MA 416G: Introduction To Optimization

This course is an introduction to modern operations research and includes discussion of modeling, linear programming, dynamic programming, integer programming, scheduling and inventory problems and network algorithms.

Instructor

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Office hours: Monday 4:30-5:30 pm and Wednesday 10:00-11:00 am, or by appointment

Textbook

***A gentle introduction to optimization*, by Guenin, Koenemann, and Tuncel, Cambridge 2014.**

The textbook should be available for purchase in the UK bookstore. You can buy it from the publisher's book website or from Amazon. Also available in eBook.

Topics

We will cover most of the seven chapters in our text books (we will skip some sections). Our pace will be approximately one chapter every 2 weeks. We will make adjustments to it as we go.

I will supplement this by additional material on dual simplex method and financial applications.

Complementary textbook:
Linear Programming: Foundations and Extensions, by Robert Vanderbei, 2008. Available through the UK Library as an e-text free of charge.

Prerequisite

Calculus (MA 213 or equivalent) and Linear Algebra (in particular, matrix operations).

I will not enforce the formal prerequisites, for the benefit of those students in other majors who are interested in optimization but did not go through the standard sequence of math courses. However, excellent knowledge of the prerequisites is crucial for succeeding in MA 416. In particular, you need to be comfortable with the following topics: Vector spaces and subspaces; matrix operations; the transpose and the inverse of a matrix; linear independence; bases and dimensions. I strongly recommend to review these topics; please do so before we start Chapter 2.

Grading

Your grade in the course will based on the following.

For undergraduate students:

- **12% Homework**
- **48% Midterm exams**
- **40% Final exam**

For graduate students:

- 10% Homework
- 40% Midterm exams
- 17% Project
- 33% Final exam

If you are an undergraduate student, **you can request to be graded as a graduate student**. However, I need to approve your request before September 15.

Exam Dates

Midterm 1 (in class): **Wed, September 27**
Midterm 2 (in class): **Mon, November 13**
Final exam: **Mon, December 11**

No make-up exam will be given except in the case of an excused absences on the day of the exam. Senate Rules 5.2.4.2 defines the following as acceptable reasons for excused absences: (a) serious illness, (b) illness or death of family member, (c) University-related trips, (d) major religious holidays, and (e) other circumstances found to fit "reasonable cause for nonattendance" by the professor. Students may be asked to verify their absences in order for them to be considered excused.

Homework

I will assign required reading from the textbook and weekly problems that you do not need to turn in (but you do need to do, if you want to do well on the exams). Moreover, there will be five homework assignments that will be collected and graded. You can work on these assignments in groups of no more than three students per group. In fact, you can turn in a single assignment per group. Some assignments will be longer and more difficult than others. Therefore, the assignments will not be weighted equally. Some assignments will contain a computational component.

Assignment 1 will be due after we finish Chapter 2.
Assignment 2 will be due after we finish Chapter 3.
Assignment 3 will be due after we finish Chapter 5.
Assignment 4 will be due after we finish Chapter 6.
Assignment 5 will be due after we finish Chapter 7.

No late homework assignment will be accepted.

Software

We will mainly use AMPL for solving linear and non-linear optimization problems. You can download a free size-limited demo version of AMPL (including popular solvers) from AMPL's download page. The full-featured AMPL+solver packages are now available under the folder Canvas/MA416G-002/Files/ampl_for_courses/. For those who prefer to work with SCIP, R, Python, SageMath, or any other programming language, feel free to do so. However, most of the examples we will discuss in class will be using AMPL.

Other references

AMPL: A Modeling Language for Mathematical Programming, by Robert Fourer, David M. Gay, and Brian W. Kernighan. This book is now freely downloadable from AMPL's website.

Project (for graduate students only)

As a part of your course grade, you are required to do a project that applies techniques we learn in this class to non-trivial "real world problem". Your project must be typed as a report, and at a minimum you must include:

- a statement of the problem and its relevance in non-mathematical terms,
- sources of data or information about the problem,
- a description of the method used to solve the problem,
- well-documented code,
- a description and an interpretation of the solution
- bibliography/references for all the sources that you have used.

The project will be due on the last day of class. I can provide you with a couple of ideas for the project but you can also come up with you own idea for the project. In this case, you need to get your idea for project approved by me no later than the second week of November. Of course, you can discuss your ideas about the project with me at any times during the semester.

Edit

Get started with AMPL (or another optimization modeling/solver system)

Yuan Zhou

Aug 23 at 8:09pm

In our class, we are going to use optimization software to solve problems.

AMPL and solvers

For our "operations research" type problems, I recommend to use the "algebraic modeling language" AMPL, which can interface with various top commercial solvers and popular open-source solvers.

Please browse through the AMPL book, which is freely available at www.ampl.com/resources/the-ampl-book/chapter-downloads/ (http://www.ampl.com/resources/the-ampl-book/chapter-downloads/) . The first chapter is an introductory tutorial and subsequent chapters provide additional tutorial material at more detailed levels.

Please install AMPL on your computer.
(1) The size-limited Demo Version (http://ampl.com/try-ampl/download-a-free-demo/) is free to download from http://ampl.com/try-ampl/download-a-free-demo/ (http://ampl.com/try-ampl/download-a-free-demo/) . It comes with the solvers and the examples.
(2) Alternatively, you can download the full-featured AMPL + solver packages from Canvas/MA416G-002/Files/ampl_for_courses/. Please refer to the instructions copied below for installing and running AMPL and the solvers. Note that this version has no limitation on problem size, but the software will stop working when the course ends.

As a preparation for the next lecture, **please model the "Notip Table Company" example from lecture 2017-08-23 in AMPL**, and run it with solver CPLEX or Gurobi. (If you prefer, you could use alternative optimization modeling/solver system other than AMPL. See below.)

Background and alternative software

0) Writing solvers for mixed-integer linear optimization problems is very hard; there are only a handful of competitive ones: CPLEX, Gurobi, SCIP, COIN-OR CBC. **Writing frontends and modeling languages is comparatively easy;** as a result, there are many.

1) If you are a math student, it is likely that you have had or will soon have some exposure to the Python-based **SageMath** system. SageMath interfaces to many solvers and has its own optimization modeling system. Because you have the full power of the Python programming language available, you will be much more flexible than with an algebraic modeling language such as AMPL.

2) Other choices for modeling languages are **ZIMPL** and **GAMS**, which can be used with many solvers.

3) A net-based system that gives access to many solvers is **NEOS**: http://www.neos-server.org/neos/ (http://www.neos-server.org/neos/)

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QUICK-START INSTRUCTIONS FOR INSTALLING AND RUNNING AMPL & SOLVERS

Windows systems

To install: Download the distribution zipfile, ampl_mswin32.zip for the 32-bit version or ampl_mswin64.zip for the 64-bit version. Double-click the zipfile icon, or apply an unzip utility, to extract the folder named ampl_mswin32 or ampl_mswin64 from the zipfile. This will be yourAMPL folder; optionally you may rename it and you may move it to any convenient location on your computer.

To run in an integrated application: Inside your AMPL folder, double-click the amplide folder icon to open that folder, and then double-click the amplide.exe file (with the black cat's-head icon) to start the AMPL IDE application. A small "AMPL IDE" window will appear while the program is being loaded, and then the full IDE application window will open. To get started, choose Help Contents from the Help menu at the top of the application window.

To run using a simple command-line interface: Double-click "sw.exe" in your AMPL folder, and type "ampl" at the prompt in the window that appears. Then you will see an "ampl:" prompt and can proceed to type AMPL commands. AMPL model and data statements will refer to files that you have saved in your AMPL folder; use any plain-text editor to create and edit these files.

To optimize using either interface: Be sure to choose a solver, by giving a command of the form "option solver xxx;" with xxx replaced by the name of a solver that you have been instructed to use.

Linux systems

To install: Download the distribution zipfile, ampl_linux-intel32.zip for the 32-bit version or ampl_linux-intel64.zip for the 64-bit version. Then "unzip" this file, using a Linux unzip command or the decompression option of the zip command, to extract the folder named ampl_linux-intel32 or ampl_linux-intel64 from the zipfile. This will be your AMPL folder; optionally you may rename it and you may move it to any convenient location on your computer.

To run in an integrated application: Inside your AMPL directory, you will find a directory named amplide. Use the cd command to make amplide your current directory, and then start AMPL IDE with the command ./amplide. A small "AMPL IDE" window will appear while the program is being loaded, and then the full IDE application window will open. To get started, choose Help Contents from the Help menu at the top of the application window.

To run using a simple command-line interface: In a command window, use the cd command to go to your AMPL directory, and type "./ampl" at the system prompt. Then you will see an "ampl:" prompt

and can proceed to type AMPL commands. AMPL model and data statements will refer to files that you have saved in your AMPL folder; use any plain-text editor to create and edit these files.

To optimize using either interface: Be sure to choose a solver, by giving a command of the form "option solver xxx;" with xxx replaced by the name of a solver that you have been instructed to use.

MacOS Systems

To install: Download the distribution zipfile, ampl_macosx64.zip. Double-click this file's icon to extract its contents. When the extraction is complete you will see a folder named ampl_macosx64. This will be your AMPL folder; optionally you may rename it and you may move it to any convenient location on your computer.

To run in an integrated application: In your AMPL folder, double-click the Amplide file (with the black cat's-head icon) to start the AMPL IDE application. A small "AMPL IDE" window will appear while the program is being loaded, and then the full IDE application window will open. To get started using AMPL IDE, choose Help Contents from the Help menu at the top of the application window.

IF YOU GET A MESSAGE that the amplide program "can't be opened" because it "was not downloaded from the Mac App Store" or it "is from an unidentified developer," then you will need to tell macOS that the program is from a trusted source, by following these steps: (1) Control-click or right-click the amplide icon. (2) Select Open from the top of contextual menu that appears. This step will only be necessary the first time that you open the AMPL IDE. After that you can open it in the usual way, by double-clicking the amplide application icon.

SPECIAL NOTE for users of macOS 10.12 Sierra: As a side-effect of a new security feature introduced with this version, you may see an error message beginning "The IDE cannot find theAMPL executable." To fix this problem, quit the IDE application and then follow these steps: (1) In your amplide.macosx64 folder, find the Amplide file (with THE cat's head icon). (2) Drag the Amplide file to your desktop. (3) Drag the Amplide file back into the amplide.macosx64 folder. Then double-click the file icon to start the AMPL IDE again.

To run using a simple command-line interface: Click on the magnifying glass at the top right of your screen, enter "terminal" in the Spotlight window, and click on the Terminal icon to open a Mac Terminal window. Use "cd" to go to your AMPL folder; for example if your AMPL folder is ampl_macosx64 on your desktop, type "cd Desktop/ampl_macosx64". Then type ./ampl; you will see an ampl: prompt and can proceed to type AMPL commands. AMPL model and data statements will refer to files that you have saved in your AMPL folder; use any plain-text editor to create and edit these files.

To optimize using either interface: Be sure to choose a solver, by giving a command of the form "option solver xxx;" with xxx replaced by the name of a solver that you have been instructed to use.