# ENG ME/EC/SE 701: Optimal and Robust Control, Fall 2013

## INSTRUCTOR

Prof. Sean B. Andersson

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Office hours: tbd

## MEETING TIME AND PLACE

Monday and Wednesday from 2-4 in Soc B57.

## INTRODUCTION AND COURSE GOALS

This course aims to provide a rigorous introduction to the fundamentals of both robust and optimal control. The two topics will be treated essentially independently. As each of those topics often fills (at least) an entire course, coverage will unfortunately be sparse with a greater emphases given on the optimal control portion. Under optimal control, topics will include the linear quadratic regular, the calculus of variations, the Pontryagin Maximum principle, and Hamilton-Jacobi theory. Robust control topics will include $\mu$–synthesis, $H_2$ control, and $H_\infty$ control.

## COURSE PREREQUISITES

Frequency-domain (or classical) control (at the level of ME 404) and linear system theory (at the level of ME 501) is a prerequisite. 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.) The standard mathematical background is assumed (linear algebra, ODEs, some exposure to PDEs, Laplace transforms, and so on). Prior experience with Matlab is assumed.

## COURSE DELIVERABLES AND GRADING

Class performance will be evaluated based on homework sets, occasional in-class quizzes, 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, as well as 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%), Quizzes (25%), Project (25%).

## 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 10.07.2013.

The last day to **withdraw** from the class (with a W appearing on your transcript) is 11.08.2013.

## 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.

*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*, Wiley (1970) [Out of print]
4. H.K. Khalil, *Nonlinear Systems*, Prentice-Hall, Third Edition, 2002.

**(Approximate) Schedule for Fall 2013**

| Date | Day | Title | Topics | Notes |
|---|---|---|---|---|
| 09.04.2013 | Wed | Course intro. and overview | | |
| 09.09.2013 | Mon | Linear systems | Primer/review | |
| 09.11.2013 | Wed | Linear quadratic regulator | Finite time, free and fixed end point | |
| 09.16.2013 | Mon | | Infinite time, stochastic | |
| 09.18.2013 | Wed | | | |
| 09.23.2013 | Mon | Introduction to robust control | | |
| 09.25.2013 | Wed | Robust control setup | Spaces and | |
| 09.30.2013 | Mon | | Performance specs | |
| 10.02.2013 | Wed | $H_2$ and $H_\infty$ control | | |
| 10.07.2013 | Mon | | | |
| 10.09.2013 | Wed | Uncertain systems | Modeling and | |
| 10.15.2013 | Tues | | control | Monday schedule |
| 10.16.2013 | Wed | Finite dim. optimization | Primer | |
| 10.21.2013 | Mon | Calculus of variations | Euler-Lagrange equations, | |
| 10.23.2013 | Wed | | constraints, sufficiency | |
| 10.28.2013 | Mon | Pontryagin Max. Principle | Free end points | |
| 10.30.2013 | Wed | | Fixed end points, transversality | |
| 11.04.2013 | Mon | | | |
| 11.06.2013 | Wed | First project presentations | | |
| 11.11.2013 | Mon | Minimum-time control | Bang-bang, PTOS, | |
| 11.13.2013 | Wed | | nonlinear | |
| 11.18.2013 | Mon | Hamilton-Jacobi-Bellman | Discrete time, | |
| 11.20.2013 | Wed | | continuous time, | |
| 11.25.2013 | Mon | | solving | |
| 12.02.2013 | Mon | Final project presentations | | |
| 12.04.2013 | Wed | | | |
| 12.09.2013 | Mon | - | - | No class (travel) |
| 12.11.2013 | Wed | - | - | No class (travel) |