ME/SE 704: Adaptive Control

Instructor

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Meeting Time and Place

Mondays and Wednesdays, 2–4pm, SOC Room B59

Description

Feedback, adaptation, and learning are essential elements in many biological and engineered systems. The subject of adaptive control provides a rigorous approach to design and analyze systems that incorporate feedback, learning, and adaptation using control theoretic tools. In this course we will study the main elements of adaptive control, as well as explore emerging research topics in the area. We will study on-line strategies for estimating the unknown parameters of a dynamical model from empirical data (i.e. system identification). We will then apply these strategies together with feedback controllers to produce adaptive control schemes that are able to control systems with unknown dynamics. We will study both the Model Reference Adaptive Control (MRAC) approach and the Adaptive Pole Placement Control (APPC) approach, with a focus on analyzing properties such as stability, convergence, persistent excitation, and boundedness of signals. We will also study techniques to make adaptation mechanisms robust to disturbances and unmodeled dynamics. Finally, we will survey modern topics from the recent adaptive control research, and explore some related techniques from machine learning.

Prerequisites

ME 501 (Dynamic System Theory) or a similar course or permission of the instructor. Exposure to nonlinear system theory (ME 762) would be helpful but is not required. We develop the necessary tools from nonlinear control theory as needed.

Structure and Expectations

The course will have four main components: lectures, homeworks, a "paper talk," and a project.

Lectures Students will be expected to attend lectures and to have read the assigned reading prior to the lecture. The reading will come from the textbook, and from recent research papers in the field.

Homeworks Homeworks will be assigned regularly throughout the semester and will come in two flavors: (i) traditional problem sets, and (ii) paper reviews where you will write a critical review of a research paper chosen from the recent literature. Of course, all homeworks should contain your own original work. Turn in your homeworks to me or to the ME front office by 5pm on the date they are due.

Paper Talk On the days that a paper review is due, I will randomly select one student to lead a class discussion about the paper. The lucky student will summarize the paper, give their analysis of its strengths and weaknesses, and facilitate a discussion among the class about the paper.

Project There will be a significant project component to this class involving three steps. First, students will write a brief proposal for what they intend to do for the project. Second, students will conduct a literature review in the area relevant to the project. Finally, students will carry out the research project, producing a written research report as well as an oral presentation for the class. Choosing a project that dovetails with your graduate research is highly encouraged.

Grading

The final course grade will be assigned according to the following weighting:

Homeworks		35%
Paper talk		15%
Course project		50%
Literature review	10%	
Proposal	10%	
Final report/presentation	30%	

Course Website

All course materials will be disseminated on the blackboard course website. A link to blackboard can be found at `http://learn.bu.edu/`.

Textbooks

Required:

P. A. Ioannou and J. Sun, *Robust Adaptive Control*, Courier Dover Publications, 2012. Available as a free download at:
`http://www-bcf.usc.edu/~ioannou/RobustAdaptiveBook95pdf/Robust_Adaptive_Control.pdf`

We will also be reading a number of research papers throughout the course. They will be made available through the Blackboard site.

Optional:

K. J. Åström and B. Wittenmark, *Adaptive Control*, Courier Dover Publications, 2013.

K. S. Narendra and A. M. Annaswamy, *Stable Adaptive Systems*, Courier Dover Publications, 2012.

S. Sastry and M. Bodson, *Adaptive Control: Stability, Convergence and Robustness*, Courier Dover Publications, 2011.

M. Kristic, I. Kanellakopoulos, and P. V. Kokotovic, *Nonlinear and Adaptive Control Design*, Wiley, 1995.

L. Ljung, *System Identification: Theory for the User*, 2nd Ed., Prentice Hall, 1999.

Planned Schedule

(IS refers to the textbook by Ioannou and Sun.)

Date	Topic	Reading	Assignments
9/3 W	Introduction	IS Chpt 1	
9/8 M	Dynamical Systems	IS Chpt 2	HW 1 out
9/10 W	Stability Theory	IS Chpt 3	
9/15 M	Stability Theory	IS Chpt 3	
9/17 W	TBD (Schwager traveling)	IS Chpt 4	HW 2 out, HW 1 due
9/22 M	Parameter Estimation	IS Chpt 4	
9/24 W	Parameter Estimation	IS Chpt 4	
9/29 M	Param ID & Adapt Observers	IS Chpt 5	HW 3 out, HW 2, due
10/1 W	Param ID & Adapt Observers	IS Chpt 5	
10/6 M	Direct MRAC	IS Chpt 6	
10/8 W	Direct MRAC	IS Chpt 6	HW 4 out, HW 3 due
10/13 M	No class (Columbus Day)		
10/14 T	Indirect MRAC (Mon sched)	IS Chpt 6	Proposals due
10/15 W	Pole Placement Control	IS Chpt 7	
10/20 M	Indirect APPC	IS Chpt 7	HW 5 out, HW 4 due
10/22 W	Indirect APPC	IS Chpt 7	
10/27 M	Robust Parameter Est	IS Chpt 8	
10/29 W	Robust MRAC	IS Chpt 9	HW 6 out, HW 5 due
11/3 M	TBD (Schwager traveling)		
11/5 W	TBD (Schwager traveling)		Lit review due
11/10 M	Robust APPC	IS Chpt 9	HW 7 out, HW 6 due
11/12 W	Neuro-Adaptive Cntl	Sanner & Slotine TNN 92	
11/17 M	L_1 Adaptive Cntl	Cao & Hovakimyan TAC 08	
11/19 W	Muli-Agent Adapt Cntl	Ogren et al. TAC 04	HW 8 out, HW 7 due
11/24 M	Gaussian Process Adapt Cntl	Chowdhary et al. CDC 13	
11/26 W	No class (Thanksgiving break)		
12/1 M	Reinforcement Learning	Peters & Schaal NN 08	HW 8 due
12/3 W	Apprenticeship Learning	Abbeel et al. IJRR 10	
12/8 M	Project presentations		Project reports due
12/10 W	Project presentations		