ENG ME/EC/SE 701: Optimal and Robust Control, Fall 2015

INSTRUCTOR

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Office hours: tbd

MEETING TIME AND PLACE

Monday and Wednesday from 2-4 in EPC 203.

INTRODUCTION AND COURSE GOALS

This course aims to provide a rigorous introduction to the fundamentals of optimal control and, time permitting, will also provide a brief introduction to robust control. The two topics will be treated essentially independently. Among the topics to be covered are the linear quadratic regular, the calculus of variations, the Pontryagin Maximum principle, and Hamilton-Jacobi theory.

This is an upper-level graduate course and my assumption (and expectation) is that everyone taking the course is excited about learning the material. This is a highly mathematical course and will be treated as such. At the same time, optimal control has many practical implications and they will be highlighted when possible, though I will always focus on mathematical rigor (see again the comment about this being an upper-level graduate course).

COURSE PREREQUISITES

Frequency-domain (or classical) control (at the level of ME 404) is a definite prerequisite, as is standard mathematical background (linear algebra, ODEs, some exposure to PDEs, Laplace transforms, and so on). Prior experience with Matlab is assumed. Linear system theory, sometimes referred to state space theory (at the level of ME 501) is technically a prerequisite as well, though I typically cover the material needed anyway and several students have taken the course while simultaneously taking ME 501. Knowledge of nonlinear systems (at the level of ME 762) is not required but would be helpful. (Required material from nonlinear system theory will be introduced as needed.)

COURSE DELIVERABLES AND GRADING

Class performance will be evaluated based on homework sets and a term project. Homeworks will be assigned semi-regularly with the total number depending on the eventual pace of the course. While you are free to discuss your efforts, each student is responsible for submitting their own homework solution, representing their own work.

The term project will be done individually. Students will make two presentations, one introducing their topic and goals, and one presenting their final results, and will also produce a final report. The goal of the project is to apply techniques learned in the class to a problem of interest, preferably on a topic that connects to the research of the student. Full details on the project will be forthcoming during the semester.

The weighting of these components with respect to grading is as follows: Homework (50%), Project (50%).

There will be no exams.

COURSE WEBSITE

A website will be setup on blackboard.bu.edu. All course materials will be disseminated there.

DROP AND WITHDRAWAL DATES

The last day to **drop** the class (without a W appearing on your transcript) is 10.07.2015.

The last day to **withdraw** from the class (with a W appearing on your transcript) is 11.06.2015.

TEXTBOOK AND REFERENCES

No textbook is required. I will be working out of personal notes and some of the references noted below.

For optimal control:

1. L.S. Pontryagin, V.G. Boltyansky, R.V. Gamkrelidze, and E.F. Mishchenko, *The Mathematical Theory of Optimal Processes*, Interscience, 1962.
2. A. E. Bryson and Y. -C. Ho, *Applied Optimal Control: Optimization, Estimation, and Control*, Taylor and Francis, 1975.
3. B.D.O. Anderson and J.B. Moore, *Optimal Control: Linear Quadratic Methods*, Dover Publications, 2007.
4. M. Athans and P. L. Falb, *Optimal Control: An Introduction to the Theory and Its Applications*, Dover Publications, 2006.
5. D. Liberzon, *Calculus of Variations and Optimal Control Theory: A Concise Introduction*, Princeton University Press, 2012.
6. I.M. Gelfand and S.V. Fomin, *Calculus of Variations*, Dover Publications, 2000.

For robust control:

1. K. Zhou and J. C. Doyle, *Essentials of Robust Control*, Prentice Hall, 1998.
2. K. Zhou, J. C. Doyle and K. Glover, *Robust and Optimal Control*, Prentice Hall, 1995.
3. G. E. Dullerud and F. Paganini, *A Course in Robust Control Theory: A Convex Approach*, Springer Verlag, 2000.

For linear and nonlinear control systems:

1. G. F. Franklin, J. D. Powell, and A. Emami-Naeini, *Feedback Control of Dynamic Systems*, 6th Edition, Prentice Hall, 2009.
2. K. J. Åström and R. M. Murray, *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, 2008. [Available also online]
3. R.W. Brockett, *Finite Dimensional Linear Systems*, SIAM, 2015. [reprint of original 1970 book]
4. H.K. Khalil, *Nonlinear Systems*, Prentice-Hall, Third Edition, 2002.

(Approximate) Schedule for Fall 2015

Date	Day	Title	Topics	Notes
09.02.2013	Wed	Course intro. and overview		
09.09.2013	Wed	Linear systems	Primer/review	
09.14.2013	Mon	Linear quadratic regulator	Finite time, free and fixed end point	
09.16.2013	Wed		Infinite time, stochastic	
09.21.2013	Mon			
09.23.2013	Wed	Finite dim optimization	Primer	
09.28.2013	Mon			
09.30.2013	Wed	Calculus of variations	Euler-Lagrange equations,	
10.05.2013	Mon		constraints, sufficiency	
10.07.2013	Wed			
10.13.2013	Tues	Pontryagin Max. Principle	Free end points	Monday schedule
10.14.2013	Wed		Fixed end points	
10.19.2013	Mon	No class	Andersson on travel	
10.21.2013	Wed	No class	Andersson on travel	
10.26.2013	Mon	Pontryagin Max. Principle		
10.28.2013	Wed			
11.02.2013	Mon	First project presentations		
11.04.2013	Wed	Minimum-time control	Bang-bang control,	
11.09.2013	Mon		PTOS,	
11.11.2013	Wed		nonlinear	
11.16.2013	Mon	Hamilton-Jacobi-Bellman	Discrete time,	
11.18.2013	Wed		continuous time,	
11.23.2013	Mon		solving	
11.30.2013	Wed			
12.07.2013	Mon	Final project presentations		
12.09.2013	Wed			

Actual schedule for Fall 2013

Date	Lec. num.	Topics
09.04.2013	1	Course intro, overview, Linear systems through variation of constants
09.09.2013	2	Completion of linear systems primer
09.11.2013	3	LQR, through LTI, infinite horizon
09.13.2013	4	Completed LQR, did intro to robust
09.18.2013	5	Robust preliminaries
09.23.2013	6	Robust performance specs and beginning of H_2
09.25.2013	7	H_2 and H_∞ control
09.30.2013	8	Uncertain systems through structured singular value
10.02.2013	9	Completed control of uncertain systems, started review of finite dim. optimization
10.07.2013	10	Completed finite dim. optimization, Calc. of variations through Gateaux
10.09.2013	11	Calc. of variations through special cases of fixed boundary
10.15.2013	12	Calc. of variations with extra conditions
10.16.2013	13	Finished calc. of variations, derived PMP with free terminal point
10.21.2013	14	PMP example, proved H is constant
10.23.2013	15	
10.28.2013	16	
10.30.2013	17	
11.04.2013	18	
11.06.2013	19	
11.11.2013	20	Project presentations
11.13.2013	21	Project presentations
11.18.2013	22	
11.20.2013	23	
11.25.2013	24	
12.02.2013	25	Final presentations
12.04.2013	25	Final presentations
12.09.2013	-	-
12.11.2013	-	-