John S. Baras

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ENEE 661 - Non Linear Control Systems

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Spring 2009 Information

tue-thr........10:30pm - 11:45pm

Location: EGR 2112

Catalog Description:

> *Prerequisite: ENEE660; MATH410 or MATH411 or equivalent; or permission of instructor.* State space methods of stability analysis including second order systems and the phase plane, linearization and stability in the small, stability in the large and Lyapunov's second method. Frequency domain methods including the describing function. Popov's method and functional analytic methods. Introduction to Volterra series representations of nonlinear systems. Applications to conrol system design.

Course Goals

This is a significantly revised version of the core course in nonlinear control systems. It is aimed to provide an introduction to Lie-algebraic and analytic methods for the qualitative behavior of nonlinear systems, and the synthesis and design of controllers for such systems. Using Lie brackets and physical examples (e.g. pumping a swing, unicycle kinematics, forced rigid body, switched electrical circuits, robot motion planning), concepts such as controllability, equilibria, periodic orbits, stability, stabilization, passivity, and steady-state response of input-output systems will be discussed. Techniques include Lyapunov's direct method, Chetaev's instability theorem, linearization, frequency domain stability analysis, and functional analytic methods. Techniques with a geometric flavor, including center manifold reduction, feedback linearization, and elementary bifurcation analysis will be introduced. We will also discuss briefly nonlinear oscillations and averaging theory. Examples from physics, engineering and biology will be used throughout the course.

Course and Topic Prerequisites

Course Prerequisite: ENEE 660 (see http://www.ece.umd.edu/class/enee660.F2010/) or equivalent, or permission of instructor. A prior course in advanced calculus (e.g. MATH 410

or MATH 411) is recommended. A good course in differential equations would also serve as adequate mathematics background.
Topic Prerequisite: It is desirable that the student be familiar with basic concepts and tools from linear system theory including, the matrix exponentials and the variation of constants formula, controllability, observability and stabilizability, and the Nyquist criterion. It would be helpful (but not essential) to be familiar with normed vector spaces, the Inverse Function Theorem, and the Implicit Function Theorem. We will cover these items. The discussion of Lie algebras and Lie groups will be self-contained and no algebraic background is assumed beyond linear algebra and what is used in ENEE 660.

Core and Optional Topics

Core Topics:
1. Vector fields, Lie brackets and controllability.
2. Existence, uniqueness and continuous dependence on initial conditions of solutions to ordinary differential equations.
3. Lyapunov's direct method for time-invariant and time-varying systems; stability and instability results of Lyapunov and Chetaev; Lasalle's Invariance Principle.
4. Regions of attraction and their estimation, matrix Lyapunov equation.
5. Linearization Theorem, stability and instability results.
6. Passivity, input-output stability and the Small Gain Theorem.
7. Passivity and absolute stability (Circle and Popov criteria).
8. Stabilization using state feedback (via linearization), and input-output linearization.
9. Periodic orbits and orbital stability.

Additional Topics (a selection from) Nonlinear observability, and invertibility; Volterra series representation and realization theory; relative degree and zero dynamics; bifurcations; perturbation theory and averaging; singular perturbations; nonlinear dynamics of algorithms for optimization; models of hysteresis; applications in robotics, network flow control, cooperative control, spacecraft dynamics, adaptive control and evolutionary games.