MGMTPhD 291: Large-Scale Optimization
Fall 2013

Lectures:
Fri 1:00PM-3:50PM (Course Code 39057)
Location: SB 223 (Paul Merage School of Business); see http://www.uci.edu/campusmaps.php

Instructor:
John Turner
Office: Paul Merage School of Business, Room SB 338
Phone: 949-824-7941  E-mail: john.turner@uci.edu
Office Hours: Mon 11AM-12PM; Wed 1PM-2PM; other times by appointment

Course Website:  https://eee.uci.edu/13f/39057
This is where you will find the papers that we will be reading.

Message Board:  https://eee.uci.edu/boards/f13/phd-largeopt/
Please use the message board rather than email for all technical questions.  This way, all students can share
in the discussion and we can learn from each other.

Course Description:

This doctoral course explores various computational techniques that are useful for solving optimization
problems with a large number of variables and/or constraints.  We will study general techniques for
computing optimal solutions to large problems using iterative methods, as well as ways to aggregate the
solution space of some types of problems to yield near-optimal solutions.  We will study Lagrangian
relaxation, column generation, Dantzig-Wolfe decomposition, and Bender’s decomposition, from both a
theoretical and practical perspective.  Students will learn to formulate and solve large-scale problems using
the modeling language AMPL, and learn how to exploit these techniques for their own research.  The
techniques we will study are applicable to a wide variety of business and engineering applications.

There are no formal prerequisites for this course beyond having a level of mathematical maturity which is
expected of a PhD student at the Paul Merage School of Business.  For example, it is expected that you
know matrix algebra and multivariable calculus.  Given that students may come from different
backgrounds, I do not assume that students have a working knowledge of optimization theory.  To get
everyone up to speed, I will cover some background material in the first two lectures.  But most
importantly, if at some point during the course I start using terminology that you are unfamiliar with,
please point this out so I can summarize any concepts which are unclear.

Course Materials (Required):

2.  Papers and handouts posted on EEE
Useful Reading (Recommended):


Course Format:
You will be exposed to large-scale optimization through two main activities: reading and presenting papers, and working on a project that implements a large-scale optimization technique. This class will blend theory and practice, and so classes will be a mix of lectures, papers presented by students, and tutorials on the use of the AMPL language for modeling math programs. By reading and presenting papers you will learn the theoretical foundations of large-scale optimization. Then, by working on a project you will be able to work through the details of a specific large-scale optimization technique.

Grading Scheme:
Class Participation: 10%
Paper Presentations: 40%
Project: 50%, with breakdown: Proposal 5%, Presentation 20%, and Written Report 25%

Class Participation:
This is a technical course, and the best way to learn the subject matter is to be engaged in classroom discussions and to ask questions either in-class or on the message board. Please the read papers that will be presented in-class before the lecture. All students need to read all papers, not just the ones that they present.

Paper Presentations:
Each student will be assigned a small number of papers to read and present in-class. Learning how to read and summarize academic papers is an important skill, especially when the subject matter is notation-heavy as will often be the case in this class. You will be graded on how well you communicate the main concepts of the paper. Please strive for clarity, correctness, and completeness (within the time allowed). You may use any combination of PowerPoint or scribbling on the whiteboard that you wish. If you choose to present your papers using just the whiteboard, I strongly suggest that you have the full presentation written down beforehand on paper, so that you can copy from your notes onto the whiteboard without making mistakes. Unless otherwise stated, it should take you 40-60 minutes to present a paper, including responding to questions that the class or I may have. For some papers I may also provide you with a series of questions that you should address; this will help you structure your presentation.
Project:

Throughout this course each student will work on a project that implements a large-scale optimization technique using the AMPL modeling language. Projects are individual work (one project per student). If possible, it is a good idea to choose a topic that is directly related to your thesis. If your current research does not directly require optimization, then perhaps there is a related problem (i.e. something tangential to your current research) that would be good for you to explore that does require large-scale optimization techniques. But feel free to choose any topic that interests you, even if it is not part of your current research program.

Once you have a chosen a topic, your next step is to write a 3-page project proposal. The proposal should describe the problem that you wish to solve, where you are going to get the input data (randomly generated is fine; real data is usually better), which modeling aspects you expect to be difficult and/or challenging, and a description of your first course of action (i.e. a very high-level description of a large-scale optimization technique that you might like to try). Proposals are due: Monday, October 14th (please send to me by email).

I will review your proposals, and provide feedback to help you get started. After this point, we will reserve some class time (perhaps 15-30 min per class) for technical questions regarding the projects that I may address on a one-on-one basis (please bring your laptops to class!). Of course, you may also post technical questions to the newsgroup and see me during office hours for help with your projects. Although projects are individual work and each student will turn in one project, you may discuss your project with other students since it is very useful to share technical knowledge of how to get AMPL to do what you want it to do and how to implement a specific large-scale optimization technique.

By the end of November, your project should be nearing completion. You will prepare a 20-minute presentation to be presented in-class on Friday, December 6th. Your presentation should clearly describe the problem you are solving, the optimization formulation you adopted, where the input data came from, the large-scale optimization technique that you used to solve the problem and how you adapted this technique to your particular problem, and your computational results.

Your final deliverable for the project is a written report, to be turned in to me by email no later than Friday, December 13th. In your report, you should describe in detail the same things that you presented more broadly in your presentation (the problem you are solving, the optimization formulation you adopted, where the input data came from, the large-scale optimization technique that you used to solve the problem and how you adapted this technique to your particular problem, and your computational results). Please include the AMPL code that you used to solve your problem as an Appendix (very important!), and describe in your report the AMPL commands that were important in your project (e.g. option relax_integrality) and why. As a rough guideline, your report should be about 15 double-spaced 12-point font pages in length, excluding the Appendix (AMPL code).

Academic Honesty and Student Conduct Policy:
Please refer to UCI’s policies: http://www.editor.uci.edu/catalogue/appx/appx.2.htm.

Course Drop Deadline:
Course Outline:  
The following is a tentative schedule for the course which may be updated as the course progresses.  
Papers marked (E) are from the *Wiley Encyclopedia of Operations Research and Management Science* 2010, J. Cochran, Editor.

### CLASS 1: Friday, September 27th

**Topics:**  
- Introduction to the Course  
- Why Large-Scale Optimization Matters to Business  
- Math programming background  
  - Problem vs. formulation, objective function, constraints, decision variables  
  - Convex sets, convex functions, sublevel sets  
  - Problem classes: convex vs. nonconvex, linear vs. nonlinear, continuous vs. integer  
  - Introduction to Solvers (CPLEX, Gurobi, COIN-OR) and Modeling Languages (AMPL)  
  - Example of using AMPL to solve a linear program  
  - Linear programming theory – extreme points, extreme rays, basis inverse  
  - Linear programming solution methods – simplex, ellipsoid, and interior point methods  
  - Integer programming theory – branch and bound, relaxations, restrictions, and inference, convex hull, valid inequalities, cutting planes

**Readings:**  
- (E) An Introduction to Linear Programming.  
- (E) Branch and Bound Algorithms.  
- (E) MILP Software.  

### CLASS 2: Friday, October 4th

**Topics:**  
- Math programming background  
  - Convex optimization theory – Lagrangian duality, KKT conditions, constraint qualifications, duality gap, shadow prices, reduced costs (shadow price interpretation)  
  - Integer programming theory – MILP modeling of logical conditions  
- Overview of Large-Scale Optimization Techniques & Motivating Topics  
  - The Knapsack Problem and the Core Heuristic  
  - Symmetry Breaking for MIP  
- Other Approaches  
  - Constraint programming, heuristics, approximation algorithms  
- Hardness  
  - Time and space complexity  
  - Chest of drawers analogy
**Readings:**

- (E) LP Duality and KKT Conditions for LP
- (E) Formulating Good MILP Models
- (E) Introduction to Large-Scale Linear Programming and Applications

**CLASS 3: Friday, October 11th**

**Topics:**

- Cutting Planes
- Equivalence of Optimization and Separation
- Presolve (Turning on/off)

**Readings:**

- (E) Branch and Cut
- (E) Gomory Cuts
- (E) Presolving MILP’s

**DELIVERABLE DUE: Monday, October 14th**

*Project proposals are due by email*
CLASS 4: Friday, October 18th

Topics:
- Column Generation
- The cutting stock problem

Readings:
- (4A) (E) Column Generation

Presentations:
1. 40min – The basics of column generation, explained using the cutting stock problem. Sources: (4A), (4B), and any textbooks/sources you choose to pull from.
2. 40min – Column generation applied to multi-commodity flows. Source: (4C).
3. 40min – Column generation applied to transit crew scheduling. Source: (4D).

CLASS 5: Friday, October 25th

Topics:
- Dantzig-Wolfe Decomposition

Readings:
- (5A) (E) Dantzig-Wolfe Decomposition

Presentations:
1. 40 min – The basics of Dantzig-Wolfe Decomposition applied to linear programs, explained using a model from the food industry. Sources: (5A), (5B), and any textbooks/sources you choose to pull from.
3. 40 min – Comparison of the Dantzig-Wolfe decomposition to decentralized decision making. Source: (5D).
CLASS 6: Friday, November 1st

Topics:
- Lagrangian Optimization
- Subgradient Optimization

Readings:
- (6C) (E) Lagrangian Optimization Methods for LP
- (6D) (E) Lagrangian Optimization Methods for Nonlinear Programming
- (6E) (E) Subgradient Optimization

Presentations:
1. 40 min – The principles of Lagrangian Optimization and Subgradient Optimization. Both of these complimentary techniques are described in detail in (6A), and your presentation should present all important parts of (6A). However, you may draw additional materials from (6B), (6C), (6D), (6E), and other textbooks/sources as you wish.
2. 40 min – Lagrangian Optimization applied to hierarchical production planning. Source: (6F).

CLASS 7: Friday, November 8th

Topics:
- Bender’s Decomposition

Readings:
- (7A) (E) Benders Decomposition

Presentations:
1. 40 min – The principles of classical Bender’s decomposition (where the subproblem is a linear program). Sources: (7A), (7B), and any textbooks/sources you choose to pull from.
2. 40 min – Generalized Bender’s decomposition theory. Source: (7C).
3. 40 min – Bender’s decomposition applied to multicommodity distribution system design. Source: (7D).
CLASS 8: Friday, November 15th

Topics:
- Comparing Methods
- Additional Topics

Readings:
- (E) Relationship Among Benders, Dantzig-Wolfe, and Lagrangian Optimization
- (E) Branch-Price-and-Cut Algorithms

CLASS 9: Friday, November 22nd

Topics:
- Aggregation Methods
- Aggregating Transportation Problems
- Aggregating Advertising Planning Problems
- A priori and a posteriori bounds

Readings:
- (E) Aggregate Planning

*** THANKSGIVING HOLIDAY (No class Friday, November 29th) ***

CLASS 10A: Friday, December 6th
DELIVERABLE DUE: Projects will be presented in-class today

CLASS 10B: Friday, December 13th (if needed)
DELIVERABLE DUE: Projects will be presented in-class today

DELIVERABLE DUE: Friday, December 13th
Written reports for your projects are due today by email