ECE 486

Control Systems

Course Goals

This is a first course in feedback control of dynamic systems. A design-oriented approach is stressed. Computer-based analysis, combined with a modern accompanying laboratory, provide a realistic setting for mastering several important design methodologies. Concurrent development of basic concepts in lecture and homework provides a foundation for continued study of advanced topics and newly emerging methods. Students come from a wide range of disciplines since control is an interdisciplinary topic.

Instructional Objectives

A. Modeling and dynamic response. After approximately 10-12 lectures, the student should:

1. be able to develop models (differential equations, state space, transfer functions) for a variety of dynamic physical systems (mechanical, electrical, electromechanical, fluid, thermal). (a, e, k, m)
2. be able to use small-signal linearization to obtain linear models for the systems modeled in 1. (k, m)
3. have a good understanding of the response characteristics of basic first- and second-order dynamic systems. Be able to correlate time-domain responses with transfer-function pole and zero locations. (a, k, m)
4. understand the use of block diagrams as a modeling tool. Be able to manipulate block diagrams for systems of interconnected components. (k)
5. understand bounded-input bounded-output stability and its connection with pole locations. (k, m)
6. understand steady-state error (tracking error and disturbance rejection), and be able to determine these errors from system block diagrams. As a design issue, be able to adjust controller gains to meet steady-state error specification. (c, e)
7. have an introductory knowledge of PID controllers. Be able to design PID controllers to meet simple specifications. (c, e)
8. understand the role of feedback in obtaining stability and reducing tracking errors in the presence of plant uncertainties. (k)

B. Root Locus Design Technique. In the next set of about 6 lectures, the student should:

9. master the principles of the Root Locus Design Method. (k)
10. be able to use the root locus to adjust gains or to develop dynamic controllers (lead, lag, PID) to meet specifications. (c, e, k)

C. Frequency Response Design Methodology. After the next 12 lectures, the student should:

11. understand and be able to obtain Bode plots and Nyquist diagrams. (a, k)
12. be able to correlate time responses, pole-zero locations, and frequency responses (Bode, Nyquist). (k)
13. master the Nyquist Stability Criterion. (n, k)
14. develop the ability to use frequency response techniques to design dynamic controllers (lead, lag, PID) to meet specifications. (c, e)
15. understand the Bode Sensitivity Function and its relation to plant uncertainty, disturbance rejection, and steady-state tracking error. (c, e)
16. understand the basic design limitations on the Bode Sensitivity Function and constraints as expressed by the Bode Gain-Phase Formula. (c, n)
17. be able to explain why non-minimum phase, time-lag, and unstable plants present special design challenges. (k, g)

D. State Space Design Methods. After the final 10-12 lectures, the student should:

18. be able to analyze state models in vector-matrix format, using the state transition matrix. (e, n)
19. have an introduction to the structural properties of state models: controllability, observability, stability. (e, k, i)
20. be able to perform pole placement designs using state feedback and observer-based controllers. (c, e)
21. have a glimpse of optimal control using the Symmetric Root Locus as a bridge to pole placement as in 20. (i, c)
22. be able to evaluate state space design from a transfer function approach, using root locus, Bode, etc. (k, e)

Laboratory Objectives

1. Become familiar with instrumentation and software commonly used in industrial control development. (b, k)
2. Improve skills in evaluating and communicating experimental results. (b, g)
3. Learn a variety of modeling and simulation methods based on actual physical systems. (a, e)
4. In a series of closely related experiments, model, design, and implement a controller for a dc motor exhibiting nonlinearities and noise. (b, c, k)
5. Complete a capstone project requiring the design of controls for a challenging control system (e.g., an inverted pendulum, torsional vibration system, or robotic arm). Modeling, design, and simulation topics from the course are applied and unified. (a, b, c, d, e, g, i, k, m)

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