

ISE 633 Large Scale Optimization for Machine Learning

Number of units: 04

Location and time: KAP 148, Tu/Th 4:00 - 5:50 PM

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Office hours: Wednesdays 3-4 PM.

Office Hours Zoom info:

<https://usc.zoom.us/j/96214367211?pwd=MzJ0SHd1UTBtY3NoS09LdHBnb3FFdz09>

Goal: The objective of the course is to introduce large-scale optimization algorithms that arise in modern data science and machine learning applications.

Course Description: The course covers the theory and tools for large-scale optimization that arise in modern data science and machine learning applications. We will cover topics such as stochastic optimization, accelerated methods, parallelization, nonsmooth optimization, online optimization, variance reduction, differential privacy in optimization, min-max games, etc.

Textbook: There is no required textbook for the class. All course materials will be presented in class or will be available online as notes. The following textbooks cover parts of the course materials and you may find them useful:

- S. Boyd and L. Vandenberghe, Convex optimization, Cambridge University Press, 2004.
 - The book is available for free here: <http://web.stanford.edu/~boyd/cvxbook>
- S. Shalev-Shwartz and S. Ben-David, Understanding Machine Learning: From Theory to Algorithms. Cambridge University Press, 2014.
 - The book is available for free here: <http://www.cs.huji.ac.il/~shais/UnderstandingMachineLearning/>
- A. Shapiro, D. Darinka, and A. Ruszczyński, Lectures on Stochastic Programming: Modeling and Theory, SIAM, 2009.
 - The book is available for free here: <http://www2.isye.gatech.edu/~ashapiro/publications.html>
- C. Dwork and A. Roth. The algorithmic foundations of differential privacy, Foundations and Trends® in Theoretical Computer Science, 2014.
 - The book is available for free here: <https://www.cis.upenn.edu/~aaroht/Papers/privacybook.pdf>

Tentative Course Plan: (Course materials may change depending on the progress)

- Background and preliminaries
 - Optimization overview, examples in machine learning, large-scale optimization, memory/time/CPU requirement
 - Linear algebra and probability basics
- Unconstrained optimization: optimality conditions and algorithms
 - Necessary and sufficient optimality conditions
 - Convex versus non-convex and their examples
 - First-order methods (unconstrained)
 - Convergence analysis: Lower and upper-iteration complexity bounds
 - Momentum and accelerated methods
- Constrained optimization
 - Examples of constrained optimization in machine learning: fairness, safety, etc.
 - KKT optimality conditions and Lagrange multipliers
 - Projection-based algorithms, examples in machine learning
- Nonsmooth optimization
 - Examples of nonsmooth optimization in machine learning: Lasso, Netflix problem and Nuclear norm regularizers, nonsmooth activations in deep learning, etc.
 - Necessary and sufficient optimality conditions
 - Algorithms and their analysis: block coordinate descent, successive upper-bound minimization, alternating direction method of multipliers, subgradient descent, proximal gradient
- Empirical risk minimization and stochastic optimization
 - Stochastic/Online/Incremental optimization, SAA and SA
 - Bias/variance tradeoffs
 - Algorithms and their analysis: (robust) stochastic (sub-)gradient descent, stochastic variance reduced gradient descent
 - Parallel optimization: synchronous vs asynchronous
- Online convex optimization
 - Examples and regret definition
 - Algorithms and their analysis: follow-the-leader, follow-the-regularized-leader, online gradient descent
- Learning via min-max optimization
 - Examples: Generative Adversarial Networks, Adversarial Learning, fair learning
 - Algorithms: Danskin's theorem, gradient descent-ascent algorithm, proximal-type methods
- Using Hessian in large-scale optimization: Hessian-vector product, CG methods
- Differential privacy and optimization (If we have time)
 - Privacy in machine learning and optimization
 - Differential privacy definition and examples
 - Lower and upper-bounds on differentially private convex optimization

Course Requirement and Grading:

- During class time midterm on Thursday, Feb 22nd (30%)
- Final exam, Thursday, May 2nd, 4:30 PM -6:30 PM (35%) [see <https://classes.usc.edu/term-20241/finals/>]
- Homework assignments (20%)
- Participation (5%)
- Scribing (10%)

Homework assignments:

- All homework assignments are **due by 11:59pm** 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 that are converted to pdf format.
- Late homework submissions are not accepted **under any circumstances**. Start your homework assignments early.
- There will be 5-6 homework assignments. The two lowest scores 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.

Scribing: In order to gain experience with technical writing, each student is required to scribe notes for one lecture. These notes will be revised by the instructor and will be posted on the course website. The scribed notes should be written in a way that they are completely understandable to a student who may have missed the class. The **deadline for your scribing assignment is one week after the lecture** you are scribing.

Class Participation: Class participation is 5% 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 in class
- Answering the questions asked by other students in the class **Slack channel** and participating in the discussions on Slack

Scribing: In order to gain experience with technical writing, each student is required to scribe notes for two lectures. The scribed notes should be written *in a way that they are completely understandable to a student who may have missed the class*. The link to the **signup sheet** and the **overleaf document** is posted on Blackboard. For your scribing assignments, pay attention to the followings:

- The deadline for the assignment is 7 days after the lecture that you are scribing.
- The previous years' scribes is shared with you on Overleaf. Do not think of the previous years' scribes as perfect and complete. The topics are even changed in some parts of the course. Edit the document as you see fit. You should directly edit on the overleaf file. Your grade will be based on the improvement you made compared to last years' notes.

Where should you ask your questions?

- 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 it, please ask the question in the course Slack channel. This will increase the interactions among all of us during this pandemic time.
- If you have questions regarding your homework assignment's grades, please email the TA.
- Email the instructor for other inquiries not listed above.

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.