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 courseneotes 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 of 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.

   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 $L_1$, $H_\infty$ and $H_2$ optimal control.
General UW Guidelines

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