2	Nyquist Stability Criterion	6.2, 6.3
–	Mon Mar 7	*Repetition and Practice Problems (Lectures #9 to #14)*	
–	Wed Mar 9	*Term Test 2 (covers Lectures #1 to #14)*	
15	Mon Mar 14	Stability Margins (gain margin, phase margin)	6.4–6.6
16	Wed Mar 16	**Frequency-Response Design**: Compensation (lead, lag)	6.7
17	Mon Mar 21	Compensation (PID)	6.7
18	Wed Mar 23	Design Specifications, Sensitivity Function	6.7.7, 6.7.8
19	Mon Mar 28	**State-Space Control**: State-Space Description, Stability, Controllability	7.1, 7.2, 7.4
20	Wed Mar 30	Full-State Feedback Design, Pole Placement	7.5–7.7
21	Mon Apr 4	Observability, Observer Design, Separation Principle	7.7, 7.8
–	Wed Apr 6	*Repetition and Practice Problems (complete material)*	

Practice Problems

Problem sets will be available online for the topics covered in the lecture. The term tests and exam will contain some questions that are highly similar to practice problems provided. It is the student's responsibility to solve the problems and understand the material. *Talk to each other and work together!*

Questions can be asked in the office hours. Some of the problems might also be covered during the repetition classes.

#	Covers	Available on
1	Introduction, Dynamic Response, Feedback Properties (Lectures #1 to #8)	Wed Jan 6
2	Feedback Properties, Root Locus Design, Frequency-Response Analysis and Design (Lectures #9 to #14)	Mon Feb 8
3	Frequency-Response Design, State-Space Control (Lectures #15 to #21)	Mon Mar 14

Lab Schedule

For the labs, the class will be divided into two groups, PRA0101 and PRA0102. The location of Labs 1–3 is BA3114. The location of Lab 4 is MC402.

Two to three students will work together on the labs. They must hand in one solution and will all receive the same grade. The lab report is due roughly one week after the lab. Please hand it in during the lecture.

	PRA0101	**PRA0102**
Lab 1 (BA3114)	Thu Feb 4	Thu Jan 28
Lab 1 Report Due Date	Wed Feb 10	Wed Feb 3
Lab 2 (BA3114)	Thu Mar 3	Thu Feb 25
Lab 2 Report Due Date	Wed Mar 9	Wed Mar 2
Lab 3 (BA3114)	Thu Mar 17	Thu Mar 10
Lab 3 Report Due Date	Wed Mar 23	Wed Mar 16
Lab 4 (MC402)	Thu Mar 31	Thu Mar 24
Lab 4 Report Due Date	Wed Apr 6	Wed Mar 30

Grading

Grades will be assigned according to the following scheme:

- Laboratories, 16%
- In-Class Presentation of Control System Example, 4%
  - Dates: Jan 20, Feb 22, Mar 23 (during regular class period, three minutes per group)
- Term Tests, 2×15% = 30%
  - Term Test 1: Feb 3 (during regular class period)
  - Term Test 2: Mar 9 (during regular class period)
- Final Exam, 50%

Allowed aid for the term tests is a single sheet of paper (letter size). Students may enter on both sides of the aid sheet any information they desire, without restriction, except that nothing may be affixed or appended to it. Allowed aid for the final exam are two (2) single sheets of paper (letter size) and a non-programmable calculator.

"Education is not the filling of a pail, but the lighting of a fire."
– Plutarch