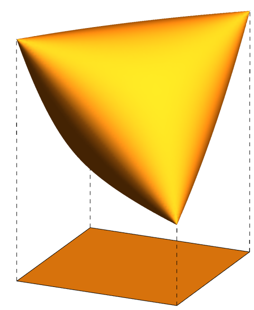
Semidefinite and Sum-of-squares Optimization (Fall 2026)



When: Tuesdays & Thursdays 12:30 PM - 01:50 PM
Where: Jacobs Hall (EBU1) Room 2315
Instructor: Yang Zheng (zhengy@ucsd.edu)
Course website: https://zhengy09.github.io/ECE285/ece285.html
Who: Graduate students (all disciplines) with an interest in convex, semidefinite, and polynomial optimization.

Course description

Convex optimization has profound impacts on many problems in control theory, discrete and nonlinear optimization, theoretical computer science, and machine learning. It is a fundamental tool to ensure efficient, resilient, and safe operations of many engineering systems, such as smart power grids, transportation, robotics, and many others. Optimization in these areas often takes the form of conic optimization, especially semidefinite programs. This course will cover semidefinite optimization, which is a far-reaching generalization of linear programs. Another emphasis of the course will be on sum-of-squares optimization that deals with optimization problems involving polynomials. Some classical applications in control and recent ones in machine learning will be covered too.

A tentative list of topics that we will cover includes

- From linear programming to conic programming; Duality theory.
- Semidefinite optimization and convex relaxations.
- Sum-of-squares and moment problems.
- Applications in control, dynamical systems, and machine learning.

Prerequisites This course assumes basic knowledge in linear algebra. Some knowledge of convex optimization will be useful. Mathematical maturity and familiarity with MATLAB, Python, or similar software.

References

1. Blekherman, G., Parrilo, P. A., & Thomas, R. R. (Eds.). (2012). Semidefinite optimization and convex algebraic geometry. Society for Industrial and Applied Mathematics.

2. Boyd, S., & Vandenberghe, L. (2004). Convex optimization. Cambridge University Press.

3. Lasserre, J. B. (2009). Moments, positive polynomials and their applications. World Scientific.

4. Laurent, M. & Vallentin, F. (2016) Semidefinite optimization, Lecture notes

5. Ben-Tal, A., & Nemirovski, A. (2001). Lectures on modern convex optimization: analysis, algorithms, and engineering applications. Society for industrial and applied mathematics.

Tentative Schedule

Week 1	L1: Introduction & course logistics	
	L2: Mathematical background	Homework 1
Week 2	L3: Review of convexity (I)	
	L4: Review of convexity (II)	
Week 3	L5: Conic programming	Homework 2
	L6: LP, QP, QCQP, SOCP, SDP	
Week 4	L7: Duality in conic programming (I)	
	L8: Duality in conic programming (II)	Homework 3
Week 5	L9: Applications of SDPs in control	
	L10: Applications of SDPs in combinatorial problems	Proposal due
Week 6	L11: Nonconvex quadratic optimization and SDP relaxations	Homework 4
	L12: Iterative inner/outer approximations	
Week 7	L13: Nonnegative polynomials, SOS, and SDP (I)	
	L14: Nonnegative polynomials, SOS, and SDP (II)	Homework 5
Week 8	Midterm exam	
	L15: SOS applications in control & machine learning	
Week 9	L16: Dual side: moment problems	Homework 6
	L17: Nonsmooth optimization	
Week 10	L18: Large-scale optimization	
	L19: Review and concluding remarks	
Week 11	Project presentation	

Course grade†

- 20% Homework (6 problem sets; will drop the lowest score)‡
- 30% Midterm exam (in class; one page of cheat sheet allowed)‡
- 50% Final project/Exam

† These weights are approximate; we reserve the right to change them later.

‡ The homework is carefully designed to develop genuine understanding of the material. Homework credit will count toward the course grade only if the midterm score is above 50%. Otherwise, the midterm score will be used for both the midterm and homework components.

It is easy, and of little value, to appear knowledgeable. It is much harder, and far more valuable, to understand a topic precisely and communicate that understanding clearly. Working carefully through the homework problems is essential to developing this understanding for this course.

Acknowledgments

The design of this course is inspired by the following excellent courses

- Topics in Convex Optimisation, University of Cambridge (Lecturer: Hamza Fawzi)
- ORF523: Convex and Conic Optimization, Princeton University (Lecturer: Amir Ali Ahmadi)
- 6.256 Semidefinite Optimization, MIT (Lecturer: Pablo A. Parrilo)