

EML 5311 : Control Theory

Spring 2007

Instructor

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Office Hours

Monday 8:30-9:30
open-door

Homework and Exams

25% Each exam (x3 exams) A written exam will be given after spring break.
25% Projects and homework Includes small projects and homework , and a large project.

Prerequisites

This course provides a graduate-level introduction to control theory which may be taken immediately following a standard course of undergraduate-level control theory. The students are expected to understand the basics of transfer functions, Bode plots, poles and zeros, feedback and feedforward, state-space modeling, PID, and a fundamental knowledge of dynamics.

Course Description

This course will introduce students to the complexities of feedback control for dynamical systems. The material will focus on characteristics found in most practical systems that do not fall within the framework of linear time-invariant (LTI) single-input single-output (SISO) systems that are covered in undergraduate-level control theory. Specifically, the discussions will investigate the effects of multivariable dynamics and nonlinear dynamics on the performance and stability of the closed-loop system. The course will investigate stability properties, effects of feedback, performance conditions, constraints, estimating linearized dynamics, and modeling.

Objectives

The fundamental objective is a deeper appreciation for controls as applied to realistic systems. Specifically, students will understand the challenges that are involved in a rigorous design of a controller and any associated claims as to the properties of the resulting closed-loop system. The material will cover both synthesis and analysis of such systems with particular emphasis on conceptual understanding of the issues causing difficulty. Students must design controllers and analyze systems in such a way that a simple trial-and-error approach will not be sufficient but rather a methodical treatment of the dynamics will reveal the required feedback law and resulting characteristics of the system.

Textbooks

The textbook for the course is

J.M. Maciejowski, "Multivariable Feedback Design," Addison-Wesley, 1989.

However, the book is not required and material will not explicitly follow the book. The course will predominantly be presented from selections of various texts and the instructor's notes.

- G.C. Graham, S.F. Graebe and M.E. Salgado, "Control System Design," Prentice-Hall, 2001.
- L. Ljung, "System Identification," Prentice-Hall, 1987.
- K. Ogata, "Modern Control Engineering," Prentice-Hall, 2002.
- J.E. Slotine and W. Li, "Applied Nonlinear Control," Prentice-Hall, 1991.
- K.Zhou, "Essentials of Robust Control," Prentice-Hall, 1998.

Schedule

The schedule is divided into several categories that reflect a major topic. The material is divided as 4 weeks on multivariable systems, 4 weeks on optimal control, 4 weeks on nonlinear control, and 3 weeks on modeling. Portions of supplementary textbooks are particularly appropriate for these topics.

WEEK 1	Feedback Loops <ul style="list-style-type: none">• gain and phase margins• sensitivity	(Maciejowski - pp. 1-13)
WEEK 2	Limitations of Feedback <ul style="list-style-type: none">• bandwidth• effects of poles and zeros	(Maciejowski - pp. 24-32)
WEEK 3	Multivariable Systems <ul style="list-style-type: none">• Smith-McMillan form• state-space form	(Maciejowski - pp. 40-44)
WEEK 4	Analysis <ul style="list-style-type: none">• poles and zeros• internal stability	(Maciejowski - pp. 45-58)
WEEK 5	Multi-Loop PID <ul style="list-style-type: none">• sequential loop-closure• dominant poles	(Ogata - pp. 681-723)
WEEK 6	Stability <ul style="list-style-type: none">• Lyapunov functions• algebraic Ricatti equations	(Zhou - pp. 233-252)
WEEK 7	Linear Quadratic Regulator <ul style="list-style-type: none">• quadratic performance• tracking	(Ogata - pp. 826-896)
WEEK 8	Linear Quadratic Gaussian <ul style="list-style-type: none">• Kalman filter• robustness	(Maciejowski - pp. 222-264)
WEEK 9	Gain Scheduling <ul style="list-style-type: none">• switching strategies• function gains	(Goodwin - pp. 559-566)
WEEK 10	Anti-Windup <ul style="list-style-type: none">• actuator constraints• state-limiter strategies	(Goodwin - pp. 293-314)
WEEK 11	Dynamic Inversion <ul style="list-style-type: none">• formulation• implementation	(Slotine - pp. 207-275)
WEEK 12	Harmonic Linearization <ul style="list-style-type: none">• describing function• analysis	(Slotine - pp. 157-190)
WEEK 13	Time-Domain Identification <ul style="list-style-type: none">• linear regressions• maximum likelihood estimator	(Ljung - pp. 141-207)
WEEK 14	Frequency-Domain Identification <ul style="list-style-type: none">• modal basis functions• equivalent systems modeling	
WEEK 15	Model Reduction <ul style="list-style-type: none">• Hankel norm• balance truncation	(Zhou - pp. 105-128)