ORIE 5380, CS 5727: Optimization Methods

Fall 2020

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Optimization is one of the core technologies used to provide business intelligence. Online retailers use optimization models to decide where to position their fulfillment centers, which fulfillment center to use to satisfy each customer order and how much inventory to store for each product in each fulfillment center. Ad exchanges use optimization models to match content providers with advertisers. Airlines use optimization models to construct their flight schedules, to plan routes for their crews and to price their tickets. On-demand transportation companies use optimization models to figure out how to incentivize their drivers when excess capacity is needed and how to price their services in response to surges in demand. In this course, we study algorithmic and computational tools for solving optimization problems with the goal of providing decision support for business intelligence. We will cover the fundamental theory of linear and integer optimization. We will emphasize optimization as a large-scale computational tool and show how to link programming languages with optimization software to develop industrial-strength decision support systems.

Staff

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Office Hours: See course calendar on course website.

Lectures

There are three lectures each week. Lectures are delivered via "zoom." Zoom links for each class are on the course calendar on the class webpage. Be careful to use the correct link for the correct class. All lectures are recorded, and two out of the three weekly lectures are delivered "live," so you have the option to view those in real time. (You are not required to view them in real time, but that will likely be more fun, assuming the scheduled time works for you.) Lectures are scheduled as follows.

- Monday 10pm-10:50pm Eastern
- Wednesday 12pm-12:50pm Eastern
- One recorded lecture (not taught live) available by Friday 5pm Eastern that is intended to follow the Wednesday lecture. The first such recorded lecture will be released by September 4 following the earlier lectures that week.

Unfortunately, this class clashes with "Data Science in the Wild." It is possible to take both courses, though of course you will have to watch a recorded version of any simultaneous lectures. I have confirmed that taking both classes is ok with the instructor of "Data Science in the Wild."

Course Website https://canvas.cornell.edu/courses/20026

Please make sure you are enrolled in the course website. All of the materials related to the course, including slides used in the lectures, source code, homework assignments and the project, will be posted on the course website. In addition, if you have questions regarding the homework, then you can use Piazza as linked from the course website. In this way, everyone in class can see the questions and the answers. We will monitor the discussion forum closely and answer the questions quickly but not instantly. In some classes the staff strive to reduce their average response time. I don't think that helps your learning; there is value in figuring out some things on your own. If you are stuck then we will help, just within 24 hours and not within 24 minutes.

Prerequisites

The course requires background in linear algebra and calculus. At a minimum, you should be comfortable with multiplying and inverting matrices, carrying out Gaussian elimination, plotting and optimizing functions (though multivariable calculus will be useful at one point). If you feel comfortable with the material during the first three weeks of the course, then it is likely that your background is adequate. Also, you need some familiarity with a programming language, such as Python or Java. All of the necessary programming tools (for python) will be covered in the lectures, but familiarity with a programming language allows you to focus on optimization, rather than fundamentals of programming.

Resources

The main resource is the course packet, which will be posted on the course website. The course packet has some parts that are intentionally left blank and we will fill those parts during lectures. You can do that by annotating the pdfs or using printed hardcopies; the choice is yours.

There are a number of good textbooks on optimization. In order of increasing mathematical sophistication, three good textbooks are as follows. Some of these books have multiple editions; any edition is fine.

- F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research*, McGraw Hill, 2009, 2012, 2014.
- R. J. Vanderbei, *Linear Programming: Foundations and Extensions*, Springer, International Series in Operations Research and Management Science, 2014, 2007, 1998.
- D. Bertsimas and J. N Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific, Series in Optimization and Neural Computation, 1997.

You can get through the course without using a textbook, but I encourage you to purchase one of the textbooks and read it to see a different angle on the lectures. The textbook by Hillier and Lieberman is comprehensive but it is introductory and slightly below the level of the class. If you have never taken a serious course on optimization before, then you should consider purchasing that textbook. The other two textbooks are less comprehensive, but they go deeper into the theory of optimization.

In addition to the course packet and a textbook, we will use computational tools for building and solving optimization models. Almost all of the computational tools that we will use are freely

available and we will provide the necessary directions to access them at appropriate points during the semester. The only computational tool that is not free is Microsoft Excel and its optimization solver, which we will use in the first two weeks of the course. In case you don't have access to that solver, you may use a freely available python alternative.

Assignments:

You should expect on the order of 10 weekly homework assignments. The assignments will be posted on the course website by Friday at 5:00pm Eastern and will be due the following Friday at 11:59am Eastern. Assignments should be neat and well organized. If you include computer outputs, clearly label them and mark your answers. Homework can be completed in pairs. Each person listed on the homework receives the grade for the homework. You can change pairs for different homework assignments.

There will be no extension for homework for any reason, but you can skip one homework assignment without any penalty. If you would like your homework to be re-graded, then you should contact us within one week after you get your homework back. We regrade the entire homework.

Grading:

Your grade will be based on homework assignments (optionally completed in pairs), equally weighted, and a project (completed individually). The project will require on the order of 2 deliverables during the semester and a final deliverable by December 7. The homework and projects will be weighed according to the following scale.

Homework	60%
Project (due December 7)	40%

Policy on Academic Conduct

Every student is expected to abide by the Cornell University Code of Academic Integrity. In particular, everybody has to turn in his or her own work, unless otherwise stated. You may discuss homework assignments with the other students, but only at the level of a zoom discussion without using files or mathematical notation. When you are writing down or typing your homework assignment, please make sure that you are only cooperating with your homework partner and not with anyone else. Sharing computer files is not allowed, except for homework files with your homework partner. You cannot get help in any way from other people that are in or outside Cornell Tech apart from the instructor and TA. We believe that homework is a learning experience and will grade reasonably, as long as you put in an honest effort. If you violate this policy, you risk having your entire homework grade set to zero or even failing the course. If you have questions as to whether certain actions violate the policy, please contact the instructor beforehand.

You are prohibited from buying and selling course materials through internet sites such as Chegg, CourseHero, and Slader. If you **buy** or otherwise access course materials through such a vendor, you face a charge of "Unauthorized Assistance," thereby violating the *Code of Academic Integrity.* Cornell faculty are able to trace posts from internet sites, including identifying the individuals who provide the original posts and those who read or download the posts. At various junctures during the course, I intend to monitor such sites.

Remember, too, that materials for sale may contain errors. There have been occasions when students have done poorly and/or their unauthorized use of purchased work was discovered because the materials they purchased contained errors.

If you **sell** course materials, even your own class notes summarizing lectures, without my authorization, you are subject to a charge of "Academic Misconduct." You may also be participating in copyright infringement. Original course materials are intellectual property that belong to the author and are not a student's property to sell.

Please see http://cuinfo.cornell.edu/aic.cfm for more information on the university code of academic integrity.

Topics Covered:

Below is a chronological list of topics that we plan to cover, along with a guess at the approximate number of lectures we will spend on each topic.

Topic	Number of Lectures
Introduction to linear programming, MS Excel solver	3
Gurobi, OR-Tools and Python	2
Modeling with integer programming	3
Geometry of linear programming	2
Linear algebra concepts	2
Fundamentals of simplex method	5
Finding initial feasible solutions	1
Unbounded problems, alternative optima, degeneracy	2
Network models	4
Weak duality	3
Strong duality	2
Economic interpretation of duality	2
Integer Programming: Branch and bound	2
Other Models*	1
Other Algorithms*	2
Optimization under uncertainty*	2

*Time-permitting and subject to change