Optimization Models in Engineering (Sp'21)

Course Title: Optimization Models in Engineering, Sp'21

Units: 4

Course Format: online, 3 hours of lecture, 1 hour discussion

Course Description

This course offers an *introduction to optimization* models and their applications, ranging from machine learning and statistics to decision-making and control, with emphasis on numerically tractable problems, such as linear or constrained least-squares optimization. The course covers two main topics: **practical linear algebra** and **convex optimization**.

You can find the outline **here**. The slides are in the Files section.

Course Objectives and Desired Outcomes

1. Develop a practical understanding of the applications and limitations of optimization as a solution approach to engineering analysis and design.
2. Develop an ability to use rapid prototyping software to guide optimization solutions.

Desired Course Outcomes: By the end of the term, students who have taken **Optimization Models in Engineering** are expected to be able to:

1. Understand the basic concepts of linear algebra: vectors, matrices, rank, projections; symmetric matrices, positive semidefinite matrices, eigenvalues; singular value decomposition and principal component analysis.
2. Learn about basic optimization models such as least-squares, linear programming, quadratic programming, and SOCP, and develop an understanding of the more general convex optimization.
3. Become aware of the wide-ranging applications where optimization models are useful, such as learning, control, finance and engineering design.
4. Be able to use prototyping software to develop optimization-based solutions in concrete applications.

Course Content

The course content will roughly follow the outline posted on the website, but is subject to change and evolve throughout the semester.

- Linear Algebra

1. Vectors, projections, matrices, symmetric matrices
2. Linear equations, least-squares and minimum-norm problems
3. SVD, PCA and related optimization problems

- Convex Optimization

1. Convex sets, convex functions, convex optimization problems
2. KKT optimality conditions, duality (weak and strong), Slater's condition.
3. Special convex models: LP, QP, GP, SOCP
4. Robustness

- Applications

1. Machine Learning
2. Control Systems
3. Engineering design
4. Finance

Recommended Textbook and Other Resources

1. **Optimization Models in Engineering (Giuseppe Calafiore and Laurent El Ghaoui) (http://livebooklabs.com/keeppies/c5a5868ce26b8125)**
2. **Webbook (https://inst.eecs.berkeley.edu/~ee127/sp21/livebook/)**

For background material, please consult

Introduction to Applied Linear Algebra, by S. Boyd and L. Vandenberghe

freely available at http://vmls-book.stanford.edu/

Zoom Links and Contact Information

Zoom links:

- Lecture: TTh 11-12:30pm, **https://berkeley.zoom.us/j/97768994466, (https://berkeley.zoom.us/j/97768994466)** passcode: **127-227A**
- Professor OH: W 10am, **https://berkeley.zoom.us/my/elghaoui (https://berkeley.zoom.us/my/elghaoui)**
- TA OH Mon. 12 pm: **https://berkeley.zoom.us/j/98405604274 (https://berkeley.zoom.us/j/98405604274)**
- TA OH Wed. 4 pm: **https://berkeley.zoom.us/j/94365075151 (https://berkeley.zoom.us/j/94365075151)**
- TA OH Fri. 4 pm (bi-weekly): https://berkeley.zoom.us/j/94002943277
  - 1/22, 2/5, 2/19, 3/5, 3/19, 4/9, 4/30
- Live Discussion / Discussion OH: **https://berkeley.zoom.us/j/94356056002 (https://berkeley.zoom.us/j/94356056002)**
  - Live discussion (lecture style): Monday 3 pm
  - All other discussion sections will be discussion OH. Please come prepared with questions related to discussion materials.

- Google Calendar **Link (https://calendar.google.com/calendar/u/1?cid=Y18zMTh1amszbGdpMzBlOGtkazk2NDl1MzdjY0Bncm91cC5jYWxlbmRhci5nb29nbGUuY29t)** (if you find helpful)
- Note that the OHs start from 1/22 onwards and Discussions start on week 2 (week of Jan. 25)

Instructor: Laurent El Ghaoui

Contact Information: (@berkeley.edu)

In case you want to email Professor El Ghaoui, please **always cc** the TA with most appropriate role(s) to your questions.

- [Instructor] Laurent El Ghaoui, elghaoui
- [HeadTA, Logistics] Tanmay Gautam, tgautam23
- [bCourses/DSP/Piazza/GradeScope] Fangda Gu, gfd18
- [Content: HW] Alicia Tsai, aliciatsai
- [Content: Exam] John Miller, miller_john
- [Content: Discussion] Ethan Guo, ethanguo
- [Reader] Jiachen Li, jiachen_li
- [Reader] Pranav Krishnamoorthi, pranav01krishna
- [Reader] Andrew Lin, linandrew
- [Reader] Ayush Kamat, akamat
- [Reader] Harshayu Girase, harshayugirase
- [Reader] Robin Chu, robinlilychu

Prerequisites: EECS 16A & EECS 16B OR Math 54, CS 70, Math 53

Online resources: **Piazza (https://piazza.com/class/kju357ef8ma5fd)**, **Gradescope (https://www.gradescope.com/)** (**P5WN4P**), and bcourses.

Discussions

There will be one discussion worksheet per week. TA Ethan Guo will work through this worksheet on Mondays at 3pm in a proper discussion section (i.e. delivered as a lecture). In case you cannot attend this section, it will be recorded and available to watch on demand. The remaining times originally intended to be proper discussions will be converted into "discussion office hours" (OH). This is an opportunity for students to ask TAs about any material covered in lectures. To make the best use of the discussion OH we encourage students to come prepared with questions. To summarize, each week a proper discussion lecture will be given covering the worksheet (Mondays at 3pm) and there will be seven "discussion OHs" to ask any questions.

Homeworks

There will be a total of 6 homeworks this semester. Homeworks will be released by the end of the day on Tuesdays according to the posted schedule. You will be responsible for submitting the homework before the start of class on the due date (again see posted schedule). Throughout this semester you can use one homework drop. This means that the homework portion of your grade will be computed based on **your best 5 homework scores**.

GSIs will try their best to monitor and answer homework questions on Piazza, but cannot guarantee that every question is answered. We encourage students to make full use of the dedicated OH to ask questions.

Homeworks submitted past their deadlines will be assigned a score of 0 with **no exceptions.**

For your actual homework write-ups, LaTeX is preferred, but not required -- we'll also accept **neatly handwritten** solutions. If you're really unsure about what "neatly" means you can make a private Piazza post, but we believe everyone has a pretty good sense of where the line is on legibility.

Exam Policies

You will have a midterm and a final exam, information on what they will cover will be released closer to the exam dates. There are also two in-class Quizzes, which will be ungraded.

Quiz 1: Thursday, February 18.

Quiz 2: Tuesday, April 13.

Midterm: Thursday, March 11, with two available times, see piazza for details.

Final Exam: Thursday, May 13th, with two available times, see piazza for details.

Grading

- Homeworks: 30% (6 homeworks total. The grade will be based on the top 5 homeworks, a dropped homework counts for 0 for this.)
- Max(Midterm, Final): 42%
- Min(Midterm, Final): 28%

DSP Accomodations

Fangda Gu (gfd18@berkeley.edu) is in charge of managing DSP accommodations. Please reach out to him by email if you need accommodations.

Course Communication

The instructor will post homeworks, discussions, homework solutions, discussion solutions, recordings of the lectures and other course-related documents on bCourses. An email broadcast will be sent out whenever something new is posted on bCourses by the instructor. Announcements are made through

bCourses. The TAs could also post announcements, clarifications, hints, etc. on **Piazza (https://piazza.com/class/ke7o7uwalvo19)** . You must check the EECS127/227A bCourses page and the EECS127/227AT Piazza page frequently throughout the term.

If you have a question, your best option is to post a message on Piazza. The staff will check Piazza regularly, and other students will be able to help you too. In cases you do not get an answer from Piazza, feel free to go to any of our office hours or send us emails for definitive answers. When using the Piazza forum, please avoid off-topic discussions, and please **do not post answers to homework questions before the homework is due**. Also, always look for a convenient category to post the question to (for example, each homework will have its own category, so please post there). That will ensure you get the answer faster.

If your question is personal or not of interest to other students, you may mark your question as private on Piazza, so only the instructors will see it. If you wish to talk with one of us individually, you are also welcome to come to our office hours. Please reserve email for the questions you can't get answered in office hours, in discussion sections, or through the forum.

It can be challenging for the instructors to gauge how smoothly the class is going. We always welcome any feedback on what we could be doing better. **If you would like to send any feedback, you can do so here (https://forms.gle/ArnBaNP8eMRNDoKM9)** .

Collaboration

We encourage you to work on homework problems in study groups of two to four people; however, you must **always** write up the solutions on your own. Similarly, you may use books or online resources to help solve homework problems, but you must always credit all such sources in your writeup, and you may never copy material verbatim. **Using previous homework and exam solutions is strictly prohibited, and will be considered academic dishonesty. This is not how you want to start your career as an engineer.**

We expect that most students can distinguish between helping other students and cheating. Explaining the meaning of a question, discussing a way of approaching a solution, or collaboratively exploring how to solve a problem within your group is an interaction that we encourage strongly. But you should write your homework solution strictly by yourself so that your hands and eyes can help you internalize the subject matter. You should acknowledge everyone whom you have worked with, or who has given you any significant ideas about the homework. This is good scholarly conduct.

Don't Be Afraid to Ask for Help

Are you struggling? Please come talk with us! The earlier we learn about your struggles, the more likely it is that we can help you. Waiting until right before an exam or the last few weeks of the semester to let us know about your problems is not an effective strategy - the later it is, the less we will be able to help you.

Even if you are convinced that you are the only person in the class who is struggling, please overcome any feelings of embarrassment or guilt, and come ask for help as soon as you need it – we can almost guarantee you're not the only person who feels this way. Don't hesitate to ask us for help – we really do care that you thrive!

Advice

The following tips are offered based on our experience.

Do the homework! The homework is explicitly designed to help you to learn the material as you go along. There is usually a strong correlation between homework scores and final grades in the class.

Keep up with lectures! Discussion sections and homework all touch on portions of what we discuss in lecture. **Students do much better if they stay on track with the course.** That will also help you keep the pace with your homework and study group.

Watch the discussion lectures! Discussion sections will help reinforce the material covered in lectures.

Come to office hours! We love to talk to you and do a deep dive to help you understand the material better.

Form study groups! As stated above, you are encouraged to form small groups (two to four people) to work together on homework and on understanding the class material on a regular basis. In addition to being fun, this can save you a lot of time by generating ideas quickly and preventing you from getting hung up on some point or other. Of course, it is your responsibility to ensure that you contribute actively to the group; passive listening will likely not help you much. Also recall the caveat above, that you must write up your solutions on your own. We strongly advise you to spend some time on your own thinking about each problem before you meet with your study partners; this way, you will be in a position to compare ideas with your partners, and it will get you in practice for the exams. **Make sure you work through all problems yourself**, and that your final write-up is your own. Some groups try to split up the problems ("you do Problem 1, I'll do Problem 2, then we'll swap notes"); not only is this a punishable violation of our collaboration policies, it also ensures you will learn a lot less from this course.

Course Summary:

Date	Details	Due