Master of Science in Control Engineering

Basic knowledge for access

1. Mathematical modeling of systems
Differential equations. Linearization. Use of the Laplace transform. Input-output and state-space representations. Transfer functions. Poles and zeros. Interconnected systems and block diagrams. Difference equations. Sampling of continuous time systems. Use of the Z-transform, Some facts from matrix theory. Simulation tools.

2. Properties of linear dynamical systems
Stability. Free and forced evolution. Steady-state and transient responses. Impulse response. Step response. Frequency response. Bode and Nyquist diagrams. Asymptotic stability and Routh criterion.

3. Feedback control systems
Requirements in the design of control systems. Feedforward, feedback, and mixed schemes. Precision. Steady-state error. Disturbance rejection and attenuation. Sensitivity analysis. Transient response and relation with the closed-loop frequency response. The cost of feedback. Performance indices.

4. Design based on the frequency response
Stability of feedback systems: Nyquist criterion. Stability margins. Bandwidth and resonant frequency. Open- vs. closed-loop frequency characteristics (Nichols chart). Lead and lag compensation. PID control.

5. Design in the Laplace domain
Root locus method. Stabilization of minimum and non-minimum phase systems. Direct design. Pole placement techniques.

6. Design based on state-space techniques
Canonical forms. Structural properties and Kalman decomposition. Controllability and stabilizability. Observability and detectability. Stabilization via state feedback. Eigenvalue assignment. Observer design. Separation principle. Stabilization via output feedback.

Reference materials

Some general reference textbooks that can be easily found internationally are:

- R. Dorf, R. Bishop: “Modern Control Systems,” (international edition), Prentice Hall, 2005.
- B. Friedland: “Control System Design: An Introduction To State-Space Methods,” Dover, 2005.
- G. Franklin, J. Powell, A. Emami-Naeini: "Feedback Control of Dynamic Systems," Addison-Wesley, 2011.
- N.S. Nise: "Control Systems Engineering," (international student edition), John Wiley, 2011.

A possible self-study can be combined with some on-line courses (free of charge) found on the web. Two suggestions from MIT are:

16.06 Principles of Automatic Control (Prof. Steven Hall, as taught in Fall 2012, Undergraduate Level)
https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-06-principles-of-automatic-control-fall-2012/

This course introduces the design of feedback control systems as applied to a variety of air and spacecraft systems. Topics include the properties and advantages of feedback systems, time-domain and frequency-domain performance measures, stability and degree of stability, the Root locus method, Nyquist criterion, frequency-domain design, and state-space methods.

16.30 Feedback Control Systems (Profs. Jonathan How and Emilio Frazzoli, as taught in Fall 2010, Undergraduate Level)
https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-30-feedback-control-systems-fall-2010/

This course will teach fundamentals of control design and analysis using state-space methods. This includes both the practical and theoretical aspects of the topic. By the end of the course, you should be able to design controllers using state-space methods and evaluate whether these controllers are robust to some types of modeling errors and nonlinearities. You will learn to:

- Design controllers using state-space methods and analyze using classical tools.
- Understand impact of implementation issues (nonlinearity, delay).
- Indicate the robustness of your control design.
- Linearize a nonlinear system, and analyze stability.