Optimization Foundations for Machine Learning and Artificial Intelligence

ISyE 4133: Advanced Optimization

Spring 2027

Course Information

- **Instructor:** Katya Scheinberg (katya.scheinberg@isye.gatech.edu)
- **Course Prefix and Number:** ISYE 4133
- **Term:** Spring 2027
- **Lectures**: Tuesday and Thursday : 9:30 am – 10:45 am, George Tower 0222
- **Office Hours**: Tuesday 3 pm – 4 pm, George Tower 1706 (also by appointment)
- **Credit Hours**: 3
- **Prerequisites**: ISyE 3133, or equivalent knowledge with basic notions of optimization formulations
- **TA**: TBA, ()

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1 Course Outline

In introductory optimization courses such as Engineering Optimization (ISyE 3133), students learn the fundamentals of linear and integer optimization models and algorithms. However, many real-world decision problems require more advanced modeling techniques, deeper theoretical insight, and customized algorithmic approaches.

Course Description

Continuous optimization models and algorithms are at the heart of many problems of Data Science, Machine Learning, AI, signal processing, economics and other modern contexts. This course introduces foundations of optimization models and algorithms as applied in these settings. Topics include unconstrained optimization, gradient descent and its variants, Newton method, convergence of algorithms, parameter tuning, line-search, stochastic gradient descent and its variants, empirical risk minimization, constrained optimization, duality, convexity, Lagrange duality. We will use examples from linear regression, Lasso regression, logistic regression, support vector machines and neural networks.

See the table for the tentative plan for the course topics. It is subject to change.

Week	Topic
1	Introduction, optimization problems
	Convex and nonconvex prolems
2	Relaxations, knapsack problem
	Linear Programming, review
3	Basic Feasible Solutions, linear algebra
	Production planning, shortest path
4	Network Flows
	Network Flows
5	LP duality, intro
	LP duality
6	Complementarity
	Simplex method
7	Min max and absolute values
	Binary Classification
8	Review
	Midterm
8	Integer Programming
	Facility Location
10	Traveling salesman
	Minimum spanning tree
11	Formulations, relaxations
	Branch and Bound
12	Cutting Stock, column generation
	Other topics
13	Nonlinear optimization, examples
	Nonlinear optimization, algorithms
14	KKT conditions
	Review

Course Learning Outcomes

This course develops advanced skills in optimization modeling and solution methods. Formulations for important classes of optimization problems and algorithms to solve them. At the end of this

course the students will have

- A deeper understanding of the theory and algorithms underlying linear and integer optimization;
- Exposure to advanced modeling techniques used in practice;
- Understanding of algorithmic complexity and its relation to practical computation;
- Experience designing and implementing algorithms for large-scale and computationally challenging optimization problems.

Required Course Materials

No textbooks or materials are required.

Lecture slides: We make skeletal slides available on Canvas before the lecture. They can be used to take notes during the lecture. Full notes from the lecture will be posted after the lecture.

Grading Policy

Course grade will be based on homework assignments, in-class quizzes and participation, midterm and final exam. The final exam will be cumulative, covering all topics studied during the semester.

Homework	10%	Weekly
In-class work	40%	Weekly
Midterm 1	25%	TBD
Midterm 2 or Final Exam	25%	TBD
Total	100%	

The course grade will be calculated using the percentages above. The natural cut-offs of 90, 80, 70 and 60 will be used for letter grades A, B, C and D. Letter grades can be increased using a curve.

Attendance Policy

Students are strongly encouraged to attend lectures and actively participate by asking for clarifications and answering questions.

We will use regular quizzes to help students check their knowledge and understanding. Some of the quizzes will be based on completed homework and material covered in past lectures. They will be graded for correctness and participation. For example, 50% of the quiz grade may be granted for only participation, while the remaining 50% will be granted based on correctness. This grade allocation is subject to change.

80% attendance or higher will count as full attendance (so lectures skipped due to illness or other uncontrolled circumstances will not be penalized). In a student misses a quiz, the grade for that quiz is zero, thus the bottom 20% of the quizzes (by grade) will be dropped.

Homework Assignments

Homework assignments will be posted on Canvas and are usually due at **9PM** but on various days of the week (check carefully).

- **Submitting homework:** The homework should be submitted by deadline posted with the homework and has to be individual work of each student. For the coding exercises, you may work with a partner, and you and your partner may turn in a single assignment.
- **Late homework:** Each student is allowed to submit up to two homework assignments up to two days late each. This is meant to cover regular issues, such as illness, sports competitions, interviews and other interruptions. After solutions have been released no late homework will be accepted.
- **Dropped homework grade:** Each student will have the lowest homework grade dropped from the total. If a student is missing one homework, this homework will have the grade 0 and will be dropped.
- **Regrade requests:** the regrade request are accepted at least 24 hours and at most 7 days after the grades are released. Any regrade request may require us to regrade your entire homework/exam, not just the grading mistake. Be aware that if the person who graded misunderstood your answer during the first grading, it was probably not clear. Explaining what you meant afterwards is not likely to earn you points.

Academic and Research Honesty/Integrity Statement

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. Review the Student Code of Conduct and the Academic Honor Code, especially Appendix A: Graduate Addendum to the Academic Honor Code.

Students are expected to perform research in an ethical and responsible manner. All Doctoral and Master's Thesis students are required to take the Responsible Conduct of Research training, and it is expected that students abide by the principles taught in that training while performing research for this thesis course.

Allegations of scientific or scholarly misconduct are handled in accordance with the procedures outlined by the Policy for Responding to Allegations of Scientific or Other Scholarly Misconduct.

Core IMPACTS

Not applicable.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services as soon as possible to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Expectations of Advisors and Advisees

At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. The Expectations of Advisors and Advisees articulates some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.