CALIFORNIA INSTITUTE OF TECHNOLOGY

Control and Dynamical Systems
CDS 270

Spring 2007

Instructor

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Office Hours: by appointment

Grading

Pass / Fail. The final grade will be based on a course project and class attendance.

Prerequisites

Linear systems and control, basic understanding of nonlinear dynamics, Lyapunov stability theory, numerical methods, and MATLAB.

Course Outline

The main goal of this course is to give a self-contained mathematical treatment of robust adaptive control theory and its current state of the art. Throughout the course both theoretical and application aspects of robust adaptive control design for uncertain dynamical systems will be presented.

Project

The course project will consist of a design, analysis, and simulation of an adaptive controller for a nonlinear dynamical system. Course projects will be assigned no later than the 5th week of classes from a list of available topics. Project reports will consist of both written and oral portions. The written portion of the report should be a description of the selected topic using the terminology and notation of the class. It is due the first day of finals week. The oral portion of the report will be a 15-25 minute presentation to the class, given during the last week of the term.

Course material

The following is a tentative outline of the material to be covered this term.

1. Introduction, Motivating Examples, Current state of the art
2. Review of Lyapunov Stability Theory
    a. Nonlinear systems and equilibrium points

   b. Linearization
   c. Lyapunov direct method
3. LaSalle extensions
4. Barbalat Lemma and Lyapunov-like Lemma
5. Uniform Ultimate Boundedness by Lyapunov Extension
6. Adaptive control architectures
   a. Basic concepts
   b. Design approach: Direct vs. indirect
   c. Certainty Equivalence Principle
7. Model Reference Adaptive Control, (MRAC)
   a. Augmentation of a nominal design
   b. Using dynamic inversion
   c. Adaptive backstepping
8. Enforcing robustness to parametric and non-Parametric uncertainties
   a. Dead-zone
   b. Sigma modification
   c. E – modification
   d. Projection operator
9. Artificial Neural Networks, (NN)
   a. Universal approximation properties
   b. Using sigmoids
   c. Using Radial Basis Functions, (RBF)
10. Adaptive NeuroControl
11. On-line parameter estimation, parameter convergence, and Persistency of Excitation (PE) conditions
12. Design Examples
   a. Adaptive Augmentation of an LQR controller with integral action
   b. Adaptive Reconfigurable Flight Control using RBF NN-s

Main Textbooks:

1. J.J. Slotine, W. Li, Applied Nonlinear Control, Prentice Hall, 1995.
2. H.K. Khalil, Nonlinear Systems, 3rd Edition, Prentice Hall, New Jersey, 2002.

Supplementary Textbooks

1. M. Krstic, I. Kanellakopoulos, P. Kokotovic, Nonlinear and Adaptive Control Design, John Wiley & Sons, New York, 1995.
2. P. Ioannou, B. Fidan, Adaptive Control Tutorial, SIAM, Advances in Design and control, SIAM, PA, 2006.
3. K. Narendra, and A. Annaswamy, Stable Adaptive Control, Dover, N.Y., 2005.
4. S.S. Sastry and M. Bodson, Adaptive Control: Stability, Convergence and Robustness, Prentice Hall, 1989.
5. R.Marino and P.Tomei, Nonlinear Control Design: Geometric, Adaptive, Robust. Prentice Hall, New Jersey, 1995.