Convex optimization: Gradient methods and Online learning

CS292A Spring 2019

Instructor: Prof. Yu-Xiang Wang

Lectures: Phelp 3526. Tuesday and Thursday 1:00 - 2:50

Piazza: `piazza.com/ucsb/spring2019/cs292a/home`

1 Overview

Nearly every machine learning problems can be written as an optimization problem with an objective function to optimize. A subset of these problems — those that come with a convex objective function and possibly a set of convex constraints — can be solved using standardized techniques in convex optimization. The associated properties, such as convexity, smoothness, sparsity, separability and so on are essential for understanding the computational properties of these problems and can be used to derive efficient iterative algorithms. In particular, the course will focus on a class of highly practical algorithm that uses only black-box accesses to the gradient information of the objective. These are what we called — first order optimization algorithms. These algorithms are intimately connected to the field of online learning — a family of game-theoretic models in machine learning that assume very little about the data generating process and efficiently learn to predict on the fly. The course will explicitly discuss the connections between these methods and problem setups.

The course is designed to help a graduate student to learn the theoretical foundation and practical algorithms of machine learning using tools from convex optimization. The techniques we learned are instrumental for understanding research papers in the field of machine learning and will be more generically applicable to problems outside machine learning that involve continuous optimization.

2 What you will learn?

1. You will be able to identify properties such as convexity, smoothness, sparsity and so on; reformulate problems into ones that have these properties;
2. You will learn how to analyze the convergence and computational complexity of first-order algorithms for each class of problems and choose appropriate algorithms for each problem of interest.
3. You will understand the meaning of regret and know the analytical tools for designing and analyzing regret-minimizing online learning algorithms.

3 Prerequisites

As this is a graduate level course, there is no hard pre-requisite, but students entering the class are expected of the following.

- Students are expected to be able to follow rigorous mathematical arguments and perform derivation and proofs using notations, definitions and theorems from calculus, linear algebra, probability and statistics.
- Students are expected to have working knowledge of basic algorithms and data structures, as well as the necessary programming experience (Your choice of Python/numpy, Matlab, or Julia).
- Basic familiarity in machine learning problems are highly recommended as most of our examples will be coming from machine learning.

4 Textbooks

We will be using two textbooks.

1. "Convex optimization" by Boyd and Vandenberghe: [Link]
2. "Introduction to Online Convex Optimization" by Elad Hazan: [Link]
3. (Optional) "Convex Analysis" by Tyrell Rockefellar: [Link]
4. (Optional) "Prediction, Learning, and Games" by Cesa-Bianchi and Lugosi: [Link]

The other two optional reference books are excellent references on these topics as well. We will not be assigning them as reading materials.

On the other hands, the scope of this course is not limited to the textbooks, we will heavily refer to lecture notes from the Stanford Course EE364B (Boyd) and CMU Course 10-725 (Tibshirani), as well as relevant research papers. These will be assigned as reading materials.

5 Assignments and Grades

The grades will be based on homework assignments, the quality of your submitted reading notes and lecture attendance.

- 80% Homework assignments.
- 15% Reading notes (Due at the beginning of every lecture)
- 5% Lecture attendance
- Bonus 5% Volunteer to scribe the lectures.
- Bonus 2% Participation (in class and on Piazza).

What are "Reading notes"? We will be assigning reading materials for every lecture. You are required to read the book chapters and the associated papers *before each lecture* and write a summary note (at least two pages long). You are required to submit the reading notes before the start of every lecture.

6 Logistics

Attendance policy: The attendance to lectures is required. It is part of the course evaluation to attend the lectures. Send PM on Piazza if you will have to miss lectures due to other personal businesses.

Late homework policy: Each student will have exactly **two late days** without penalty. There will be no exception to this rule.

7 Policy on Academic Integrity

Please read this section carefully.

The university, the department, and this instructor all take the issue of academic integrity **very** seriously. A university requires an atmosphere of mutual trust and respect. While collaboration is an integral part of many scholarly activities, it is not always appropriate in a course, and it is never appropriate unless due credit is given to all participants in the collaboration. This goes for both ideas and programming or other work.

Here are some examples:

- Allowed: Discussion of lecture and textbook materials
- Allowed: Discussion of how to approach assignments, what techniques to consider, what textbook or lecture material is relevant
- Not allowed: Sharing ideas in the form of code, pseudocode, or solutions
- Not allowed: Turning in someone else's work as your own, even with that person's permission.
- Not allowed: Allowing someone else to turn in your work as his or her own.
- Not allowed: Turning in work without proper acknowledgment of the sources of the content (including ideas) contained within the work.

For some views on academic integrity at UCSB see the Academic Integrity page of the Office of Judicial Affairs.

Summary: Academic integrity is absolutely required - dishonesty (cheating, plagiarism, etc.) benefits no one and hurts everyone. If you are not sure whether or not something is appropriate, please ask the instructor or TA.

8 Students with Disabilities

If you are a student with a disability and would like to discuss special academic accommodations, please contact the instructor. In addition, students with temporary or permanent disabilities are referred to the Disabled Students Program (DSP) at UCSB. DSP will arrange for special services when appropriate (e.g., facilitation of access, note takers, readers, sign language interpreters). Please note that it is the student's responsibility to communicate his or her special needs to the instructor, along with a letter of verification from DSP.