Adaptive Control, CDS 270

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

Course Outline: The main goal of the 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 model reference control design for uncertain dynamical systems will be presented.

Project: Individual projects will be assigned. Each student will be asked to design, simulate, and analyze an adaptive controller for a nonlinear dynamical system. Project report will be due a week before the final exam.

Homework

- assigned once every two weeks
- students are not required to turn the homework in
- solutions will be available on the homework due dates
- students can grade on their own, if they like

Grading Policy

- course to be taken for grades or P/F
- the entire grade will be based on a course project that students will propose in week 5 and turn in by end of week 9
- grades will be assigned as follows: A = average, B = bad, C = catastrophic

Course material

1. Course overview: 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. Artificial Neural Networks, (NN)
    a. Universal approximation properties
    b. Using sigmoids
    c. Using Radial Basis Functions, (RBF)
9. Enforcing robustness to parametric and non-Parametric uncertainties
    a. Dead-zone
    b. Sigma modification
    c. E – modification
    d. Projection operator
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.

Additional / Supplementary Textbooks

1. M. Krstic, I. Kanellakopoulos, P. Kokotovic, Nonlinear and Adaptive Control Design, John Wiley & Sons, New York, 1995.
2. K. Narendra, and A. Annaswamy, Stable Adaptive Control, Prentice Hall, 1989.
3. S.S. Sastry and M. Bodson, Adaptive Control: Stability, Convergence and Robustness, Prentice Hall, 1989.
4. P. Ioannou, J. Sun, Robust Adaptive Control, Prentice Hall, New Jersey, 1996.
5. F. Lewis, S. Jagannathan, S., A. Yesildirek, Neural Network Control of Robot Manipulators and Nonlinear Systems, Taylor & Francis, 1998.
6. R.Marino and P.Tomei, Nonlinear Control Design: Geometric, Adaptive, Robust. Prentice Hall, New Jersey, 1995.