1. ES306H Advanced Control Systems

2. 3 credit hours, 2 recitation hours and 2 laboratory hours

3. Course coordinator: Professor Kiriakos Kiriakidis

4. Textbook: Control Systems Engineering (Eleventh Edition), Nice, 2015

5. Specific course information

   a. This course builds upon the foundation established in ES305H and covers the analysis and design of state-space control systems. Specifically, state feedback control and state estimation methods are presented and supported by a series of laboratory projects on the design and implementation of state-space control systems for physical systems. This honors course focuses on deeper analysis of the linear and advanced control toolsets and includes an open-ended control design project. [spring]

   b. Prerequisite: ES301, ES305H

   c. Required course

6. Specific goals for the course

   a. At the conclusion of the course, students will be able to:

      - Apply classical control design and understand the limits of its performance
      - Understand state equations and their ability to describe the internal dynamics of a system
      - Understand control system performance specifications in terms of matrix characteristic roots
      - Apply linear algebra to solve problems arising in control design
      - Apply series expansion to approximate nonlinear terms
      - Apply differential equation methods to solve for the state vector in time
      - Analyze the effect of multiple feedback loops on the characteristic polynomial (state feedback)
      - Evaluate the performance of state feedback design against implementation and operational costs
      - Understand the need for a state estimator with feedback (unknown inputs and ICs)
      - Synthesize a state estimator given a plant model and output measurement

- Understand control of a physical plant via a communication network (Cyber-Physical System)
- Analyze by simulation the effect of communication delays on system performance

b. This course addresses the following student outcomes:
   - (a) an ability to apply knowledge of mathematics, science, and engineering
   - (b) an ability to design and conduct experiments, as well as to analyze and interpret data
   - (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) lack of controllability or observability in engineered systems
   - (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

7. Topics covered:

   - Limits of Classical Design
   - Applied Matrix Algebra: Caley-Hamilton Theorem; Matrix Exponential
   - Solution of State Equations
   - Controllability and Diagonal Form
   - Pole Placement
   - State Estimation
   - Networked Control Systems: Time Delays and Cyber Attacks