EE578 - Convex Optimization

Convex optimization theory is the cornerstone of modern optimization theory and at the heart of many machine learning, AI, data science, and control theory techniques.

Contact Info

Instructor: Dan Calderone
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Prerequisites

- Solid background in linear algebra
- Experience in Matlab or Python

Lecture

Date & Time: TBA
Location: TBA
Zoom link: TBA

Materials

CVX RESOURCES: Python: https://www.cvxpy.org/examples/basic Matlab: http://cvxr.com/cvx/

Notes/Slides

Collected materials can be accessed here.
Teaching website: https://danjcalderone.github.io/teaching.html

Textbooks

Main text: *Convex Optimization* by Boyd Vandenberghe (required - free online)
Advanced Text: *Convex Analysis* by Rockafellar (not required)

Other Resources

The Matrix Cookbook (matrix formula reference)

Video Resources

*some of these videos are the best references on the subject
3blue1brown: https://www.3blue1brown.com/

Graphing Tools

- https://www.geogebra.org/graphing

Course Schedule

PART 1: Review - Linear Algebra and Calculus (unconstrained optimization)

- Lecture 1 (01/07): Linear Algebra Review Part 1
- Lecture 2 (01/14): Linear Algebra Review Part 2 - Equality constraints, affine spaces
- Lecture 3 (01/21): Linear Algebra and Calculus Review Part 3 - Lagrange multipliers, equality constrained optimization
- Lecture 4 (01/28): Inequality constraints, Lagrangians, KKT conditions, introduction to duality.
- Lecture 5 (02/04): Duality, strong duality and convexity, computing duals, introduction to CVX (coding)

PART 2: Network Flow Problems

- Lecture 6 (02/11) -
  - Primal Problem - "Routing flow along shortest path"
    - Intuition: Mass conservation of flow variables
    - Convex Principles: Stationarity, feasibility, and complementary slackness
  - Dual Problem - "Computing minimum travel time."
    - Intuition: Dynamic programming for optimal travel times.
    - Convex Principles: Convex duality, Lagrangians, Fenchel-duality

PART 3: Markov Decision Processes - Stochastic Flow Problems

- Lecture 7 (02/18):
  - Primal Problem "Finding a maximum reward policy."
    - Intuition: Stationary policies of stochastic flow problems,
    - Convex Principles: Stochastic dynamics, transition kernels, finite and infinite horizon
  - Dual Problem "Computing optimal reward value."
    - Intuition: Value-iteration and optimal reward-to-go
    - Convex Principles: Bellman equation, duality

PART 4: Algorithms & Examples

- Lecture 8 (02/25)
  - Simplex Method
  - Projected gradient descent
  - Saddle point methods
  - Interior Point methods
  - Q-learning
- Lecture 9 (03/3) : Survey of Other Convex Programs Overview
  - Clustering/classification
  - Support vector machines

- Optimal control
  - Online convex optimization: Multi-armed bandit problems
  - Convex Relaxations
  - Semi-definite programming (SDPs)
  - Stochastic Gradient Descent
- Lecture 10 (03/10) : Optional Topics

Grades

- **Homework:** 60%
- **Midterm:** 20%
- **Final:** 20%

Homeworks

General Policy

Homeworks will be assigned each week after class and due 10 days later. Self-grades/error explanations for the previous week's homework will be due at the same time. Your writeup must be submitted as a single self-contained `.pdf` document, including commented source code for any computational tools used to complete the assignment. Every student can turn in one homework late for full credit with no questions asked. Other extensions can be given for exceptional circumstances but must be requested well in advance (teacher discretion) of the deadline. Homeworks will be worth 80% of your grade. Solutions will be provided after each assignment is due.

Self-assessment/Rubric

Each homeworks will divided into sub-problems worth 2 points each. To provide training and feedback that helps cultivate self-reflection, you will grade your homework assignments and receive oversight and feedback from the instructional staff regarding the accuracy of your self-assessment. Self-assessment will be due with the next assignment. We will provide detailed solutions on the day of the homework submission deadline, and you will have until the following due date to grade each of your homework sub-problems on a 0,1,2 point scale:

- **0 points:** - no effort / not attempted
- **1 points:** - attempted, but incomplete or incorrect solution
- **2 points:** - complete and correct solution

For any sub-problem that earns a 1, you have the opportunity to explain the error in your solution and how to correct it; if this explanation is correct, you earn the full 2 points on the problem. You do not give yourself the 2 points if you got an incorrect problem and corrected it. The grader will assign you the extra point after going through your homework. To specify grades and provide explanations of any errors, use the Comment feature in Canvas's Assignment page for the homework.

Notes and caveats intended to ensure the integrity of this process:

- if you did not attempt the problem initially, you will receive 0 points;
- if you do not grade a problem, you will receive 0 points;

- if you grade incorrectly (i.e. initial solution is incomplete or incorrect and your explanation is incomplete or incorrect), you will receive 1 or 0 at the discretion of the instructional staff (this ensures you cannot simply assign all ”2”s, nor can you receive full credit for incomplete or incorrect explanations).

Frequently Asked Questions (FAQ)

Q: Should I download my.pdf, add comments (e.g. via Adobe Acrobat), and re-upload the .pdf?
A: That's fine, but it's probably easier to use the in-browser ”CrocoDoc” viewing and annotation pane provided in Canvas.

Q: Does my .pdf need to contain all of my homework writeup materials, or can some be in an .m file?
A: Your writeup must be submitted as a single self-contained .pdf document, including commented source-code for any computational tools used to complete the assignment.

Submission guidelines

Please make homeworks neat and organized. Points may be deducted if not. You are welcome (and we encourage you) to typeset your homework assignments rather than write them by hand. We will provide both .pdf and .m files for homework assignments and solutions. If you write your solutions by hand, you must create a legible scan; if you have any doubts about the fidelity of your scans, send a sample to the TA / Prof in advance of the homework deadline.

Exams

There will be take-home midterm and final exam worth 20% of your grade each. The exam will be open-book/open notes/open internet. You will not be allowed to collaborate with anyone on the exams. Exams will be graded by the professors (rather than being self-graded).

Final Project

The final project will involve applying the techniques learned in class to a practical modeling problem of your choice. More details will be posted later in the quarter.

1 Coding Resources

Coding can be done in Matlab or Python.

- Control Tutorials for MATLAB and Simulink: http://ctms.engin.umich.edu/CTMS/index.php?aux=Home
- Python: https://colab.research.google.com/