ISE 417: Nonlinear Optimization

Spring 2020

Syllabus

Course Information

Lectures:	Tuesday and Thursday, 5:50–7:05pm, Mohler Lab 375
Office hours:	Tuesday and Thursday, 7:05–8:00pm, Mohler Lab 479

Instructor Information

Name:	Daniel P. Robinson
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Zoom:	https://lehigh.zoom.us/j/7222472336

Office Hours

Please come to office hours if you have any questions about the course. Please make use of this time to ask questions about course content, conceptual questions, homework, etc. I am also available through email (always) and on Zoom (sometimes). Please use email for simple, short, logistical questions, and use office hours for more involved questions. 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. In certain cases, I may also choose to meet via Zoom. Please find all of my contact information above under "instructor information".

Course Description

One of our fundamental goals as engineers is to optimize, whether it be designs, systems, processes, or decisions. This, along with the fact that so many phenomena behave in a nonlinear manner, brings us to the desire to solve *nonlinear optimization* problems (NLPs). The purpose of this course is to introduce the basic theoretical principles underlying nonlinear optimization problems and the numerical methods that are available to solve them. We begin with fundamental (sub)gradient methods and Newton's method for unconstrained optimization, which represent the core of numerous nonlinear optimization algorithms. We then develop an understanding of optimality conditions and duality in the presence of nonlinear functions, ending by discussing modern numerical methods for nonlinear constrained optimization.

Course Objectives

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

- Understand how nonlinear functions can be used to model complex optimization problems.
- Understand how to characterize types of solutions of NLPs.
- Understand and be able to use common methodology for the numerical solution of NLPs.
- Understand the central role of (sub)gradient methods in the numerical solution of NLPs.
- Understand the central role of Newton's method in the numerical solution of NLPs.
- Understand the role of constraint qualifications in characterizing constrained NLP solutions.
- Be familiar with various software packages available for solving NLPs.
- Be able to apply course concepts in practice to solve NLPs.

Textbook

The primary textbook for the course is [7]. Reading the textbook is not required, but it is recommended. You are not responsible for textbook material that is not covered in lecture. Course material also will be derived from [1, 2, 3, 4, 5, 6, 8].

[1] Dimitri P. Bertsekas. *Constrained optimization and Lagrange multiplier methods.* Computer Science and Applied Mathematics. Academic Press Inc. [Harcourt Brace Jovanovich Publishers], New York, 1982.

[2] Dimitri P. Bertsekas. *Nonlinear Programming.* Athena Scientific, Belmont, Massachusetts, second edition, 1999.

[3] Dimitri P. Bertsekas. *Convex Optimization Theory.* Athena Scientific Belmont, 2009.

[4] Stephen Boyd and Lieven Vandenberghe. *Convex Optimization.* Cambridge University Press, New York, NY, USA, 2004.

[5] Andrew R. Conn, Nicholas I. M. Gould, and Philippe L. Toint. *Trust-Region Methods.* Society for Industrial and Applied Mathematics (SIAM), Philadelphia, PA, 2000.

[6] Roger Fletcher. *Practical Methods of Optimization.* Wiley-Interscience [John Wiley & Sons], New York, 2001.

[7] Jorge Nocedal and Stephen J. Wright. *Numerical Optimization.* Springer-Verlag, New York, 1999.

[8] Andrzej P Ruszczyński. *Nonlinear optimization*, volume 13. Princeton university press, 2006.

Prerequisites

Mathematical Logic, Multivariable Calculus, Linear Algebra, and Real Analysis.

Software

In this class we will develop numerical algorithms using Matlab.

Course Website

I will use Course Site to post homework assignments, course lectures, and other information about the course. Please check Course Site regularly for updates.

Exams

You will have one midterm exam (in-class and cumulative) and one final examination (oral, in my office, and cumulative). The exams will be closed-book and closed-notes. **No make-up exams will be given,** and no credit will be given for any missed exam.

Homework

You will have regular homework assignments. The homework assignments are likely to take you a fair amount of time, so get started on them early.

Late Assignments: Homework assignments must be received no later than 11:59PM on the due date assigned, which may be found on Course Site. Homework *must* be submitted via Course Site as a *single* PDF file. **No credit will be given for any homework assignment turned in late.** If you wish to have a late assignment graded for no credit, I will be happy to oblige.

LaTeX: Homework solutions must be submitted as a single PDF document produced with LaTeX. There are no exceptions to this requirement. I am happy to provide assistance for those new to LaTeX; simply email me to set up a time or come to office hours.

Clarity: Homework must be typed, clearly organized, and with problems in the correct (assigned) order. If I have difficulty following your homework, I will not go to great lengths to decipher it. Please take this seriously.

Working Together: You may work on the homework assignments individually or with a partner. You may *discuss* homework assignments with students, but you must individually write-up and turn in each assignment. If a student *copies* any solution (written by someone in the class or otherwise) and submits it to be graded as their own individual work, this will be considered a violation of Lehigh's academic integrity principles, and will be reported as such. You must cite any people or sources (other than the lecture slides) that helped you on a particular problem. For example: "Jane Doe and I worked on this problem together" or "I got help from Jane Doe on problem #3," or "I consulted *Linear Programming for Dummies*, Section 4.2, by John Doe when solving question #2." Please take this seriously.

Remember that you are ultimately responsible for mastering the material on your own, and your performance on the exams will depend on your ability to do so. Therefore, you should make sure that you fully understand all of the details of the write-up you submit.

I encourage you to come to my office hours for help when you are stuck.

Re-grade Requests

If you disagree with the grade you received on a homework or exam problem, you may submit a request for that problem to be re-examined. This request must be submitted **in writing no more than 48 hours after you receive the graded assignment.** It must contain a clear explanation, in no more than one paragraph (one paragraph for each grade being challenged), of why you feel the grade you received is incorrect. Once I re-examine your work and decide whether to change your grade, the decision will be final.

Class Participation

You are expected to attend class regularly, come to class prepared, participate in the discussions we have in class, and ask questions when you are confused. A portion of your grade will be based on class participation.

Grading

Your grade will be calculated as follows:

Item	Percentage
Homework assignments	35%
Midterm exam	30%
Final exam	30%
Class participation	5%

Use of Electronic Devices

The use of computers, smart phones, tablets, and other mobile electronic devices is permitted to be used in class but *only* as a tool for taking notes on lecture material. Any other use of electronic devices without my prior consent is prohibited.

Accommodations for Students with Disabilities

If you have a disability for which you are or may be requesting accommodations, please contact both your instructor and the Office of Academic Support Services, Williams Hall, Suite 301 (610-758-4152) as early as possible in the semester. You must have documentation from the Academic Support Services office before accommodations can be granted.

The Principles of Our Equitable Community

Lehigh University endorses The Principles of Our Equitable Community `http://www.lehigh.edu/~inprv/initiatives/PrinciplesEquity_Sheet_v2_032212.pdf`. We expect each member of this class to acknowledge and practice these Principles. Respect for each other and for differing viewpoints is a vital component of the learning environment inside and outside the classroom.

Academic Integrity

Read the material on Academic Integrity available on the Provost's Academic Integrity site (`http://www.lehigh.edu/~inprv/faculty/academicintegrity.html`) and on the CITL web site (`https://citl.lehigh.edu/academic-integrity-resources`). Example behaviors that violate Lehigh's academic integrity principles include (but are not limited to) plagiarism, cheating, copying assignments from previous semesters, creating disruptions, and unfairly exploiting the efforts of others.

Perhaps the most misunderstood violation of academic integrity is plagiarism. Plagiarism is defined in the Lehigh student handbook as "the unacknowledged appropriation of another's work, words, or ideas in any themes, outlines, papers, reports, or computer programs." This includes "innocent plagiarism," in which an author essentially quotes another author's work when paraphrasing it.

There will be a zero-tolerance approach to academic integrity violations in this class: **Work that violates the academic integrity principles will receive a grade of zero**. All offenses will be reported to the Lehigh Office of Student Conduct so that appropriate action may be taken.

Tentative Course Schedule

The following is a *tentative* schedule for lectures and midterm. These are likely to change many times throughout the course. I will send regular updates throughout the semester as to the material that I will be covering during each lecture.

Week	Dates	Topics	Notes
1	1/21, 1/23	Introduction, Convexity and Differentiability	
2	1/28, 1/30	Unconstrained Optimization Theory	
3	2/04, 2/06	Fundamental (Sub)gradient Algorithms, Newton's Method	
4	2/11, 2/13	Line Search Methods	
5	2/18, 2/20	Trust Region Methods	
6	2/25, 2/27	Conjugate Direction Methods	
7	3/03, 3/05	Quasi-Newton Methods	Midterm Exam
8	3/10, 3/12		Spring Break
9	3/17, 3/19	Constrained Optimization Theory	
10	3/24, 3/26	Constraint Qualifications, Duality Theory	
11	3/31, 4/02	Linear Optimization, Quadratic Optimization	
12	4/07, 4/09	Penalty Methods	
13	4/14, 4/16	Sequential Quadratic Optimization	
14	4/21, 4/23	Interior-Point Methods	
15	4/28, 4/30	Nonlinear Optimization Software	
16	5/05–5/09		Final Exams

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