

CO 673/CS 794 – Fall 2019: Course Outline

Optimization for Data Science

Instructor: Kimon Fountoulakis DC3611 Office Hours: Mon 3-4pm

Lectures: TTh 04:00-05:20 DC 2585

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CS794 Web Site (Piazza): piazza.com/uwaterloo.ca/fall2019/cs794/home

Course Description

The course will cover optimization techniques used especially for machine learning and data science. Because these fields typically give rise to very large instances, first-order optimization (gradient-based) methods are typically preferred.

Tentative Schedule

Week 1	Sep 5	Introduction, Preliminaries
Week 2	Sep 10	Image Denoising, Convexity, First-order Optimality Conditions
Week 3	Sep 17	Gradient Descent, Convergence of Gradient Descent
Week 4	Sep 24	Total Variation Image Denoising
Week 5	Oct 1	Newton's method, Convergence of Newton's method
Week 6	Oct 8	Conjugate Gradients and Newton-CG
Week 7	Oct 15	Reading Week
Week 8	Oct 22	Compressed Sensing and Proximal Gradient Descent
Week 9	Oct 29	Local Graph Clustering and Coordinate Descent Method
Week 10	Nov 5	Logistic Regression and Randomized Optimization Methods
Week 12	Nov 17	Non-convex optimization, Recommender System and Face Reconstruction
Week 11	Nov 12	Optimization methods for non-convex optimization
Week 13	Nov 24	Neural networks and optimization methods for Neural Networks

• Course Objectives

After finishing this course, students should be able to

1. Recognize optimization problems arising in data science and know how to distinguish convex from nonconvex.
2. Have a toolkit of algorithmic techniques that can be used on these problems.
3. Know how to write code for common optimization algorithms.
4. Know how to analyze certain classes of algorithms.

• Sources of Information

The main source of information for the course is the material covered in the class lectures. It is therefore imperative that you attend the lectures and take notes. There will be a list of suggested readings from the notes, available on the web.

• Optional texts:

- S. Bubeck, *Convex Optimization*: Algorithms and Complexity, Foundations and Trends in Machine Learning, 2015. Preliminary version available on arxiv.org.

- P. Jain and P. Kar, *Nonconvex optimization for Machine Learning*, 2017. Preliminary version available on arxiv.org.
 - L. Bottou and F. E. Curtis and J. Nocedal, *Optimization Methods for Large-Scale Machine Learning*, Preliminary version available on arxiv.org.
 - S. Boyd and L. Vandenberghe, *Convex Optimization*, available on the web.
 - J. Nocedal and S. J. Wright, *Numerical Optimization*. 2nd Edition.
- **Piazza.** We will make use of Piazza for online class discussion, announcements, assignment posting, and general course management, so please be sure to sign up and keep up with postings. Rather than emailing questions to the instructor or TA, you are encouraged to post your questions on Piazza so that everyone can benefit from the discussion and answers. However, note that you must not post solutions to assignment questions on the forum. Our class Piazza page can be found at: piazza.com/uwaterloo.ca/fall2019/cs794/home. The sign-up link for the course is at piazza.com/uwaterloo.ca/fall2019/cs794.
 - **Programming Languages.** Python and/or Matlab
 - **Required Background.** Knowledge of linear algebra, multivariate calculus, basic analysis (convergence, limits), basic probability (common distributions, means, and so on). Knowledge of programming in one of Python, Matlab.
 - **Assignments and Late Policy.** Assignments will be posted on the Piazza page for the course. Check to make sure you are using the most recent version (corrections will be made to the posted assignment if necessary).
Put your name, student ID on the first page. Please retain a copy of your assignment after submission. Assignments are to be handed in electronically on UW Learn. The submission should include **one pdf file** containing the assignment answers and the cover sheet and all the files required to run the code, with no folder structure (not zipped). Late assignments submitted any time in the 24 hours immediately following the deadline will be marked, and receive half (i.e. 50 percent) credit for correct answers. Assignments submitted after 24 hours will not be marked and receive zero.
Assignment solutions will be discussed in class. Assignment marks will be posted on LEARN (or equivalent). Notify the instructor immediately if you believe the mark was recorded incorrectly. The marks recorded on LEARN are considered final two weeks after the assignments or midterm are returned.
 - **Questions about the current assignment.** TAs and/or instructors will monitor the Piazza forums, and hold office hours throughout the term. As this is a graduate CS course the TAs will, for the most part, **not** help students debug programs. Students are expected to be able to do this themselves at this stage.
 - **Assignment Marking.** The assignments will consist of programming problems and (possibly) analytical work. IMPORTANT: most of the marks for the programming problems will be given for your description of your algorithm (i.e. pseudo-code) and explanation of the results. Simply handing code will get very few marks. Assignment figures and graphs should be carefully thought out to present the data and your conclusions in an effective and clear manner. Poor presentation of your work will result in a poor mark. In all cases, we expect you to explain your algorithms, and describe the results you see in detail. Matlab and Python have good plotting facilities. Create figures with Matlab or Python to include in your assignments.
 - **Assignment Marking Appeals.** If you feel your assignment was marked incorrectly, write an explanation of what you would like reviewed, submit it along with the assignment to the course instructor, who will pass your concern on to the appropriate TA. Requests for reviews of marking must be submitted within one week from the time the assignments are returned in class.

- **Assignment Retention.** Unclaimed assignments will be retained until the term grades become official in the Quest system. After that time, they will be destroyed in compliance with Waterloo's shredding procedures: <https://uwaterloo.ca/central-stores/confidential-shredding>
- **Course Grade.** Every time that we introduce a new application/problem. You will be asked to implement a solver for that problem. Also, you will be asked to compare algorithms that can solve the same problem. Each assignment has the same weight. Your final grade will simply be the average of the assignment grades.
- **Collaboration.** You are encouraged to discuss assignments with other individuals in the class. However, the submitted assignment should be your own work. Note that current Math faculty policy is that a mark of -100% can be recorded for the assignment in question in the case of cheating/copying.
- **Plagiarism.** Plagiarism is representing the work of others as your own. Plagiarism on assignments includes copying another student's solution and submitting it as your own, allowing another student to copy your solution, collaborating excessively with another student, or obtaining solutions from any other source. See the section on Discipline below for typical penalties.

All academic offenses are reported to the Associate Dean for Undergraduate Studies and are recorded in the student's file. Any subsequent academic offense in the same course or in other courses will lead to more severe penalties, up to and including suspension and expulsion.

We encourage you to discuss general concepts and problems with classmates, tutors, TAs, and the instructor. However, the solution that you submit must be worked through by yourself and written in your own words. It is not acceptable to work on an assignment with somebody else and write it up individually. The only exceptions are assignments or projects which the instructor designates as group activities. When discussing course matters, do not take notes, and do not look at another person's partial solutions, or show them yours.

- **Academic Integrity.** In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Refer to the Academic Integrity website for details: <http://www.uwaterloo.ca/academicintegrity/>
- **Grievance.** A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, <http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm> When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.
- **Discipline.** A student is expected to know what constitutes academic integrity to avoid committing academic offenses and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offenses and types of penalties, students should refer to Policy 71, Student Discipline: <http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm> For typical penalties check Guidelines for the Assessment of Penalties: <http://www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm>
- **Avoiding Academic Offenses.** Most students are unaware of the line between acceptable and unacceptable academic behaviour, especially when discussing assignments with classmates and using the work of other students. For information on commonly misunderstood academic offenses and how to avoid them, students should refer to the Faculty of Mathematics Cheating and Student Academic Discipline Policy http://www.math.uwaterloo.ca/navigation/Current/cheating_policy.shtml
- **Appeals.** A decision made or penalty imposed under Policy 70, Student Petitions and Grievances (other than a petition) or Policy 71, Student Discipline may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72, Student Appeals, <http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm>

- **Note for Students with Disabilities.** AccessAbility Services with website <http://uwaterloo.ca/disability-services/>, located in the new addition to Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the office at the beginning of each academic term.