E&CE 682: Multivariable Control Systems

Instructor: Prof. Daniel Miller (EIT3116; ext. 35215; miller@uwaterloo.ca)

Schedule: Lectures: Monday 2:30pm - 5:30pm (EIT3151)

Calendar Description: An introduction to control theory for linear time-invariant finite-dimensional systems from both the state-space and input-output viewpoints. State-space theory: the concepts of controllability, observability, stabilizability, and detectability; the pole-assignment theorem; observers and dynamic compensation; LQR regulators. Input-output theory: the ring of polynomials and the field of rational functions; the algebra of polynomial and rational matrices; coprime factorization of transfer matrices; Youla parametrization. Introduction to optimal control.

Text: I will provide coursenotes on LEARN; I will place some relevant textbooks on reserve in the library.

Grading:

- There will be exercises spread throughout the notes. Depending on the size of the class, I will mark some of them to yield an assignment mark (20%).
- There will be an individual project worth 30%. It will entail modelling a physical system, designing a state estimator(s) and a controller(s), and carrying out some MATLAB simulations. Details will be provided in the second or third week fo class.
- There will be a final exam worth 50%.

Assumed Background: ECE380 (or equivalent) and familiarity with basic linear algebra.

Detailed Description:

1. Introduction to Linear Multivariable Systems

Some detailed examples include electrical systems and mechanical systems, including an inverted pendulum.

2. Mathematical Preliminaries

Vector spaces, matrices, matrix manipulations, norms, solving linear differential and difference vector equations.

3. Multivariable LTI Systems: An Input-Output Approach

State-space to transfer function, similarity transformations, discretizing a continuous-time system, poles and zeros of a multivariable system.

4. Controllability

Controllability, reachability, PBH test, equivalence of pole placement and controllability, controllable canonical form.

5. Observers and Observability

Observability, detectability, PBH test, observers, separation principle.

6. LQR Optimal Control

Cost functions, dynamic programming, Riccati equation, optimal LQR feedback, properties of the optimal LQR feedback.

7. Youla Parametrization and its Applications

Matrix fractional descriptions of transfer functions, Bezout identity, parametrization of all stabilizing controllers, an introduction to L_1, H_∞ and H_2 optimal control.

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For typical penalties check Guidelines for the Assessment of Penalties,
www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

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