Department of Industrial and Systems Engineering
Spring 2006

Nonlinear Programming

(IE 417)

Meeting: Tuesday and Thursday 5:35–6:50PM 451 Mohler Lab

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This course will cover topics in practical nonlinear programming. You will learn the theory and methods behind solving optimization problems in which the objective and constraints are described by nonlinear functions.

Required Text

Jorge Nocedal and Stephen J. Wright. *Numerical Optimization* (Springer, 1999).

Recommended Texts

There are lots of good books on nonlinear programming. Here is one that has been used in this course in the past.

M. Bazaraa, H. Sherali, and C. M. Shetty. *Nonlinear Programming: Theory and Algorithms* (John Wiley & Sons, 1993).

You may also want a book on matlab, although the online help with matlab is quite good. If you want a slightly advanced book on matlab, I might suggest

Desmond J. Higham and Nicholas J. Higham. *MATLAB Guide, Second edition* (SIAM, 2005).

Finally, if you need some help in doing proofs and in gaining the requisite mathematical sophistication, I would recommend the book

Daniel Solow. *How to Read and Do Proofs* (John Wiley & Sons, 1990).

Course Overview

This is a first course in nonlinear programming, suitable for students with some programming background and a degree of *mathematical sophistication*. Historically, this is a Ph.D. level course, and I will also teach it as such. Students registered for this course typically should have taken IE406.

Optimization algorithms are being used to solve larger and more complex problems than ever before. The textbook (and hence this course) will emphasize the more recent techniques for large-scale nonlinear programming. Software is of course an integral component of nonlinear programming, so this course will also have a computational component.

Other than using "google" to find the answer on the Internet, you are free to use whatever software tools you think are necessary to help you complete the assignments. Matlab, Maple, and Mathematica may all come in handy. You're going to be mostly on your own to learn these tools.

Teaching Style

I believe that students learn best by doing. This course will be a lot of work. I am going to try something different this semester. Roughly *half* of the class time will be devoted to doing exercises as a class. As such, I will not have time to lecture on all the material in the sections that you are required to know. You will be assigned readings that are to be completed before lecture.

I envision that on the Thursday of each week, I will give a lecture giving the background and important concepts for a particular topic, and homework will be assigned. Students should complete as much of the homework as they can, and come prepared the following Tuesday to *present their answers* to the class.

It is very important for graduate students to cultivate the ability to perform an accurate (self)-assessment of work. At the beginning of class, students will give me a list of the problems that they can do, and I will decide who will present problems on that day. (I will also present some problems).

Course Objectives

The course has the following objectives:

1. Obtain a firm background in the theory of nonlinear programming—both constrained and unconstrained.
2. Implement knowledge of theory by solving many different instances with algorithms of a variety of classes.
3. Gain Experience in presenting difficult technical material to others
4. Cultivate the ability to access the accuracy of your own work and the work of others

Requirements and Grading

This course is (hopefully) *not* about getting a good grade. Instead, it should be about challenging yourself and learning about a very interesting field of optimization – nonlinear programming. It won't be easy! It sounds like a cop out from the teacher, (and maybe it is), but you will learn the most if you study many of these concepts yourself. In particular, since nonlinear programming is not one of my main areas of research, I will be (re)-learning some of this material along with you!

Academic Integrity

You are all graduate (or Ph.D.) students. You are all grown-ups. **Do not cheat**. If you have any question or concern about what constitutes cheating or improper collaboration, *please* contact me. In particular, on every paper you turn in to me, you must cite *all* external sources you used to produce your answers. This policy especially applies to the Internet (include a web address as part of the citation) and external collaborators. An excellent web site with lots of useful information about the integrity policy and procedures at Lehigh is `http://www.lehigh.edu/~indost/integrity.html`. If I suspect that you are cheating, you will make me sad. Then you will make me mad. Do not do this.

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, University Center 212 (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.

Grading Scheme

The course grade will be based on a weighted average of four components:

- 20% Problem Sets
- 20% Quiz #1
- 20% Quiz #2
- 40% Final Exam

The quizzes and final exam will be nearly entirely taken from the exercises. So if you know how to do the homeworks, then you will do well on the exams. I will post as many answers to the exercises as I have time to type up myself.

Collaboration can be a helpful tool in learning difficult material. Too much collaboration, however, stagnates your ability to be creative and resourceful in problem solving. Therefore, the exercises can be worked in groups of at most two two people. You will get more credit for the problems sets if you work alone.

There is going to be an inordinate[1] amount of homework. In fact, I would not expect any student to be able to complete all the exercises that will be assigned. At the beginning of each problem session, you will simply submit a list of the exercises that you (and potentially your group-mate) were able to do.

[1]That means large

I will look at the list and decide on who (and what) exercises will be presented that day. I may periodically ask that you submit written (preferably typed in LaTeX) answers to certain exercises, so also be prepared to do that. It will *quite negatively* affect your homework grade if I call on you to present your answer to a problem to the class, and you are unable to do so. I will suspect that you have been lying to me on *all* your assignments!

Very (Tentative) Chronological Syllabus

I have a very busy travel schedule this semester, and all my travel details have not yet been finalized. When I am unable to be at class, we will decide on a makeup procedure.

I may ask that we extend the lecture time on certain days so that I can cover the requisite material. I am sure that you will all soon love nonlinear programming *so much* that you will all love to stay extra time in order to learn more about it.

Part I: **Unconstrained Optimization** — *Jan. 19—Feb. 7*

Fundamentals of Unconstrained Optimization: Characterizing Solutions. Mathematical Review and Background: Convexity, Analysis, Linear Algebra, Line Search Algorithms, Trust Region Algorithms. Newton's Method and approximations for large-scale optimization

Readings: Parts of Chapters 2, 3, 4, 5, 6, 8, 9

Quiz #1: February 28

Part II: **Constrained Optimization: Fundamentals** — *Mar. 2—Mar.30*

First and Second Order Optimality Conditions. Constraint Qualifications. Quadratic Programming.

Readings: **Portions of Chapter 12, 15, and 16**

Quiz #2: April 4

Part III: **Modern Constrained Optimization** — *Apr. 11—Apr.27*

Penalty, Barrier, and Augmented Lagrangian Methods. Sequential Quadratic Programming. Interior Point Methods.

Readings: Parts of Chapters 17, 18. Supplementary material

Final Exam: First week of May