

ISE 633 Large Scale Optimization for Machine Learning

Number of units: 03

Location and time: Tuesday/Thursday 12:30-1:50pm, see Blackboard for the Zoom link.

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Office hours: Wednesdays, see Blackboard for the Zoom link.

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: Large scale optimization algorithms that arise in modern data science and machine learning applications. We will cover topics such as stochastic optimization, accelerated methods, parallelization, online optimization, variance reduction, randomized linear algebra, 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:

- D. P. Bertsekas, Nonlinear Programming, Belmont: Athena scientific, 1999.
- 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>

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

- Week 1:
 - Optimization overview, examples in machine learning, large scale optimization, memory/time/CPU requirement
 - Mathematical Basics
- Week 2:
 - Unconstrained optimization, necessary optimality conditions, smooth versus non-smooth optimization
 - Sufficient optimality conditions, convex versus non-convex optimization
- Week 3:
 - Gradient methods (unconstrained), choices of direction,
 - Asymptotic convergence, Newton method
- Week 4:
 - Rate of convergence of gradient descent, first order oracle model
 - Lower and upper bounds in the oracle model
- Week 5:
 - Accelerated Nesterov's Method
 - Constrained optimization, optimality conditions
- Week 6:
 - KKT optimality conditions and Lagrange multipliers
 - Projection and algorithms, examples in machine learning
- Week 7:
 - Exploiting multi-block structure of the problem, examples in machine learning, block coordinate descent methods
 - Different block selection rules and convergence analysis
- Week 8:
 - Block successive upper-bound minimization and its convergence
- Week 9:
 - Alternating direction method of multipliers
 - Non-smooth optimization and examples in machine learning
- Week 10:
 - Necessary and sufficient conditions in non-smooth optimization, successive upper-bound minimization, proximal operator
 - Multi-block methods in non-smooth optimization

- Week 11:
 - Stochastic/Online/Incremental optimization
 - Incremental gradient and its analysis
- Week 12:
 - Sample Average Approximation and Stochastic Approximation
 - Analysis
- Week 13:
 - Parallelization: synchronous vs asynchronous
 - Adversarial viewpoint and regret analysis
- Week 14:
 - Non-convexity and examples in machine learning: principal component analysis, deep learning, non-negative matrix factorization
 - Local optimality results
- Week 15:
 - One topic from a list of suggested topics: randomized linear algebra, Min-max games, ...

Course Requirement and Grading:

- During class time midterm on October 15 (30%)
- Final exam, Tuesday December 08, 11am-1pm (35%)
- 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 which 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 two lectures. 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.

Class Participation: Class participation is 5% of your entire grade. This grade will be based on the following two criteria:

- Being present in the online lectures and actively participate in the discussions online
- Answering the questions asked by other students in the class **Slack channel** and participate 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.

University policies:

- *Statement for Students with Disabilities.* Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to your course instructor (or TA) as early in the semester as possible. DSP is located in STU 301 and is open from 8:30am to 5:00pm, Monday through Friday. Website and contact information for DSP:
http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html, (213) 740 – 0776n (Phone), (213) 740-6948 (TDD only), (213) 740-8216 (FAX), ability@usc.edu.
- *Statement on Academic Integrity.* USC seeks to maintain an optimal learning environment. General Principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect ones own academic work from misuse by others as well as to avoid using another's work as ones own. All students are expected to understand and abide by these principles. SCampus, The Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: <http://usc.edu/dept/publications/SCAMPUS/gov/>. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review should there be any suspicion of academic dishonesty. The Review process can be found at: <http://usc.edu/student-affaris/SJACS/>. Information on intellectual property at USC is available at: <http://usc.edu/academe/acsen/issues/ipr/index.html>.
- *Emergency Preparedness/Course Continuity in a Crisis.* In case of emergency, when travel to campus is difficult, if not impossible, USC executive leadership will announce a digital way for instructors to teach students in their residence halls or homes using a combination of the Blackboard LMS (Learning Management System), teleconferencing, and other technologies. Instructors should be prepared to assign students a "Plan B" project that can be completed "at a distance". For additional information about maintaining your classes in an emergency, please access: <http://cst.usc.edu/services/emergencyprep.html>.