ISE 530: Optimization Methods for Analytics

Number of units: 04

Location: GER 206

Time: Tu/Th, 2:00 PM – 3:50 PM

Instructor: Meisam Razaviyayn (razaviya@usc.edu)
    Office hours: 11:00 AM - 12:00 PM Tuesdays

Teaching Assistant: Yinbin Han (yinbinha@usc.edu)
    Office hours: 3:00 PM – 4:00 PM Mondays

Office Hours Zoom info
https://usc.zoom.us/j/96248883689?pwd=eDFEdS9KVVpIMWVTVmtCSnFIQ1h6QT09

Course Description
Fundamentals of Linear Programming, Integer Programming, quadratic and nonlinear programming for analytics and data science problems.

Course Overview
This course covers the most common classes of optimization problems, their theory, and basic methods for finding their numerical solutions. The topics provide a set of fundamental tools for the understanding and solution of a variety of data-analytic problems including those arising from operations, statistics, machine learning, financial engineering, and data-driven modeling.

Learning Objectives
At the end of this course, students will be able to:
- Describe common optimization problem classes (linear, quadratic, non-linear, and integer)
- Identify their mathematical properties, and basic algorithms for solving them
- Develop a set of tools to be applied to a variety of problems

Textbook
- Richard W. Cottle and Mukund N. Thapa, *Linear and Nonlinear Optimization*, ISBN 978-1-4939-7053-7; Springer New York (2017).
- Gerard Cornuejols and Reha Tütüncü, *Optimization Methods in Finance*. Fourth Printing, Cambridge University Press.
    - Available at https://www.andrew.cmu.edu/user/gc0v/webpub/book.pdf

Modeling Language References
- Some parts of the homework assignments require programming with AMPL. You should familiarize yourself with AMPL (the book below) and NEOS server: https://neos-server.org/neos/
- Robert Fourer, David M. Gay, and Brian W. Kernighan, *AMPL: A Modeling Language for Mathematical Programming*, Second edition, ISBN 0-534-38809-4; Available at https://ampl.com/resources/the-ampl-book/

Recommended Preparation
This course makes heavy use of linear algebra and matrix operations and assumes that you are comfortable with college-level mathematical reasoning typical of an engineering curriculum. If you are not comfortable with these background materials, either quickly review them or postpone taking the course until you are ready. In addition, this course requires programming with Python. Make sure you are familiar with Python coding for implementing algorithms that require matrix operation in homework assignments.

Course Notes
Course lecture notes will be posted online after each session.

Homework assignments
- All homework assignments are **due by 11:59:00 pm** on the date indicated.
- Homework assignments must be submitted via Blackboard. **Only one pdf file** should be submitted for each homework assignment. You can submit latex pdf files, word converted pdfs, or scanned images which are converted to pdf format.
- Late homework submissions are not accepted **under any circumstances**. Start your homework assignments early.
- There will be biweekly (sometimes weekly) homework assignments. The two lowest scored homework assignments will not be considered in your final grade.
- You are encouraged to discuss homework assignments with other students. However, each student is required to submit his/her own personal work.

Class Participation: Class participation is 10% of your entire grade. This grade will be based on the following two criteria:
- Being present in the lectures, and actively participating in the discussions
- Answering the questions asked by other students in the class **Slack channel** and participating in the discussions on Slack

Where should you ask your questions?
- If you have a technical question, or a question regarding homework assignments or other parts of the course that you think other students, the TA, or the instructor can answer it, please ask the question in the course Slack channel. Your question might be the question of other students as well.
- If you have questions regarding your homework assignment's grades, please email the TA.
- Email the instructor for other inquiries not listed above.

Grading Breakdown
- Midterm Exam, Feb 22, during class time (30%)
- Final exam, Thursday May 2, 2-4 PM (35%) (see https://classes.usc.edu/term-20241/finals/)
- Homework assignments (25%)
- Participation (10%)

Tentative Course Plan:

- **Optimization and Modeling**
  - what is optimization?
  - modeling
  - understanding basic optimization concepts

- **Linear Programming**
  - modeling (selected models and as a modeling tool)
  - standard LP
  - transforming to LP and to standard LP
  - simplex method and its variations
  - duality theory for LP

- **Unconstrained Optimization**
  - root finding methods
  - properties of unconstrained optimization
  - convexity in unconstrained optimization
  - algorithms (descent methods, coordinate descent, Newton's method)
  - optimality conditions and stationarity definition
  - convexity in unconstrained optimization

- **Quadratic Programming**
  - applied models (least-squares regression, portfolio selection)
  - the LASSO estimator and extensions
  - a touch of theory
  - algorithms and implementation

- **Nonlinear Programming: Foundation**
  - applied models (logistic regression, LASSO, least squares regression, SVM, etc.)
  - convex optimization
  - inequality constraints
  - duality in nonlinear optimization (weak duality, strong duality, KKT conditions, constraint qualification)

- **Nonlinear Programming: Algorithms**
  - (projected) gradient descent
  - coordinate descent algorithm
  - using duality in algorithms
  - penalty methods
  - examples and implementation in machine learning and data analytics applications

- **Integer Programming**
  - IP examples (knapsack, set covering/partition/packing, logical relations)
  - basic algorithms for IP

Statement on Academic Conduct and Support Systems

Academic Integrity:
The University of Southern California is a learning community committed to developing successful scholars and researchers dedicated to the pursuit of knowledge and the dissemination of ideas. Academic misconduct, which includes any act of dishonesty in the production or submission of academic work, comprises the integrity of the person who commits the act and can impugn the perceived integrity of the entire university community. It stands in opposition to the university's mission to research, educate, and contribute productively to our community and the world.

All students are expected to submit assignments that represent their own original work, and that have been prepared specifically for the course or section for which they have been submitted. You may not submit work written by others or "recycle" work prepared for other courses without obtaining written permission from the instructor(s).

Other violations of academic integrity include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), collusion, knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

The impact of academic dishonesty is far-reaching and is considered a serious offense against the university. All incidences of academic misconduct will be reported to the Office of Academic Integrity and could result in outcomes such as failure on the assignment, failure in the course, suspension, or even expulsion from the university.

For more information about academic integrity see the student handbook or the Office of Academic Integrity's website, and university policies on Research and Scholarship Misconduct.

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment, or what information requires citation and/or attribution.

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. The Office of Student Accessibility Services (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Support Systems:

Counseling and Mental Health - *(213) 740-9355 – 24/7 on call*
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

988 Suicide and Crisis Lifeline - *988 for both calls and text messages – 24/7 on call*
The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline is comprised of a national

network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

Relationship and Sexual Violence Prevention Services (RSVP) - *(213) 740-9355(WELL) – 24/7*
Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

Office for Equity, Equal Opportunity, and Title IX (EEO-TIX) - *(213) 740-5086*
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

Reporting Incidents of Bias or Harassment - *(213) 740-5086 or (213) 821-8298*
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

The Office of Student Accessibility Services (OSAS) - *(213) 740-0776*
OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

USC Campus Support and Intervention - *(213) 740-0411*
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity, Equity and Inclusion - *(213) 740-2101*
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - *UPC: (213) 740-6000, HSC: (323) 442-1200*
Non-emergency assistance or information.

Office of the Ombuds - *(213) 821-9556 (UPC) / (323-442-0382 (HSC)*
A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

Occupational Therapy Faculty Practice - *(323) 442-2850 or* otfp@med.usc.edu
Confidential Lifestyle Redesign services for USC students to support health-promoting habits and routines that enhance quality of life and academic performance.