IE 316: Advanced Operations Research Techniques

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Office Hours: M 10:00-11:00, TR 2:30-3:30
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Course web page: http://www.lehigh.edu/~tkr2/teaching/ie316/
Course meeting time: TR 1:10-2:25 355 Mohler Lab

Description of Course

This course will cover techniques for the solution and analysis of deterministic linear models used in Operations Research. The primary types of models to be addressed will be linear programming, network flow, and integer linear programming. Time permitting, we will also consider more complex models, such as those incorporating nonlinear constraints or uncertainty. The main emphasis will be on solution techniques and on analysis of the underlying mathematical structure of these models. As a supporting theme, the course will also emphasize effective modeling techniques, the use of modeling languages, such as AMPL, and the use of commercial solvers.

Course Objectives

The goals of this course are for each student to:

1. **Improve the ability to rigorously prove mathematical statements.**
2. **Cultivate an ability to analyze the structure of and mathematically model various complex system occurring in industrial applications.**
3. **Develop knowledge of the mathematical structure of the most commonly used deterministic linear optimization models.**
4. **Develop an understanding of the techniques used to solve linear optimization models using their mathematical structure.**
5. **Develop an understanding of the use of modeling languages for expressing and solving optimization models.**
6. **Develop knowledge of existing commercial solvers for linear optimization.**

Required Text

- **D. Bertsimas and J.N. Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific (1997).**

Other References

- **R. Fourer, D.M. Gay and B.W. Kernighan, *AMPL: A Modeling Language for Mathematical Programming*, Duxbury Press (1997).**

- **Daniel Solow, *How to Read and Do Proofs: An Introduction to Mathematical Thought Processes,* Wiley (2001).**
- **Daniel J. Velleman, *How to Prove It: A Structured Approach,* Cambridge University Press (1994).**

Course Requirements

1. **<u>Lectures</u>: Students will be expected to attend and participate in the lectures. Part of the grade will be determined by overall class participation. Lecture materials will be available for reference before the lecture on the course web page.**

2. **<u>Reading</u>: There will be required readings associated with each lecture. Most readings will be from the course text, but students are encouraged to seek supplementary material. Links to supplementary reading material available over the Web can be accessed from the course page.**

3. **<u>Problem Sets and Quizzes</u>: Problem sets will be given according to the schedule below. Students are encouraged to work together, but each student should write up his/her solutions independently. The last homework will be weighted twice the others and will be comprehensive. There will be two quizzes and a final. All exams will be open book and open notes.**

Schedule of Homeworks and Quizzes (subject to change)

<u>Homework/Quizzes</u>	**<u>Date</u>**
Homework #1	**Sept 10**
Homework #2	**Sept 17**
Homework #3	**Sept 24**
Quiz #1	**Oct 1**
Homework #4	**Oct 15**
Homework #5	**Oct 22**
Homework #6	**Oct 29**
Quiz #2	**Nov 7**
Homework #7	**Nov 14**
Homework #8	**Nov 21**
Homework #9	**Dec 5**
Final Exam	**??**

Schedule of Topics (subject to change)

Topic	Lectures
Review of Modeling	**2**
The Geometry of Linear Models	**4**
The Simplex Method	**4**
Using AMPL/CPLEX	**1**
Duality Theory	**4**
Sensitivity Analysis	**2**
Large-scale Linear Programming	**2**
Network Flow Models	**4**
Integer Programming Models	**2**
Advanced Models and Methods	**1**

Rough Guide to Textbook Coverage

Primary Chapters/Sections to be covered in Lecture:

Chapter 1, Sections 1, 4
Chapter 2, Sections 1-6
Chapter 3, Sections 1-3, 5
Chapter 4, Sections 1-6, 8
Chapter 5, Sections 1-5
Chapter 6, Sections 1-3
Chapter 7, Sections 1-5, 8-10
Chapter 10, Section 1-3
Chapter 11, Section 1-2, 4

Suggested Supplementary Reading:

Chapter 1, Section 2-3, 5-6
Chapter 2, Sections 7-8
Chapter 3, Section 6, 7
Chapter 4, Sections 7, 9-10

Grading Scheme

25% Homework
20% Quizzes (each)
25% Final
10% Class Participation

Teaching Philosophy and Policies

Group Work

You are encouraged to work together on problem sets. However, you must ultimately demonstrate your understanding of the material by writing up your own solutions without the help of other students or their written work.

Referencing the Work of Others

You should attempt the problem sets on your own before consulting outside references. However, I do not want to discourage the use of research materials as a way to supplement your understanding of the course material. If you do use external references in developing your solutions, and especially if you quote directly from these references, please cite them! Failure to cite references will result in severe penalty.

Lateness

I will allow a total of 7 days of lateness on assignments throughout the semester. These 7 days can be split up in any way you choose. In other words, you can have one assignment late by 7 days or 7 assignments each late by one day. After that, there is a penalty of 10% off per late-day on each assignment. No assignment will be accepted more than 7 days late. Exceptions to this rule will be made on a case-by-case basis. Please let me know if you will be turning in an assignment late.

Grading

I do not believe in giving a formula for determining grades (but I will give one anyway). I believe your grade should reflect the actual learning that took place in the course. Hence, the way to maximize your grade in the course is to learn and understand the material. Most formulaic grading systems allow you (even encourage you) to maximize your grade without necessarily maximizing your learning. I want to discourage you from disconnecting these two goals.

Higher learning involves not just acquiring knowledge, but developing the ability to "know what you don't know." I call this ability *self-assessment of knowledge*. Among other things, it involves knowing when you do and do not have a rigorous proof or an accurate answer. One of the goals of this course is to cultivate your ability to perform an accurate self-assessment of your work. Hence, you are encouraged to think about and state accurately not only the parts that you *do* understand from each homework, but also the parts that you *do not*. Please do not muddle your way through proofs and other exercises in the hope that I will not read them carefully. You will get additional credit for an accurate self-assessment of your answer or approach. Hence, if you have gotten most of the way through a proof and just cannot complete the last step or even if you are missing a step in the middle but know how to do the rest, just try to write down what you have done so far and what it is that you don't know how to do. This will help me to better gauge where your understanding is incomplete so that we can review these areas in class. It will also demonstrate your understanding of your own work.

Effective learning also involves knowing where to go to get help when you realize that your knowledge or understanding of a topic is incomplete. This could mean asking a classmate some questions, consulting external references, or coming to office hours. It can also mean asking a question in class when you don't understand part of the lecture. Chances are, other people don't understand it either. This is all an important part of *class participation*.

Another area in which you will be evaluated is by the *level of detail* and *rigor* in your proofs and homework answers. In general, you should err on the side of giving too much detail in your written work. One mistake students make is assuming that since I assigned the problem, I have already thought of every possible approach to it (including the one you chose). Many times, however, I will not have thought of the approach you are using and will therefore need some help in understanding your thought process. The more explicit you are, the easier it will be for me to grade and the more you will demonstrate your understanding. If you spend hours coming up with the answer to a problem, don't short-change yourself by spending only a few minutes writing it down. Take some time to think about how best to present your thoughts. Otherwise, you may be throwing your hard work away.

Another mistake students make, especially with respect to the level of detail that should be provided in proofs, is to use journal articles and/or textbooks as examples. In general, the proofs that appear in journal articles are not detailed enough for our purposes. Journal articles are inherently space-constrained and hence the level of detail is sacrificed and the reader asked to fill in the blanks in the interest of brevity. You should not write your problem sets as if you are space-constrained.

To summarize, you will be graded according to my overall assessment of your learning in the course and your understanding of the course material. This includes your ability to perform self-assessment, your ability to ask questions to increase your understanding, and your ability to express your ideas in written form rigorously and with an appropriate level of detail.

Learning Styles

There are many different styles of learning. Some people gain better understanding from listening to something being explained orally. Some get better understanding from written material. Some like a combination of both. I do my best to accommodate various styles of learning. However, feel free to let me know what your learning style is so that I can take that into account when determining the future direction of the course.

Office Hours and Appointments

My door is always open, but I would appreciate it if you could try to utilize office hours as much as possible. If you would like to make an appointment outside office hours, just call or send an e-mail.