

# Convex Optimization: Spring 2023

Machine Learning 10-725

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**Lectures:** Tuesdays and Thursdays 12:30-1:50pm, Doherty Hall, 2315.

## Overview and objectives

Nearly every problem in machine learning and computational statistics can be formulated in terms of the optimization of some function, possibly under some set of constraints. As we obviously cannot solve every problem in machine learning, this means that we cannot generically solve every optimization problem (at least not efficiently). Fortunately, many problems of interest in machine learning can be posed as optimization tasks that have special properties—such as convexity, smoothness, sparsity, separability, etc.—permitting standardized, efficient solution techniques.

This course is designed to give a graduate-level student a thorough grounding in these properties and their role in optimization, and a broad comprehension of algorithms tailored to exploit such properties. The focus will be on convex optimization problems (though we also may touch upon nonconvex optimization problems at some points). We will visit and revisit important applications in machine learning and statistics. Upon completing the course, students should be able to approach an optimization problem (often derived from a machine learning or statistics context) and:

1. identify key properties such as convexity, smoothness, sparsity, etc., and/or possibly reformulate the problem so that it possesses such desirable properties;
2. select an algorithm for this optimization problem, with an understanding of the advantages and disadvantages of applying one method over another, given the problem and properties at hand;
3. implement this algorithm or use existing software to efficiently compute the solution.

## Outline of material

Here is a rough outline of the course topics.

**Core topics:** Split into 4 parts, as follows.

- Theory I: Basics of convex analysis
- Algorithms I: First-order methods
- Theory II: Duality and optimality
- Algorithms II: Second-order methods

**Advanced topics:** We will choose a handful of advanced topics to cover, depending on current research trends and class interests.

## Logistics

**Prerequisites:** Students entering the class are expected to have a pre-existing working knowledge of basic algorithms and data structures; however, the class has been designed to allow students that do not have this background, but have strong analytical/mathematical skills, to catch up and fully participate. Students are expected to be comfortable with rigorous mathematical arguments. Though not formally required, having taken 10-701 or an equivalent machine learning or statistics class will be very helpful, since we will frequently use applications in machine learning and statistics to demonstrate the concepts we learn in class. Finally, several homework assignments will involve programmatic implementation of an optimization algorithm being studied in the course.

**Class website:** The class website is <http://www.stat.cmu.edu/~siva/teaching/725>. The class schedule, lecture notes, homeworks, etc., will be posted there.

**Office hours:** The weekly schedule for office hours can be found on the course website.

**Discussion group:** We will use Piazza for class discussions.

**Textbook:** Lectures are intended to be self-contained. But a terrific reference for a lot of the material covered in class is *Convex Optimization* by Boyd and Vandenberghe, which is available online for free (<http://www.stanford.edu/~boyd/cvxbook/>). We will often draw examples or problems from this book. In addition, a thorough mathematical reference for much of the underlying convex analysis we cover is *Convex Analysis* by Rockafellar. Other relevant references will be listed at the end of each set of lecture slides.

**Homework:** There will be 6 homework assignments, approximately evenly spaced throughout the semester. The homeworks will be posted on the course website, and will be submitted according to the instructions given there.

**Quizzes:** There will be 6 quizzes, accompanying each homework (due at the same time as the homework). The quizzes will be posted on the course website, and will be submitted alongside the homework.

**In general, late homework/quizzes will not be accepted.** In the case of a conference deadline or something of the like, you must give us at least **5 days notice** if

you are requesting an extension, and we can give you +2 or +3 days. In the case of an emergency (sudden sickness, family problems, etc.), no notice is needed, and we can give you a reasonable extension. But we emphasize that this is reserved for true emergencies. **For any extension request please email the Education Associate, Daniel Bird (dpbird@andrew.cmu.edu).**

The homeworks are structured to give you experience in both written mathematical exercises and programming exercises. As we will often reuse problems from previous versions of the course, or problems covered by papers and webpages, you **must not to copy, refer to, or look at** previous solutions in preparing your answers.

Also, while it is completely acceptable for you to collaborate with other students in order to solve the problems, we assume that you will be taking **full responsibility in terms of writing up your own solutions and implementing your own code**. You must indicate on each homework the students with whom you collaborated.

**Little test(s):** There will be one or two “little” test(s), taken during one (or two) of the lecture periods. It will consist of true/false and multiple choice questions.

**Evaluation:** The grading breakdown is as follows.

Homework	60%
Quizzes	20%
Little test(s)	20%

**Gradebook:** We will use Canvas for recording and keeping track of grades throughout the class.

## Accommodations for students with disabilities

If you have a disability and are registered with the Office of Disability Resources, please use their online system to notify us of your accommodations and discuss with us your needs as early in the semester as possible. We will work with you to ensure that accommodations are provided as appropriate. If you suspect that you may have a disability and would benefit from accommodations but are not yet registered with the Office of Disability Resources, consider contacting them at [access@andrew.cmu.edu](mailto:access@andrew.cmu.edu).

## Take care of yourself

Take care of yourself. Do your best to maintain a healthy lifestyle this semester by eating well, exercising, avoiding drugs and alcohol, getting enough sleep and taking some time to relax. This will help you achieve your goals and cope with stress.

All of us benefit from support during times of struggle. You are not alone. There are many helpful resources available on campus. Asking for support sooner rather than later is often helpful.

If you or anyone you know experiences any academic stress, difficult life events, or feelings like anxiety or depression, we strongly encourage you to seek support. Counseling and Psychological Services (CaPS) is here to help: call 412-268-2922 and visit their website at <http://www.cmu.edu/counseling/>. Consider reaching out to a friend, faculty or family member you trust for help getting connected to the support that can help.

If you or someone you know is feeling suicidal or in danger of self-harm, call someone immediately, day or night:

- CaPS: 412-268-2922
- Re:solve Crisis Network: 888-796-8226

If the situation is life threatening, call the police:

- On campus: CMU Police: 412-268-2323
- Off campus: 911

If you have questions about this or your coursework, please let us know.