UNIVERSITY of ROCHESTER

Continuous Algorithms for Optimization and Sampling

CSC 574 / DSCC 574-1 Spring 2024

Meeting Information

Tuesday/Thursday 11:05 am-12:20 pm
Meliora Hall Room 209

Instructor

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Office Hours

2:00-3:00 pm, Tuesday, Wegmans Hall 2403

Prerequisites

Students should be familiar with multivariate calculus, linear algebra, basic probability and statistics, and have good MATLAB or Python programming skills. Prior knowledge of optimization and sampling is helpful but not required.

Course Description

Traditional algorithms in computer science are designed in a discrete manner. Nonetheless, recent years have witnessed great advances from a continuous perspective, particularly in the design of optimization and sampling algorithms. There is a deep connection between optimization and sampling, either through optimization as the limit of sampling, or through sampling as optimization in the space of probability measures. Motivated by this viewpoint, this course aims to develop a systematic way to design and analyze algorithms for both areas from the continuous perspective. More particularly, this course starts from continuous optimization, discusses stochastic optimization in detail, introduces optimal transport as a bridge connecting optimization and sampling, and finally delves into sampling.

Topics (subject to change)

- Introduction
- Continuous optimization
    - Subgradient method
    - Proximal gradient method
    - Accelerated gradient method
    - Inexact proximal point methods
- Stochastic optimization
    - Stochastic approximation and sample average approximation
    - Dynamic programming and reinforcement learning

    - Risk averse optimization
    - Distributionally robust optimization
    - Statistical efficiency
- Optimal transport
    - Monge-Kantorovich problem and Kantorovich duality
    - Wasserstein space and Otto's calculus
    - Transport inequalities
    - Entropic regularization and gradient flows
    - Sinkhorn algorithm
    - Economics applications
- Sampling
    - Rejection sampling and Metropolis–Hastings filter
    - Stochastic calculus
    - Langevin Monte Carlo
    - Proximal sampling
    - Generative models

Textbooks

1. Amir Beck. *First-Order Methods in Optimization*. SIAM, 2017.
2. Alexander Shapiro, Darinka Dentcheva, and Andrzej Ruszczynski. *Lectures on Stochastic Programming: Modeling and Theory*. SIAM, 2021.
3. Cédric Villani. *Topics in Optimal Transportation*. American Mathematical Society, 2021.
4. Sinho Chewi. *Log-Concave Sampling*. Draft, 2023.

Recommended Readings

1. Yin Tat Lee and Santosh Vempala. *Techniques in Optimization and Sampling*. Draft, 2023.
2. Sébastien Bubeck*. Convex Optimization: Algorithms and Complexity.* Foundations and Trends® in Machine Learning. 2015.
3. Alexander Shapiro*. Tutorial on Risk Neutral, Distributionally Robust and Risk Averse Multistage Stochastic Programming.* EJOR, 2020.
4. Alexander Shapiro. *Topics in Stochastic Programming*.
5. Gabriel Peyré and Marco Cuturi*. Computational Optimal Transport.* Foundations and Trends® in Machine Learning. 2019.
6. Marcel Nutz*. Introduction to Entropic Optimal Transport.* Lecture notes, 2022.
7. Alfred Galichon. *Optimal Transport Methods in Economics.* Princeton University Press, 2018.
8. John Duchi. *Introductory Lectures on Stochastic Optimization*.
9. John Duchi. *Introductory Lectures on Information Theory and Statistics*.
10. William Haskell. *Introduction to Optimization*. Lecture notes, 2018.
11. William Haskell. *Introduction to Dynamic Programming*. Lecture notes, 2018.
12. Aaron Sidford. *Optimization Algorithms*. Lecture notes, 2023.

Assessments & Grading

The evaluation is fully based on a course project including a proposal (20%), two presentations (25% midterm and 25% final) and a report (30%).

The final grade will be assigned as a letter grade according to the following scale:

A	90-100%
B	80-89%
C	70-79%
D	60-69%
F	0-59%

Project

The course project is intended to give students the opportunity for in-depth exploration of a topic in optimization and sampling algorithms. Course projects could look like one of the following:

- An in-depth survey of one of the topics covered in the class. A survey consists of a rigorous academic review of the literature related to the topic interpreted in the student's own words, and a possible discussion of future areas of research.
- An application of the algorithms discussed in class on a data set or an engineering application. The application can be non-standard; in fact, proposing new applications for the material developed in class is encouraged. However, the methodology in the implementation needs to involve techniques that we discuss during the class.
- A conceptual (i.e., either theoretical or simulation-based) topic of novel research related to the class. Preliminary results and directions for future work are common outcomes.

Project proposals that do not neatly fall into one of these categories are also welcome. Students will be asked to submit a proposal on **February 27**, make the midterm presentation on **March 19/21**, make the final presentation on **April 25/30**, and submit a report on **May 2**.

Academic Integrity

Academic integrity is a core value of the University of Rochester. Students are strongly encouraged to discuss homework problems with one another. However, each student must write up and turn in their own solutions, written in their own words/consisting of their own code. All assignments and activities associated with this course must be performed in accordance with the University of Rochester's Academic Honesty Policy. More information is available at: http://www.rochester.edu/college/honesty.

Absences/Late Submissions

Out of fairness to the entire class, late submission of homework will not be accepted in the absence of a prior agreement between the student and instructor. In particular, excused absences include illnesses, religious observations, career fairs and job interviews. In the event than an excused absence such as above prevents a student from submitting an assignment, their homework grade will be calculated on a prorated basis.

Diversity, Equity, Inclusion, & Belonging

Instructors, teaching assistants, and students should work together to ensure that our class is a welcoming, inclusive, respectful, and vibrant place for all of its members to share, learn, and grow. Our class will not tolerate discrimination, prejudice, or harassment of any kind. More resources can be found at: https://www.rochester.edu/diversity/.

Accessibility

Students needing academic adjustments or accommodations because of a documented disability must contact the Disability Resource Coordinator for the school in which they are enrolled. I am happy to accommodate any and all accommodations, so long as they are documented with the Office of Disability Resources. I am glad to meet to discuss your specific situation or to help ensure you have the support you need. For additional information, please see: https://www.rochester.edu/college/disability/.