University Of California, Berkeley
Department of Mechanical Engineering

ME 132 - Dynamic Systems and Feedback [3 units]

Undergraduate Required

Syllabus

CATALOG DESCRIPTION

Physical understanding of dynamics and feedback. Linear feedback control of dynamic systems. Mathematical tools for analysis and design. Stability. Modeling systems with differential equations. Linearization. Solution to linear, time-invariant differential equations.

COURSE PREREQUISITES

Math 53, 54, Physics 7A-7B. Programming (E 77) Ordinary differential equations (Math 1B, Math 54) Elementary linear algebra (Math 54)

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Course notes provided.

COURSE OBJECTIVES

Carefully motivate the purposes of a feedback system, specifically regulation in the presence of external influences/disturbances, sensitivity reduction, command reference tracking and stabilization. Understand the tradeoffs in play, such as increased sensitivity to sensor noise and the possibility of dynamic instability due to likely plant-behavior variability. Develop analytic skill to quantitatively predict the behavior of a feedback system, given mathematical models of the individual components (plant, actuator, sensor, control law).This involves a considerable review of the student's background in linear, ordinary differential equations. Develop a basic understanding of how numerical simulation can be used to predict the behavior of complex systems governed by (linear and nonlinear) ordinary differential equations. Develop skills in using professional computer-aided control system design and analysis tools, e.g., Matlab Control System Toolbox. Develop skills in using professional model-based simulation tools, e.g. Simulink, to explore and discover properties of feedback systems made up of a (possibly) large number of complex components, where analytical tools are either less effective, nonexistent, or beyond the scope of an undergraduate class. Understand how linearization can be used to design linear feedback control laws for regulation of a nonlinear system near an operating point. Perform robustness analysis, such as gain margins, time-delay margins, and percentage-variation margins at single points in a complex, multi-loop system. Understand that margins are dependent on the location in the loop, consequently the sensitivity of the overall system performance to a given component varies from component to component (in an interconnected system, some components are more important than others).

DESIRED COURSE OUTCOMES

At the end of the course, students are able to:
Effectively communicate about feedback systems, using common standardized terms: differential equation, transfer function, state, stability, closed-loop sensitivity, linearization, frequency response, damping ratio, natural frequency, time-constant, open-loop gain, steady-state gain, saturation, windup, margins, loop-breaking point, overshoot, poles, reverse-reaction. Analyze the performance of a closed-loop control system given mathematical models of the components

a. Assess the stability of the system using differential equation theory

b. Apply frequency-response and time-domain methods to assess system response to process disturbances, sensor noise, commands

c. Use open-loop Bode plots to assess the robustness (gain-margin, time-delay margin) of a feedback system

Analyze (in a limited manner) the performance of a closed-loop control system given experimental data (i.e., frequency response measurements) about the components

a. Limited, in that Nyquist theory is not covered, hence the student can, only under the assumption of closed-loop stability, compute robustness margins and various closed-loop frequency responses.

Use modern control system analysis software (e.g., Matlab Control System Toolbox) for system manipulation, analysis and simulation.

Perform complex modeling of dynamic systems, using Simulink.

a. Perform detailed 1-parameter studies, using Simulink, to assess the effect of a parameter of the performance/behavior of a closed-loop system

Design simple feedback control laws (complexity of PID, with roll-off filter) for 1st, 2nd and 3rd order systems, emphasizing different objectives (disturbance attenuation, noise sensitivity, robust stabilization).

Linearize a nonlinear system about an operating point, design a linear feedback control based on the linearized model to regulate the true nonlinear system in the vicinity of the operating point.

Design antiwindup schemes for controlling systems with hard limits on input magnitudes.

TOPICS COVERED

Introduction to feedback systems: Benefits and pitfalls of feedback. Block diagrams for system models. Numerical simulation of dynamic systems. Simulink. Arithmetic of Feedback Loops, basic tradeoffs. Proportional Control of first-order systems. Review of linear, ordinary differential equations. Integral control, rate feedback. Sinusoidal steady-state response of systems. Transfer function descriptions of systems. Transfer functions of system interconections. Relationship between frequency-response function and transfer functions. Arithmetic of Feedback Loops, loop-shaping. Robustness margins. State-space models. Jacobian linearization.

Properties of systems described by state-space models (Stability, frequency response, transfer function).

CLASS/LABORATORY SCHEDULE

Three hours of lecture and one hour of laboratory per week.

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

Students learn the basic properties of feedback systems, and should be able to immediately and successfully apply simple (PID-like) feedback strategies to a host of industrial problems. Students also develop modest proficiency in computer-aided tools, specifically Matlab Control System Toolbox and Simulink, both of which are used ubiquitously in the industry.

RELATIONSHIP OF THE COURSE TO ABET PROGRAM OUTCOMES

(a) an ability to apply knowledge of mathematics, science, and engineering
(c) 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
(e) an ability to identify, formulate, and solve engineering problems
(i) a recognition of the need for, and an ability to engage in life-long learning
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

12 homework assignments
2 midterm exams
1 final exam

PERSON(S) WHO PREPARED THIS DESCRIPTION: Andrew Packard March 17, 2006