Course Overview

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Developed and refined over the past six years, this course provides a comprehensive review of recent developments in control theory and investigates their practical application to industrial problems. Beginning with an overview of fundamental modeling and hardware tradeoffs that affect control-system performance, the course systematically examines identification and controller synthesis techniques for both linear and nonlinear systems, including the fundamentals of robust and adaptive control for uncertain systems. Each topic is thoroughly reviewed, beginning with its theoretical foundations and proceeding to implementation issues that should be considered in practice.

This course is suitable for control practitioners who wish to obtain a broad perspective of the control engineering enterprise as well as engineers from all industries seeking a coherent, self-contained examination of recent developments relevant to control practice.

First Day

Defining the Issues and Challenges in Control Engineering

Course Overview
Control-System Design: Strategy, Physics, Architecture, and Hardware
Plant Properties, Achievable Performance, and Basic Tradeoffs

Developing Linear Models for Control

Linear Plant Modeling: Representation and Properties
Empirical Linear Modeling: System Identification in the Time and Frequency Domains

Linear Controller Analysis and Synthesis

Minimal-Information Control: The Art and Science of PID Tuning
Frequency Domain Advances: From KYP to Generalized KYP
Uncertainty Measures and Robustness Analysis: From H2 to Hinfinity

Controller Synthesis for Performance and Robustness

Robust Controller Synthesis
Adaptive Stabilization and Command Following

Second Day

Developing Nonlinear Models for Control

Nonlinear Plant Modeling: Model Properties and Structure
Nonlinear Identification Methods for Block-Structured (Grey-Box) Models

Inexact Approaches to Nonlinearity

Treating Nonlinearity as Uncertainty: Absolute Stability, Linear Matrix Inequalities, and Integral Quadratic Constraints
Treating Nonlinearity as Linearity: Gain Scheduling, Linear Parameter Varying Systems, and Frozen Linear Methods

Exact Approaches to Nonlinearity

Feedback Linearization: Methods and Pitfalls
Backstepping: A Constructive Nonlinear Approach

Implementing Real Control in Real Hardware

Facing the Reality of Constraints: Traditional and Modern Approaches
Adaptive Disturbance Rejection with Applications to Tonal and Broadband Disturbances
A Case Study for Controller Design and Implementation: Active Chatter Control

Dennis Bernstein is a Professor in the Aerospace Engineering Department at the University of Michigan. From 1982 to 1984 he was a member of the technical staff of MIT Lincoln Laboratory in the Control Systems Engineering Group, and from 1984 to 1991 he was a Staff Engineer with Harris Corporation Government Aerospace Systems Division in the Structural Controls Group. In 1991 he joined the Aerospace Engineering Department of the University of Michigan. He has published more than 150 journal papers and 250 conference papers, has served as an associate editor of several major journals, and is currently Editor in Chief of the *IEEE Control Systems Magazine*. At the University of Michigan he has taught undergraduate and graduate courses on systems and control theory with applications to aerospace systems. In addition, he founded the Noise, Vibration, and Motion Control Laboratory, which supports the development of control experiments for concept validation and technology transition. He was a plenary speaker at the 2001 IEEE Conference on Decision and Control, and he is the author of *Matrix Mathematics: Theory, Facts, and Formulas with Application to Linear Systems Theory* published by Princeton University Press in 2005.

Carl Knospe is an Associate Professor in the Mechanical and Aerospace Engineering Department at the University of Virginia, where he has taught both graduate and undergraduate courses on dynamics and control. Over the past 15 years, he has served as a consultant to industry on control systems and mechatronics, and has taught short courses on these topics throughout North America and Europe. The author of over 40 peer-reviewed journal articles and 80 conference publications, Professor Knospe has received numerous Best Paper awards at international conferences. He is currently an Associate Editor for both *IEEE Transactions on Control Systems Technology* and *IEEE Control Systems Magazine*, where he recently served as Editor for the *Special Issue on PID Control*. His research focuses on the application of control theory to electromechanical systems, manufacturing, and vibration control.