University Of California, Berkeley
Department of Mechanical Engineering

ME 190Y: Practical Control System Design: A Systematic Optimization Approach (1 unit)

Undergraduate Elective

Syllabus

FULL DESCRIPTION

Can feedback control design be automated, whereby the engineer specifies closed-loop time-domain and frequency domain objectives, and a reliable algorithm produces a suitable control system? Thanks to a clever transformation discovered by Youla and others, the answer is a qualified ”yes”. Using elementary, but sound theory, some dominant aspects of control system design can be reduced to convex optimization problems, and solved numerically on a case-by-case basis. By contrast, introductory courses (such as ME 132) in feedback control usually focus attention on a few successful, important control architectures (eg., PI, lead-lag) and processes which are well controlled by these strategies. While it is critical to learn the introductory material, students are left asking “what else is possible?” The material in this course addresses this lingering question, and often shows why the architectures learned in the elementary course are so important in practice. In this 1-unit course, students will learn the theory and gain practical experience in using the technique.

CATALOG DESCRIPTION

The Youla-parametrization of all stabilizing controllers allows certain time-domain and frequency-domain closed-loop design objectives to be cast as convex optimizations, and solved reliably using off-the-shelf numerical optimization codes. This course covers the Youla parametrization, basic elements of convex optimization, and finally control design using these techniques.

COURSE PREREQUISITES

ME 132 or EECS 128 (EECS 20 may suffice) or similar introductory experience regarding feedback control systems. The student should understand basic properties of feedback systems, be comfortable with transfer function and differential equation descriptions of systems, and be familiar with typical feedback objectives such as disturbance rejection, command following, noise insensitivity and closed loop stability.

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Notes and slides in class, both based on Linear Controller Design: Limits of performance, by Stephen Boyd and Craig Barratt, available in pdf format at http://www.stanford.edu/~boyd/lcdbook/.

DESIRED COURSE OUTCOMES

This course gives the student an ability to apply knowledge of mathematics, science and engineering; an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; an ability to identify, formulate, and solve engineering problems; an ability to communicate effectively; and a knowledge of contemporary issues.

TOPICS COVERED

1. (1 lecture) Review of design objectives in a feedback system, role of the sensitivity and complementary sensitivity functions;
2. (3 lectures) Conservation laws in feedback systems: Bode integral theorem, maximum modulus theorem, closed-loop consequences of open-loop right-half-plane poles and zeros;
3. (3 lectures) Youla parametrization of all stabilizing controllers for a plant;
4. (2 lectures) Convex sets, convex functions, convex optimization;
5. (2 lectures) Formulating control design problems as optimizations: pitfalls and best practices;
6. (3 lectures) Design examples, interpreting the results in classical control context;
7. Last lecture: 1-hour final exam.

CLASS/LABORATORY SCHEDULE

1 Lecture per week

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

The focus of the course is optimization-based control system design, using sound theory to ensure that the optimizations are convex. The use of numerical tools to enable (and automate) advanced design is prevalent in industry, and this class reinforces this notion.

RELATIONSHIP OF THE COURSE TO ABET PROGRAM OUTCOMES

This course gives the student an ability to apply knowledge of mathematics, science and engineering; an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability; an ability to identify, formulate, and solve engineering problems; an ability to communicate effectively; and a knowledge of contemporary issues.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

- Weekly graded homework assignments: 70%
- 1 midterm quiz, 15%
- 1 final exam, 15%

PERSON(S) WHO PREPARED THIS DESCRIPTION

Andrew Packard, 10/28/08