CSE203B Convex Optimization

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Outlines

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Staff

- Instructor
  - CK Cheng, ckcheng+203B@ucsd.edu
- TAs, Office hours: TBA (Piazza)
  - Guo, Enming, enguo@ucsd.edu
  - Sahu, Kunind, kusahu@ucsd.edu
  - Wu, Po-Chun, pow001@ucsd.edu

Information about the Instructor

- Instructor: CK Cheng
- Education: Ph.D. in EECS UC Berkeley
- Industrial Experiences: Engineer of AMD, Mentor Graphics, Bellcore; Consultant for technology companies
- Research: Electronic Design Automation: VLSI Layout (Moore's Law Extension), Simulation, Graph-Based Machine Learning (Small World Effect, Classification)
- Email: ckcheng+203B@ucsd.edu, Office: Room CSE2130
- Office hours will be posted on Piazza
- Websites
  - http://cseweb.ucsd.edu/~kuan
  - http://cseweb.ucsd.edu/classes/wi25/cse203B-a

Logistics: Class Schedule and Links

Class Lectures: 11:00-12:20 PM TTH, Peter 108

Discussion Sessions: 8:00-8:50 AM W, WLH 2001

Class Links

- Class website: Slides and announcements
  http://cseweb.ucsd.edu/classes/wi25/cse203B-a
- Canvas: Roster
- Piazza: Q&A platform
  https://piazza.com/ucsd/winter2025/cse203b_wi25_a00/home
- Gradescope: Submissions of HWs, Exam, Project outlines, Project reports
- UCSD Podcast: Video records of lectures and discussion sessions

Logistics: Textbooks

Required textbook: (reading and part of HW assignment)

- Convex Optimization, Stephen Boyd and Lieven Vandenberghe, Cambridge, 2004 Review appendix A in the first week

References

- Numerical Recipes: The Art of Scientific Computing, Third Edition, W.H. Press, S.A. Teukolsky, W.T. Vetterling, and B.P. Flannery, Cambridge University Press, 2007.
- Matrix Computations, 4th Edition, G.H. Golub and C.F. Van Loan, Johns Hopkins, 2013.
- High-Dimensional Data Analysis with Low-Dimensional Models, J. Wright and Y. Ma, Cambridge, 2022.
- Websites of CSE203 from previous years

  https://cseweb.ucsd.edu/~kuan/

Logistics: Tasks

Homework (Exercises and Assignments)

- Discussion is permitted (only for this class)
- Exercises: Submit as a group (<= 4 members)
- Assignments: Write the solution individually

Midterm Exam

- Open book and internet search is allowed but no help from anyone

Project

- A team of 4 or less members but no more than 4
- Teamwork is encouraged because of the scope and timeframe of the project
- Use piazza to search for team members

Logistics: Grading/Expectation

- Level 1: Definitions and proofs (slides, taking notes in classes)
- Level 2: Examples and applications (hws)
- Level 3: New formulations and usage (exam, project)
- Level 4: Open problems (HWs, project, exam)

Logistics: Grading

Homework (50%)

- Exercises from the textbook (Grade by completion)
- Assignments (Grade by content)

Midterm Exam (25%)

- Take-home exam 48 hours
- Midterm,10AM, Sun 2/23/2025 - 10AM, Tuesday 2/25/2025, (W7-8)

Project (25%)

- Theory or applications of convex optimization
- Survey of the state of the art approaches
- Outlines and references (Due 1/31/2025, W4)
- Report (Due 2:30 PM Thursday 3/20/2025, W11)

Scope of Convex Optimization

For a convex problem, a local optimal solution is also a global optimum solution.

Scope: Brief history of convex optimization

Theory (convex analysis): 1900–1970

Algorithms

- 1947: a simplex algorithm for linear programming (Dantzig)
- 1970s: ellipsoid method and other subgradient methods
- 1980s & 90s: polynomial-time interior-point methods for convex optimization (Karmarkar 1984, Nesterov & Nemirovski 1994)
- 2000+: many methods for large-scale convex optimization

Applications

- before 1990: mostly in operations research, a few in engineering
- 1990+: many applications in engineering (control, signal processing, communications, circuit design, . . .)
- 2000+: machine learning and statistics

Ref: Boyd

Scope: Optimization Classification

Tradition

Linear Programming	Nonlinear Programming	Discrete Integer Programming
Simplex	Lagrange multiplier	Trial and error
Primal/Dual	Gradient descent	Cutting plane
Interior point method	Newton's iteration	Relaxation

This class emphasizes convex and continuous problems.

Convex Optimization	Discrete Problems
Primal/Dual, Lagrange multiplier	Local Optimal Solution Search, SA (Simulated Annealing), ILP (Integer Linear Programming), MLP (Mixed Integer Programming), SAT (Satisfiability), SMT (Satisfiability Modulo Theories), etc.
Gradient descent	
Newton's iteration	
Interior point method	

Scope: Convex vs. Nonconvex Continuous Optimization Problems

Scope: Coverage

1. Problem Statement (Key word: **convexity**)
- Convex Sets (Ch2)
- Convex Functions (Ch3)
- Formulations (Ch4)

2. Tools (Key word: **transform mechanism**)
- Duality (Ch5)
- Optimal Conditions (Ch5)

3. Applications (Ch6,7,8) (Key words: complexity, optimality)

   Coverage depends upon class schedule

4. Algorithms (Key words: **Taylor's expansion**)
- Unconstrained (Ch9)
- Equality constraints (Ch10)
- Interior method (Ch11)

Scope: Coverage

CSE203B Convex Optimization

- Optimization of a convex function with constraints that form convex domains.

Background

- Linear algebra
- Polynomial and fractional expressions
- Log and exponential functions
- Optimality of continuously differentiable functions

Concepts and Techniques to Master in CSE203B

- Convexity
- Hyperplane
- Duality
- KKT optimality conditions
- Gradient Descent
- Newton's Method