University of California, Berkeley
Department of Electrical Engineering and Computer Sciences

EECS 127: Optimization Models in Engineering

Course Number: EECS 127
Course Title: Optimization Models in Engineering
Units: 4
Course Format: 3 hours of lecture, 1 hour discussion
Instructors: Alex Bayen
Contact Information: eecs127227f19@gmail.com, bayen@berkeley.edu
Prerequisites: EE 16A, EE 16B, CS 70, Math 53
Grading: Letter
Online resources: Piazza, bCourses, Gradescope (**MZYNXZ**), and course website

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. (4 Units.)

Course Objectives

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 Outcome:

By the end of the term, students having 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. Understand four basic optimization models: least-squares, linear, quadratic and second-order cone programming, and have a general understanding of the more general convex optimization.
3. Be aware of the wide-ranging applications where optimization models are useful, including in machine learning applications.

4. Be able to use prototyping software such as CVX to develop optimization-based solutions in concrete applications.

Content

The course will cover the following material. The course calendar below follows the book closely. The content will roughly be organized in lectures with the following topics:

1. Vectors
2. Matrices
3. Eigenvalue and singular value decomposition
4. Linear equations
5. Least squares
6. Convexity
7. Gradient descent
8. Linear programming
9. Quadratic programming
10. Second order cone programming
11. Robust optimization
12. Duality
13. Optimality conditions
14. Applications: learning
15. Applications: control

Some application topics might be added mid-semester. It is strongly recommended that the students use the book *Optimization Models*, G.C. Calafiore and L. El Ghaoui, Cambridge University Press, October 2014.

Discussion

Discussion sections will take place every week. Students are strongly encouraged to attend and ask questions. Discussions will begin on **Friday August 30th, 2019**. Discussion frequency and policy is as follows:

- Current discussion sections are (tentative):
- **Wednesday 11:00am - 12:00pm**, Le Conte 3, TA: Oladapo Afolabi
- **Wednesday 12:00pm - 1:00pm**, Cory 247, TA: Oladapo Afolabi
- **Wednesday 1:00pm - 2:00pm**, Cory 521, TA: Suvansh Sanjeev
- **Wednesday 2:00pm - 3:00pm**, Evans 60, TA: Suvansh Sanjeev
- **Friday 1:00pm - 2:00pm**, Haviland 12, TA: Elena Jia
- **Friday 2:00pm - 3:00pm**, Haviland 12, TA: Elena Jia
- **Friday 3:00pm - 4:00pm**, Dwinelle 88, TA: Oladapo Afolabi
- **Friday 4:00pm - 5:00pm**, Dwinelle 219, TA: Oladapo Afolabi

Discussion material will be released on Thursdays.

Solutions to the discussion material will be released on Friday after the last discussion of the week.

Homework / Exams

Homework will be assigned every Thursday on bCourses and will be due the following Thursday at 11:00pm. Homework will be electronically submitted to Gradescope (**entry code: MZYNXZ**) as follows:

1. A single PDF consisting of the following components:
    a. Scanned handwritten work or a LaTeX file containing answers to non IPython questions
    b. A PDF of all iPython notebooks
2. All IPython notebooks in .ipynb format

You will need to select the pages associated with each question through Gradescope. Late homework will not be accepted, but to account for the vicissitudes of life, we will drop the 2 lowest homework scores from the final grade calculation.

Discussion and collaboration, as opposed to copying, of homework is encouraged. In other words, you are encouraged to discuss the homework with your classmates but you must write your own derivations and do your own calculations, etc. Do not hesitate to ask the professor or the GSIs for clarifications and hints for the homework problems during Homework Parties and Office hours. We encourage cooperation rather than competition.

Homework Grading

Every homework questions will be graded by the teaching staff.

Exam Policies

The 127 Fall 2019 semester will have two midterms and one final. The midterm times will be during class hours and date will be communicated in class. Current schedule (below) is TENTATIVE. The final will be held during the designated final exam slot released by campus. Makeup exams will not be scheduled.

Please plan for exams at these times and **email the Head GSI at** eecs127227f19@gmail.com **during the first two weeks of the semester per university policy if you know about any exam conflicts.** If an emergency arises that conflicts with the exam times, email the Head GSI as soon as possible. Emergency exam conflicts will be handled on a case-by-case basis. We do not provide specific accommodations for conflict with other classes, conflict with personal activities, even planned in advanced, extracurricular or not. We try to accommodate situations of personal hardship to the best of our abilities.

Course Evaluation

The course grade will be based on the following evaluation:

- Homework (30%)
- Midterm 1 (20%)
- Midterm 2 (20%)
- Final (30%)

This policy rewards consistency and regular work, as well as final knowledge acquisition.

Redemption policy: Exams cover all material until the exam. Grade of midterm 1 (resp. 2) will be replaced with grade of final if grade of final is higher than grade of midterm 1 (resp. 2):

- grade midterm 1 = max(grade midterm 1, grade final)
- grade midterm 2 = max(grade midterm 2, grade final)

Schedule

The following schedule is TENTATIVE. It might be modified throughout the semester. Reading are provided in the table for the convenience of the students, however it is strongly recommended to read the entire book throughout the chapter.

Week	Lecture #	Date	Lecture	Suggested reading (book)	Suggested reading (livebook)	Hw given	Hw due	Discussion	Discussion solution released
1	1	8/29/19	Introduction	Ch. 1	Sec. 1			1	
	2	9/3/19	Quiz, introduction to convex optimization						
2	3	9/5/19	Vectors and functions	Ch. 2	Sec. 2.1	HW1		2	1
	4	9/10/19	Vector calculus	Ch. 2	Sec. 2.1				
3	5	9/12/19	Matrices and linear maps	Ch 3, except sec. 3.3, 3.4.9, 3.7	Sec. 2.2, except 2.5	HW2	HW1	3	2
	6	9/17/19	Symmetric matrices and their eigenvalues	Ch. 4	Sec. 2.5				
4	7	9/19/19	Singular value decomposition	Ch. 5	Sec. 2.6	HW3	HW2	4	3
	8	9/24/19	Linear equations	Ch. 6, except 6.5	Sec. 2.3				
5	9	9/26/19	Least-squares and variants	Ch. 6, except 6.5	Sec. 2.4	HW4	HW3	5	4
	10	10/1/19	More least-squares						
6		10/3/19	MIDTERM			HW5	HW4	6	5
	11	10/8/19	Convexity	Ch. 8, sections 8.1, 8.2	Sec. 3.1.1 - 3.1.2				
7	12	10/10/19	Convex optimization problems	Ch. 8, sections 8.3, 8.4	Sec. 3.1.3	HW6	HW5	7	6
	13	10/15/19	Gradient descent	Ch. 12	Sec. 3.1.4				
8	14	10/17/19	Linear Optimization	Ch. 9, sec. 9.3	Sec. 3.2	HW7	HW6	8	7
	16	10/22/19	Quadratic optimization	Ch. 9, all sections except 9.7	Sec. 3.2				
9	17	10/24/19	Second-order cone optimization	Ch. 10, section 10.1, 10.2	Sec. 3.3	HW8	HW7	9	8
	18	10/29/19	Robust optimization	Ch. 10, section 10.3	Sec. 3.4				
10	19	10/31/19	Gradient descent			HW9	HW8	10	9
		11/5/19	MIDTERM						
11	20	11/7/19	Weak duality	Ch. 8, section 8.5	Sec. 3.1.5	HW10	HW9	11	10
	21	11/12/19	Strong duality	Ch. 8, section 8.5	Sec. 3.1.5				
12	22	11/14/19	Optimality conditions	Ch. 10, section 10.1 to 10.3	Sec. 3.3, 3.4	HW11	HW10	12	11
	23	11/19/19	Machine learning applications	Ch. 13	Sec. 3.2.5, 3.4.4				
13	24	11/21/19	Machine learning applications	Ch. 13	Sec. 3.2.5, 3.4.4	HW12	HW11	13	12
	25	11/26/19	Control applications, LQR	Ch. 15	Sec. 5.5				
14		11/28/19	Thanksgiving						
	26	12/3/19	More LQR						
15	27	12/5/19	Review				HW12	14	13
		12/10/19	Deadweek						
16		12/12/19	Deadweek						14
17		12/18/19	FINAL						

Please also see our link to Google calendar

Office Hours

Mondays:

- Elena Jia (3-4pm, Cory 400)

Tuesdays:

- Alex Bayen (12:30-1:30pm, Cory 258)
- Suvansh Sanjeev (1-2pm, Cory 212)

Wednesdays:

- Theophile Cabannes (10-11am, Cory 212)

Thursdays:

- Alex Bayen (12:30-1:30pm, Cory 258)
- Suvansh Sanjeev (1-2pm, Soda 320)
- Sukrit Arora (1-2pm, Soda 320)

Homework Party

Monday nights either 8-10pm or 9-11pm in Cory or Soda (precise time and location will be posted each week and can be found on the course calendar)

Practice problems

We will be providing weekly practice problems this semester on Gradescope (**entry code: 9GV43V**) that are intended to provide basic practice with the mechanics of the machinery we develop in this course.

These problems are ungraded, but we encourage everyone to take a look at them, as they provide checkpoints through which students can gauge their progress and understanding, and develop questions to bring to office hours.

Each week, the practice problems will be released on Thursday after the lecture and due the next Tuesday evening. While working on the problems on Gradescope, if the student selects the correct answer, an explanation of the problem will be shown. After the due date, students should be able to see the answers on Gradescope.

Policies

Disabled Students' Program (DSP): We are happy to accommodate students with special needs as determined by the DSP office. Please contact the Head GSI in the first two weeks of class to request appropriate accommodations. Please share your accommodation letter with the Head GSI in this email.

Course Materials

STRONGLY RECOMMENDED:

1. Calafiore, Giuseppe and El Ghaoui, Laurent. *Optimization Models*.

The following material might be of great interest.

2. Boyd, Stephen, and Lieven Vandenberghe. *Convex optimization*. Cambridge university press, 2004.
3. Livebook:http://livebooklabs.com/keeppies/c5a5868ce26b8125 (you can register on thelivebook platform for free)

Course Communication

The instructors and TAs will post announcements, clarifications, hints, etc. on Piazza. You must check the EE127 Piazza page frequently throughout the term. (You should already have access to the EE127 Spring 2019 forum. If you do not, please let us know.)

If you have a question, your best option is to post a message there. The staff will check the forum regularly, and other students will be able to help you too. When using the 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 send email to:** eecs127227f19@gmail.com

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, labs 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.

Take part to discussion sections! Discussion sections are not auxiliary lectures. They are an opportunity for interactive learning. The success of a discussion section depends largely on the willingness of students to participate actively in it. As with office hours, the better prepared you are for the discussion, the more you are likely to benefit from it.

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.