ECE 6744/ ME 6544/AOE 6744: Linear Control Theory
Course Syllabus

Instructor: Mazen Farhood
224-13 Randolph Hall
E-mail: farhood@vt.edu
Phone: 231-2983

Meeting Time: Tuesdays and Thursdays, 3:30 to 4:45 PM

Meeting Place: Whittemore 277

Office Hours: Tuesdays 5:00 to 6:30 PM and Thursdays 5:00 to 6:30 PM

Grader: TBA

Description: This course covers optimal controller and observer design for multi-input, multi-output linear systems. Major course topics include a review of linear system theory, linear-quadratic optimal control theory, linear-quadratic Gaussian (optimal controller/observer) theory, and methods for ensuring robustness to model uncertainty and time delays.

References: Texts Focusing on Linear Optimal Control

P. Dorato, C. T Abdallah, and V. Cerone. *Linear Quadratic Control: An Introduction*, Krieger Publishing.

B. D. O. Anderson and J. B. Moore. *Linear Optimal Control*, Prentice Hall, Englewood Cliffs, NJ, 1971.

R. W. Brockett. *Finite Dimensional Linear Systems*, John Wiley and Sons, New York, NY, 1970.

H. Kwakernaak and R. Sivan. *Linear Optimal Control Systems*, John Wiley and Sons, New York, NY 1972.

More General Texts on Optimal Control

A. E. Bryson, Jr. and Y.-C. Ho. *Applied Optimal Control: Optimization, Estimation, and Control*, (Revised Printing) Taylor and Francis, New York, NY 1975.

R. F. Stengel. *Optimal Control and Estimation*, Dover, New York, NY 1986.

Grade:

20%	Homework
30%	Midterm Exam
30%	Final Exam
20%	Final Project

Final Project: The final project must be related to the course and is subject to the instructor's approval. A one-page proposal describing the project topic and scope is due on Friday, March 4. A written paper describing the project is to be submitted on Friday, April 29. You may apply the techniques discussed in this course to an interesting control problem of your choosing or present a detailed survey paper describing a special topic in optimal control theory.

Course Topics:

I. Linear System Theory
  A. Linear Algebra
    i. Vector spaces and norms
    ii. Linear maps; range and null space
    iii. Existence and uniqueness of solutions to linear alebraic equations
    iv. The eigenvalue problem
    v. Symmetric matrices and quadratic forms
    vi. Similarity transformations and the Jordan form
  B. Linear ODEs
    i. Linearization of nonlinear ODEs
    ii. The state transition matrix
    iii. Stability of equilibria
  C. Control and Estimation
    i. Controllability, stabilizability, and modal decomposition (The Cayley-Hamilton Theorem)
    ii. Observability, detectability, and modal decomposition
    iii. Stabilization by pole placement
    iv. State estimation by pole placement

II. The Linear-Quadratic Controller
  A. Derivation of the LQ controller by dynamic programming
    i. Solution for time-varying systems
    ii. Solution for time-invariant systems
    iii. Steady-state (infinite horizon) solution for time-invariant systems (The Linear-Quadratic Regulator)
      1. Penalty matrix selection
      2. Guaranteed degree of stability
    iv. LQ optimal trajectory tracking
  B. Derivation of the LQ controller from least squares theory
    i. Least squares optimization in Euclidean space; the pseudoinverse
    ii. Least squares optimization in function space
  C. Robustness of the LQR state feedback controller
    i. Nyquist plots
    ii. Stability (gain and phase) margins

III. State Estimation
  A. Introduction to stochastic systems
  B. The Kalman-Bucy filter
  C. Special Topic: The extended Kalman-Bucy filter and adaptive identification

IV. Combined State Estimation and Feedback Control
  A. The LQG controller and the separation principle
  B. Loss of robustness and loop transfer recovery