ISE 630 Foundations of Optimization

Units: 4
Spring 2025—MW—12:00-1:50pm
Location: DMC200

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Course Description

A broad introduction to optimization that covers convex sets, convex functions, structures of optimization problems, Lagrangian and conjugate duality, first- and second-order optimality conditions, and algorithms. The course covers applications in engineering and statistics through a diverse set of models. It introduces students to numerical optimization through hands-on computations.

Learning Objectives

Definitions and applications of derivatives, gradients, Hessians, subgradients, and subderivatives; subdifferential calculus rules, normal and tangent cones, and first- and second-order optimality conditions. Formulations, reformulations, and approximations of optimization problems in data smoothing, inventory control, estimation, classification, regression, product mix, pollution control, network design, monitoring functions, multi-component systems, and other applications.

Definitions and applications of convex analysis. Algorithms and their supporting theory: gradient descent method, Newton's method, proximal point method, conjugate gradient method, acceleration, proximal gradient methods, interior-point method, subgradient method, stochastic gradient descent method, SQP, L-shaped method, and proximal composite method.

Definitions and applications of expectation functions, quantiles, superquantiles, risk and uncertainty modeling, recourse models, and subgradients of expectation functions. Definitions and applications of epigraphical approximations, set-analysis, epigraphical nesting, sup-projections, error analysis, and difference-of-convex functions. Definitions and applications Rockafellians, stability analysis, Lagrangians, duality, saddle points, and augmented Lagrangian. By the end of the course, students will be able to reason formally about optimization models and algorithms.

Recommended Preparation: Multivariable calculus on the level of MATH 229; linear algebra on the level of MATH 225 or MATH 245.

Required Readings

Royset & Wets, An Optimization Primer, Springer. (Available online or USC bookstore.)

Homeworks

All homeworks must be submitted by **11am (in the morning)** on the due date. Late assignment will NOT be accepted without approval by the instructor prior to the submission time. Homework extension will only be granted under exceptional circumstances such as medical emergencies.

Each homework must be submitted as a single PDF file in Brightspace. Handwritten and hand-drawn submission are acceptable if neatly done. Excessively long submissions, e.g., with code or code output, is discouraged.

You are encouraged to discuss homework assignments with other students. However, each homework is to be completed individually.

You are allowed to use AI tools (e.g., ChatGPT and image generation tools) as you prepare your homework submission. Keep in mind the following:
- Midterm and final exams will be closed book, with only a cheat sheet available. It is therefore important that you understand the material. Blindly copying answers may not help you to reach the expected understanding.
- AI tools are permitted to help you brainstorm topics or revise work you have already written.
- Proceed with caution when using AI tools and do not assume the information provided is accurate or trustworthy. If it gives you a number or fact, assume it is incorrect unless you either know the correct answer or can verify its accuracy with another source. You will be responsible for any errors or omissions provided by the tool. It works best for topics you understand.
- AI is a tool, but one that you need to acknowledge using. Please include a paragraph at the end of any assignment that uses AI explaining how (and why) you used AI and indicate/specify the prompts you used to obtain the results and what prompts you used to get the results. Failure to do so is a violation of academic integrity policies.

Be thoughtful about when AI is useful. Consider its appropriateness for each assignment or circumstance. The use of AI tools requires attribution. You are expected to clearly attribute any material generated by the tool used.

Questions and Help

If you have a question regarding homework assignments or other parts of the course that you think other students, the TA, or the instructor can answer, please ask the question in Brightspace. You can also email the TA or the instructor at any time.

Midterm and Final Exams

There will be two in-class midterm exams and one final exam. The exams are closed book. Phones and other devises must remain in your bag or pocket.

On Midterm 1 you can only bring: pencils/pens, erasers, blank scratch paper, and one sheet of paper with notes on one side.

On Midterm 1 you can only bring: pencils/pens, erasers, blank scratch paper, and one sheet of paper with notes on both sides.

On Final you can only bring: pencils/pens, erasers, blank scratch paper, and two sheets of paper with notes on all sides.

Class Participation

A student will receive full credit for class participation if present and actively participating in classroom discussions.

Grading Breakdown

Assessment Tools	% of Grade
Class participation	5
Homework (scale 0-10)	25
Midterm 1 (scale 0-100)	20
Midterm 2 (scale 0-100)	20
Final (scale 0-100)	30
TOTAL	100

Grading Scale

Letter grade	Corresponding numerical point range
A	95-100
A-	90-94
B+	87-89
B	83-86
B-	80-82
C+	77-79
C	73-76
C-	70-72
D+	67-69
D	63-66
D-	60-62
F	59 and below

Tentative Schedule

Week 1
Jan 13 1.A The Mathematical Curtain Rise, 1.B Data Smoothing, 1.C Optimization under Uncertainty
Jan 15 (Homework 1 due) 1.D Convex Analysis

Week 2
Jan 20 MLK Day
Jan 22 (Homework 2 due) 1.E Estimation and Classification, 1.F Gradient Descent Method

Week 3
Jan 27 1.G Newton's Method, 1.H Acceleration and Regularization
Jan 29 (Homework 3 due) 2.A Formulations, 2.B Subderivatives and Subgradients

Week 4
Feb 3 2.C Subgradient Calculus, 2.D Proximal Gradient Methods
Feb 5 (Homework 4 due) 2.E Linear Constraints, 2.F Karush-Kuhn-Tucker Condition, 2.G Interior-Point Method

Week 5
Feb 10 2.H Support Vector Machines, 2.I Subgradient Method, 2.J Conic Constrains
Feb 12 (Homework 5 due) 3.A Product Mix Optimization, 3.B Expectation Functions, 3.C Risk Modeling

Week 6
Feb 17 President's Day (Homework 6 due)
Feb 19 In-Class Midterm 1 (Sections 1.A-H, 2.A-J, 3.A-C; Homeworks 1-6)

Week 7
Feb 24 3.D Models of Uncertainty, 3.E Risk-Adaptive Design, 3.F Optimality in Stochastic Optimization

Feb 26 (Homework 7 due) 3.G Stochastic Gradient Descent

Week 8
Mar 3 3.H Simple Recourse Problems, 3.I Control of Water Pollution, 3.J Linear Recourse Problems
Mar 5 (Homework 8 due) 4.A Formulations, 4.B Network Design and Operation, 4.C Epigraphical Approximation Algorithm

Week 9
Mar 10 4.D Constraint Softening, 4.E Set Analysis, 4.F Robotic Path Planning
Mar 12 (Homework 9 due) 4.G Tangent and Normal Cones I, 4.H Tangent and Normal Cones II

Week 10
Mar 17 Spring break
Mar 19 Spring break

Week 11
Mar 24 4.I Subdifferentiability
Mar 26 (Homework 10 due) 4.J Optimality Conditions, 4.K SQP and Interior-Point Methods

Week 12
Mar 31 5.A Rockafellians
(April 1 Homework 11 due)
April 2
In-Class Midterm 2 (Sections 1.A-H, 2.A-J, 3.A-J, 4.A-K, 5.A; Homeworks 1-11)

Week 13
April 7 5.B Quantitative Stability, 5.C Lagrangians and Dual Problems
April 9 (Homework 12 due) 5.D Lagrangian Relaxation, 5.E Saddle Points, 5.F Strong Duality

Week 14
April 14 5.G Reformulations, 5.H L-Shaped Method, 5.I Monitoring Functions
April 16 (Homework 13 due) 6.A Second-Order Analysis, 6.B Augmented Lagrangians

Week 15
April 21 6.C Epigraphical Nesting, 6.D Optimality Conditions
April 23 (Homework 14 due) 6.E Sup-Projections, 6.F Proximal Composite Method

Week 16
April 28 6.G Design of Multi-Component Systems, 6.H Difference-of-Convex Functions, 6.I DC in Regression and Classification
April 30 6.J Approximation Errors
May 4 (Homework 15 due)

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct is in contrast to the university's mission to educate students through a broad array of first-rank academic, professional, and extracurricular programs and includes any act of dishonesty in the submission of academic work (either in draft or final form).

This course will follow the expectations for academic integrity as stated in the USC Student Handbook. All students are expected to submit assignments that are original work and prepared specifically for the course/section in this academic term. You may not submit work written by others or "recycle" work

prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

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

Academic dishonesty has a far-reaching impact and is considered a serious offense against the university. Violations will result in a grade penalty, such as a failing grade on the assignment or in the course, and disciplinary action from the university itself, such as suspension or even expulsion.

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.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. (Living our Unifying Values: The USC Student Handbook, page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relation to the class, whether obtained in class, via email, on the internet, or via any other media. Distributing course material without the instructor's permission will be presumed to be an intentional act to facilitate or enable academic dishonestly and is strictly prohibited. (Living our Unifying Values: The USC Student Handbook, page 13).

Statement on University Academic and Support Systems

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.

Student Financial Aid and Satisfactory Academic Progress:

To be eligible for certain kinds of financial aid, students are required to maintain Satisfactory Academic Progress (SAP) toward their degree objectives. Visit the Financial Aid Office webpage for undergraduate- and graduate-level SAP eligibility requirements and the appeals process.

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 consists 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 on call*
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) 740-2500*
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 – 24/7 on call*
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 – 24/7 on call*
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.