IE496: Numerical Methods for Optimal Control

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Description: This course covers basic mathematical principles and practical numerical methods for solving optimal control problems. The first part of the course introduces necessary background on the theory of calculus of variations, optimal control problems, and Pontryagin's minimum (or maximum) principle. The second part focuses on direct methods for optimal control, which will involve covering numerical methods for solving large-scale nonlinear optimization problems. Time-permitting, the course will also cover dynamic programming and the Hamilton-Jacobi-Bellman equation.

Course Objectives: The objectives of this course are for students to do the following:

- Learn about basic calculus of variations problems and their formulations.
- Learn first and second order optimality conditions for calculus of variations problems.
- Understand the Euler-Lagrange equation and Hamiltonian mechanics.
- Understand Potryagin's maximum principle.
- Learn about numerical methods for solving ordinary differential equations.
- Learn about direct methods for solving optimal control problems.
- Understand the Hamilton-Jacobi-Bellman equation.
- Be familiar with various software packages available for solving optimization problems.
- Be able to apply course concepts in practice to solve optimal control problems.

Lectures: Wednesdays and Fridays, 8:45am-10:00am in Mohler 375.

Office Hours: I have reserved Thursdays, 10:00am-12:00pm, for office hours. I am also available through e-mail (always) and on Google Talk (often). If I do not respond to an e-mail within 24 hours, then please assume that I have not received it and send a follow-up e-mail. If I do not respond on Google Talk, then I am either busy or you are contacting me too late in the day, in which case you can try again the next day (during work hours) or send an e-mail instead. I am also willing to meet at other times, but in such cases please e-mail me in advance to set up a mutually convenient time.

Course Site: Lecture notes will be posted on Course Site prior to each lecture. Homework assignments, solutions, announcements, and other important material will also be posted on Course Site. Important information, corrections, and updates about the course may also be sent by e-mail (via Course Site).

Textbook: There is no required textbook for the course, but the following are recommended:

- D. Liberzon, *Calculus of Variations and Optimal Control Theory*, Princeton University Press, Princeton, NJ, USA, 2012.
- J. Betts, *Practical Methods for Optimal Control and Estimation Using Nonlinear Programming*, SIAM, Philadelphia, PA, USA, 2010.

LaTeX: All work must be submitted as documents produced with LaTeX. There are no exceptions to this requirement. Assistance for learning LaTeX will be given in the form of the source for all documents produced for the course (including that for this syllabus). Moreover, I will provide style files and templates for all homeworks. It is not required that you use the style files and templates provided, but it is highly recommended, especially if you are unfamiliar with LaTeX.

Grading: Your grade will be calculated as follows.

Homework:	30%
Midterm Exam:	20%
Final Exam:	20%
Student Lecture:	20%
Participation:	10%

Homeworks: There will be regular homework assignments throughout the semester, generally assigned and due every other week. Each homework must be submitted electronically. No credit will be given for any late assignment. You are free to consult with other students when working on homework, but the work you turn in must be your own. Please cite any references you use, including fellow students.

Collaboration Policy: The sharing of ideas is educationally useful and you are encouraged to discuss assignments with other students. However, *plagiarism* of any kind is destructive, fraudulent, and unacceptable. You are **strictly** forbidden to copy another student's written work or code, whole or in part, and submit that work under your name. You are also **strictly** forbidden to make trivial or mechanical changes to another student's written work or code and submit that work under your name. Note that while electronic plagiarism is easier to perform (via copy-and-paste), it is also easier to detect. Plagiarized work will receive no credit and repeat offenses will result in more severe action. A sure way to avoid this issue is to discuss the assignments with fellow students, but then write your solutions individually and independently.

Exams: The midterm will be a cumulative, closed-book, closed-notes, in-class, *written* exam. The final will be a cumulative, closed-book, closed-notes, *oral* exam.

Student Lecture: Everyone will be required to give a lecture to the class. The topic of the lecture can be a particular aspect of the theory of optimal control, ordinary differential equations, or numerical methods that would be relevant to the course, or can be on a journal article (in preparation or published) related to optimal control and its applications. The timing of the student lectures and the topics will be determined during the semester, with the idea that most student lectures will take place in the second half of the semester.

Participation: Attendance will not be taken. However, participation will factor into your grade. If you are unable to participate in lecture, then participation entails being a presence online — via e-mail or Course Site — or in office hours. In short, if by the end of the semester I do not remember your having been in the course, then your participation grade will suffer.

Emergencies: Everyone is responsible for all material covered and announcements made in lecture. If you believe you will miss a long period of time in the course due to illness, family emergencies, etc., then please contact me as early as possible. Under no circumstances will I give credit for missed work unless you have discussed your absence with me in advance.

Regrade Requests: If you disagree with a grade you receive on a homework, exam, or project component, then you may submit a regrade request. This request must be in writing and submitted no more than 48 hours after you receive the graded assignment.

Recording Devices: Voice and/or video recording devices may be used only with the approval of everyone in the classroom. Please let me know in advance if you wish to use these types of devices.

Students with Disabilities: If you have a disability for which you are or may be requesting accommodations, please contact me and the Office of Academic Support Services, University Center C212 (610.758.4152) as early as possible in the semester. You must have documentation from Academic Support Services before accommodations can be granted.