IE417: Nonlinear Optimization

Instructor: Frank E. Curtis
Office: Mohler 475
Phone: 610.758.4879 (Office), 646.789.5490 (Google Voice)
E-mail: `frank.e.curtis@gmail.com`
IM: `frank.e.curtis` (Google Talk)
Web: `http://coral.ie.lehigh.edu/~frankecurtis`

Description: Our primary goal as engineers is to optimize, whether it be designs, systems, processes, or decisions. This, along with the fact that practically everything around us is inherently nonlinear, brings us to the need to solve *nonlinear optimization* problems. The purpose of this course is to introduce the basic theoretical principles behind nonlinear optimization and the numerical methods that are available to solve these types of problems. We begin with Newton's method, the central component in nearly all nonlinear optimization algorithms. We then develop an understanding of optimality conditions and duality in the presence of nonlinear functions, and finally discuss modern numerical methods for nonlinear 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 nonlinear optimization problems (NLPs).
- Understand and be able to use common methodology for the numerical solution of NLPs.
- Understand the central role of Newton's method in the numerical solution of NLPs.
- Understand the central 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.

Prerequisite: IE406: Introduction to Mathematical Optimization.

Lectures: Wednesdays, 5:10pm-8:00pm in Mohler 375.

Office Hours: I have reserved Wednesdays, 2:00pm-4:00pm, 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: The required textbook for the course is:

- J. Nocedal and S. J. Wright, *Numerical Optimization*, Second Edition, Springer Series in Operations Research, Springer, New York, NY, USA, 2006.

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 the following recommended textbooks:

- M. S. Bazaraa, H. D. Sherali, and C. M. Shetty, *Nonlinear Programming: Theory and Algorithms*, John Wiley & Sons, Hoboken, NJ, USA, 2006.

- D. P. Bertsekas, *Nonlinear Programming*, Second Edition, Athena Scientific, Belmont, MA, USA, 1999.
- R. L. Burden and J. D. Faires, *Numerical Analysis*, Seventh Edition, Brooks/Cole, Pacific Grove, CA, USA, 2001.
- J. E. Dennis, Jr. and R. B. Schnabel, *Numerical Methods for Unconstrained Optimization and Nonlinear Equations*, Classics in Applied Mathematics, SIAM, Philadelphia, PA, USA, 1996.
- R. Fletcher, *Practical Methods of Optimization*, Second Edition, John Wiley & Sons, Chichester, West Sussex, England, 1987.
- A. Ruszczyński, *Nonlinear Optimization*, Princeton University Press, Princeton, NJ, USA, 2006.

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 and exams, as well as for the project (see below). 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%
Project:	20%
Midterm Exam:	20%
Final Exam:	25%
Participation:	5%

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.*

Project: The course project will involve implementing software and writing a report to describe your software and numerical results obtained on test problems. Much of the code will come from the accumulation of coding exercises that will be made available throughout the semester. All coding must be done in Matlab. If you are not experienced in coding and/or Matlab, then I suggest you start practicing early as you will be expected to learn these things on your own. Ask me if you have any questions. The grade for the project will be based on the quality of your report, the correctness of the code, and the comments/documentation that you provide. When in doubt, comment every line of your code.

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.

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.

Preliminary Schedule:

Week	**Date**	**Topics**	**Notes**
1	08/28	Newton's Method, Numerical Analysis	
2	09/04	Convexity Theory	
3	09/11	Unconstrained Optimization Theory	
4	09/18	Line Search Methods	
5	09/25	Trust Region Methods	
6	10/02	Conjugate Direction Methods	
7	10/09	(No lecture)	
8	10/16	Quasi-Newton Methods	Midterm
9	10/23	Constrained Optimization Theory	
10	10/30	Constraint Qualifications, Duality Theory	
11	11/06	Linear Optimization, Quadratic Optimization	
12	11/13	Penalty Methods	
13	11/20	Sequential Quadratic Optimization	
14	11/27	(No lecture)	
15	12/04	Interior-Point Methods, Nonlinear Optimization Software	Project due