Note: Lectures begin 1/18/22, Discussion Sections and Office Hours begin on 1/21/22.

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**.

Special Notes for Spring 2022:

Course Delivery: We will follow campus guidelines on remote vs. in-person instruction (i.e., we resume in-person starting 1/31 as of the time of this writing). When public health conditions permit, the **default mode of instruction for this course is in-person only**. When we are in remote-mode, all lectures, discussions and office hours will be held over zoom. **Zoom links are available here (https://bcourses.berkeley.edu/courses/1511729/pages/zoom-links)** .

Health: If you have COVID symptoms, please do not attend in-person activities. Instead, keep up with the class by doing the suggested readings, watching the course capture, and reviewing supplementary material as available.

When attending in-person lectures, discussions, and office hours, students must adhere to the current campus directives/requirements related to COVID-19. Refusal to do so may result in the student being asked to leave.

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 below, but is subject to change and evolve throughout the semester. A tentative schedule can be found **here (https://docs.google.com/spreadsheets/d/1i4ZwcpiD5QG_0xamfyNWd7xnaVMD1kp2/edit?usp=sharing&ouid=117716470780508407306&rtpof=true&sd=true)** . (Note: you will need to be logged into your UC Berkeley account in order to access this.)

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

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

- 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) (https://www.cambridge.org/highereducation/books/optimization-models/B49D5B838649B04D8483A4CF85882003#overview)**
2. **Webbook (https://inst.eecs.berkeley.edu/~ee127/sp21/livebook/)**

Slides from the Fall 2021 offering of EECS 127/227AT are provided in the Files section of bCourses as a supplemental reference. The present course offering will follow the same general outline.

For background material, students are encouraged to consult

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

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

For further reading, students may wish to consult

Convex Optimization, by S. Boyd and L. Vandenberge

freely available at https://web.stanford.edu/~boyd/cvxbook/bv_cvxbook.pdf (https://web.stanford.edu/~boyd/cvxbook/bv_cvxbook.pdf)

Course Staff, Contact Information, and Office Hours

Instructor: Thomas Courtade, courtade@berkeley.edu. OH: Mon 10-11am, 265 Cory Hall (except Monday 1/24, which will shift one day to Tues 1/25.).

Student Instructors:

- [HeadTA, Logistics/DSP/GradeScope] Efe Aras, efearas96@berkeley.edu (mailto:efearas96@berkeley.edu) . OH: Weds 3-4pm, Cory 400.
- [Content: HW] Rodrigo Henriquez Auba, rhenriquez@berkeley.edu (mailto:rhenriquez@berkeley.edu) .
- [Content: HW] Andrew Lin, linandrew@berkeley.edu (mailto:linandrew@berkeley.edu) . OH: Mon 4-5pm, online.
- [Content: Discussion] Michael Jayasuriya, mjayasur@berkeley.edu (mailto:mjayasur@berkeley.edu) . OH: Fri 2-3pm, Cory 400.
- Sara Pohland, spohland@berkeley.edu (mailto:spohland@berkeley.edu) . OH: Weds 2-3pm, Cory 400.
- Albert Zhang, albertczhang@berkeley.edu (mailto:albertczhang@berkeley.edu) . OH: Fri 3-4pm, Cory 400.
- Andrew Zhang, zhand@berkeley.edu (mailto:zhand@berkeley.edu) . OH: Mon 3-4pm, Cory 400.

Readers:

- Sarthak Kamat, sartk@berkeley.edu (mailto:sartk@berkeley.edu)
- Aryan Jain, aryanjain@berkeley.edu (mailto:aryanjain@berkeley.edu)
- Jeffrey Wu, jeffrey.wu13579@berkeley.edu (mailto:jeffrey.wu13579@berkeley.edu)

Discussion Sections

The discussion sections will focus on applying course concepts to problem solving. You are expected to attend one discussion section per week. Our default policy is that you may attend any discussion section you want. However, if load-balancing becomes an issue, we may need to restrict attendance.

Homework

- Homework will be assigned (roughly) weekly, and will be due each Wednesday at 11:59 PM.
- Homework should be submitted as a PDF to Gradescope (enrollment code: YV68WG).
- Any homework that is illegible or too difficult to read will get a 0. (LaTeX typesetting is preferred, but not required.)
- Homework will be self-graded through a link given to you on a pinned Piazza post. The self-grade assignments will open every Thursday morning and are due the following Monday at 11:59 PM.
- You will be allowed to turn in self-grades up to a week late, for 75% credit.
- Your lowest homework score will be dropped automatically.
- You will have the opportunity to earn an extra homework drop by responding to the mid-semester survey.
- Your homework grades are given by 1.25 x min(your self grade, .8), i.e. the max score is 80% so that a few minor mistakes are not disproportionately penalized.

Except when required by DSP accommodations, **no HW extensions will be granted** (the drop policy exists so that we don't have to grant exceptions on a case-by-case basis). If you have a DSP letter, you should coordinate with Efe Aras (who will coordinate with the instructor) so that we can arrange for a suitable accommodation.

Homework Self-Grade Policy

We will periodically be checking self-grades internally to ensure that they are accurate. If we find that your self-grades do not align with our scores (either positively or negatively), we will reach out to you and adjust your self-grades. If you do not hear from us, your self-grades will be used for your homework grade. Please remember the Academic Dishonesty policy and the Berkeley honor code and make a good-faith effort to report your self-grades accurately.

Each problem is worth 20 points:

- 20: fully correct
- 15: minor mistakes or missed small detail
- 10: right direction, about halfway progress, missed some details
- 5: wrong or no clear direction, major details missed
- 0: didn’t attempt, very incorrect

For problems with subparts, we will specify the breakdown; apply the rubric similarly to each subpart.

Exam Policies

You will have a midterm and a final exam. There are no alternate exams*.

Midterm: 3/15/2022, 2:00-3:30pm (in-class).

Final Exam: 5/9/2022, 11:30am-2:30pm.

(*Given the unique circumstances of the semester, if you find yourself in a situation that presents a serious hardship, you may contact course staff to determine whether an accommodation is warranted. **In situations that will foreseeably result in a need for accommodation, requests must be made no later than Friday Feb. 11** using **this form (https://forms.gle/tyaUCcTPBjvDj9167)** .)

Grading

Your course grade breakdown as follows:

- Homework: 30%. Your lowest HW score will be dropped automatically. You will have the opportunity to earn another HW drop by filling out a mid-semester survey. More information on HW grading can be found in the "Homework" section.
- Final: 40%
- Midterm: 30%

Midterm clobber policy: We want to reward mastery of material at the end of the course, despite a misstep along the way. If your final exam z-score exceeds that of your midterm, we will *partially* clobber your midterm score by replacing the midterm z-score with the average of the midterm and final z-scores.

DSP Accommodations

Efe Aras (**efearas96@berkeley.edu (mailto:efearas96@berkeley.edu)**) will be the contact person for DSP accommodations. Please reach out to him by email if you need accommodations. By law, we are only allowed to provide those accommodations listed on your DSP letter. Letters should be received in a timely fashion to ensure proper accommodations can be arranged.

Course Communication

Course staff will post homeworks, discussions, homework solutions, discussion solutions, and other course-related documents on bCourses. Announcements are made through bCourses. Homework clarifications, hints, etc. will generally be posted on Piazza. 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. When using Piazza, please avoid off-topic discussions, and please **do not post answers to homework questions before the homework is due**. Course staff will try their best to answer questions on Piazza, but keep in mind that course staff have finite bandwidth themselves. In case you do not get an answer from Piazza, please avail yourself of office hours.

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.

We will have a mid-semester survey to gauge how smoothly the class is going and what we can do to improve. If you'd like to provide other feedback or suggestions for improvement, you can email Prof. Courtade. More generally, if you'd like to share your experiences and any suggestions for improving the EECS Department climate, you may do so via the **EECS Student Incident Reporting Form (https://docs.google.com/forms/d/e/1FAIpQLSc4NYHdUJ8IzYA1SoiTinWBybGWkj0mfmdnHAeygAxkZajelQ/viewform)**. See also the section on Inclusion, below.

Piazza

The official online forum for this course will be Piazza. On or around January 18, 2022, all students will be enrolled in Piazza by course staff using the email addresses provided in the official course roster. If you are enrolled in this course and have not been added by the time lectures have begun, please contact Efe Aras.

Expectations regarding conduct on Piazza: It shouldn't have to be said, but please keep your posts constructive, respectful, and course-related. We want Piazza to be a resource that promotes a positive and inclusive culture for learning and collaboration. Trolling, rants, or other abusive behavior that does not contribute to this goal won't be tolerated, and may result in revocation of your Piazza privileges. In short, keep it professional.

Collaboration

You are encouraged to discuss homework and lab assignments with your classmates. However, you must always write up the solutions on your own, and you must never copy the solutions of other students. Similarly, you may use books or online resources to help solve homework problems, but you must credit all such sources in your writeup and you must never copy material verbatim. You are reminded of the Department's **Policy on Academic Dishonesty (https://eecs.berkeley.edu/resources/students/academic-dishonesty)**. In particular, you should be aware that copying solutions, in whole or in part, from other students in the class or any other source without acknowledgment constitutes a violation of this policy and risks serious consequences.

Policy on Course Content

The University's Policy on **Classroom Note-Taking and Recording (https://sa.berkeley.edu/classroom-note-taking-and-recording-policy)** applies to this course. You are free and encouraged to use course materials for personal use (in collaborations with other students, in your research, etc.). You are also granted permission to post any notes you create on your own personal website. You are expressly prohibited from publicly uploading course materials created by teaching staff (exams, HW, solutions, videos, etc.). In particular, any upload of course content to websites such as CourseHero.com, Chegg.com, Youtube, etc., which distribute and monetize content

without permission from the instructor or University will be considered a violation of University Policy, and referred to the **Center for Student Conduct (https://sa.berkeley.edu/conduct)** .

Inclusion

We are committed to creating an environment welcoming of all students where everyone can fulfill their potential for learning. To do so, we intend to support a diversity of perspectives and experiences and respect each others' identities and backgrounds (including race/ethnicity, nationality, gender identity, socioeconomic class, sexual orientation, language, religion, ability, etc.). To help accomplish this:

- If you feel like your performance in the class is being impacted by a lack of inclusion, please contact the instructors, an academic advisor, or the departmental **Faculty Equity Advisor (https://engineering.berkeley.edu/about/equity-and-inclusion/faculty-equity-advisers/)** . An anonymous feedback form is also available **here (https://engineering.berkeley.edu/about/equity-and-inclusion/feedback/)** .
- If you feel like your performance in the class is being impacted by your experiences outside of class (e.g., family matters, current events), please don't hesitate to come and talk with the instructor(s) or academic advisors in Engineering Student Services. We want to be a resource for you.
- There is no tolerance for sexual harassment or violence. If your behavior harms another person in this class, you may be removed from the class or the University either temporarily or permanently.
- If you have a name and/or pronouns that differ from your legal name, designate a preferred name for use in the classroom **here (https://registrar.berkeley.edu/academic-records/your-name-records-rosters)** .
- As a participant in this class, recognize that you can be proactive about making other students feel included and respected.
- Remember the **Berkeley honor code**, which everyone is expected to adhere to: "*As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others.*"

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.

Attend lectures! Go to discussion section! Do the homework! Discussion sections and homework are designed to reinforce the important concepts introduced in lecture. Each of these course components serves an important role in the learning process, and ignoring any one piece can undermine the foundation on which your understanding will be built.

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! 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 violation of our collaboration policies, it also ensures you will learn a lot less from this course.

Other Resources

For academic performance: The **Center for Access to Engineering Excellence or CAEE (https://engineering.berkeley.edu/student-services/academic-support)** (227 Bechtel Engineering Center) is an inclusive center that offers study spaces, nutritious snacks, and tutoring in courses for Berkeley engineers and other majors across campus. The Center also offers a wide range of professional development, leadership, and wellness programs, and loans iclickers, laptops, and professional attire for interviews.

For disability accommodations: The **Disabled Student's Program (http://dsp.berkeley.edu)** (DSP 260 César Chávez Student Center #4250; 510-642-0518) serves students with disabilities of all kinds, including temporary disabilities. Services are individually designed and based on the specific needs of each student as identified by DSP's Specialists. If you have already been approved for accommodations through DSP, please know that DSP is ready to quickly adjust your accommodations if your situation changes.

For mental wellbeing: **Counseling and Psychological Services (https://uhs.berkeley.edu/caps)** (CAPS) is available as part of University Health Services (the Tang Center). Services are offered at many locations, including on-site in the **College of Engineering (https://engineering.berkeley.edu/students/advising-counseling/counseling/)**. CAPS services are available to all students, regardless of insurance, and initial visits do not cost anything. CAPS has

expanded allowing students to receive help immediately with same-day counseling (510-642-9494), online resources, and a 24/7 counseling line at (855) 817-5667. Short-term help is also available from the Alameda County Crisis hotline: 800-309-2131. If you, or someone you know, is experiencing an emergency that puts their health at risk, please call 911.

For recovery from sexual harassment or sexual assault: The **Care Line or the PATH to Care Center (https://care.berkeley.edu/care-line/)** (510-643-2005) is a 24/7, confidential, free, campus-based resource for urgent support around sexual assault, sexual harassment, interpersonal violence, stalking, and invasion of sexual privacy. The Care Line will connect you with a confidential advocate for trauma-informed crisis support including time-sensitive information, securing urgent safety resources, and accompaniment to medical care or reporting.

For solving a dispute: The **Ombudsperson for Students (http://students.berkeley.edu/Ombuds)** (102 Sproul Hall; 642-5754) provides a confidential service for students in need of a neutral party to resolve University-related disputes (academic or administrative). The Ombudsman can provide information on policies and procedures affecting students, facilitate students' contact with services able to assist in resolving the problem, and assist students in complaints concerning improper application of University policies or procedures. All matters referred to this office are held in strict confidence.

For basic needs (food, shelter, etc): The **Basic Needs Center (https://basicneeds.berkeley.edu/)** provides housing, food, transportation support, among other support needed to thrive at UC Berkeley. Specifically, the **UC Berkeley Food Pantry (https://pantry.berkeley.edu)** (#68 Martin Luther King Student Union) aims to reduce food insecurity among students, especially the lack of nutritious food. Students can visit the pantry as many times as they need and take as much as they need while being mindful that it is a shared resource. The pantry operates on a self-assessed need basis; there are no eligibility requirements. The pantry is not for students and staff who need supplemental snacking food, but rather, core food support.