CSCI 675: Convex and Combinatorial Optimization (3 Units)
Fall 2014

Basic information

- Lecture time: Tuesdays and Thursdays, 11:00am - 12:20pm.
- Lecture place: VKC 151
- Instructor: Shaddin Dughmi
  - Email: shaddin@usc.edu
  - Office: SAL 234
  - Office Hours: TBA
- TA: TBA
  - Email: TBA
  - Office Hours: TBA
- Course Homepage: `http://www-bcf.usc.edu/~shaddin/cs675fa14`

Course Description

Topics include: Convex sets and functions; convex optimization problems; geometric and Lagrangian duality; simplex algorithm; ellipsoid algorithm and its implications; matroid theory; submodular optimization.

Course Motivation

Over the past half century or so, computer science and mathematical optimization have witnessed the development and maturity of two different paradigms for algorithm design. The first approach, most familiar to computer scientists, is combinatorial in nature. The tools of discrete mathematics are used to understand the structure of the problem, and algorithms effectively exploit this structure to search over a large yet finite set of possible solutions. The second approach, standard in much of the operations research and mathematical optimization communities, primarily employs the tools of continuous mathematics, high dimensional geometry, and convex analysis. Problems are posed as a search over a set of points in high-dimensional Euclidean space, which can be performed efficiently when the search space and objective function are "convex."

Whereas many optimization problems are best modeled either as a discrete or convex optimization problem, researchers have increasingly discovered that many problems are best tackled by a combination of combinatorial and continuous techniques. The ability to seamlessly transition between the two views has become an important skill to every researcher working in algorithm design and analysis. This course intends to instill this skill by presenting a unified treatment of both approaches, focusing on algorithm design tasks that employ techniques from both. The intended audience for this course are PhD students, Masters students, and advanced undergraduates interested in research questions in algorithm design, mathematical optimization, or related disciplines.

Prerequisites and Preparation

Prerequisite Courses: CSCI 570 or CSCI 670 or permission of instructor.

Recommended Preparation: Mathematical maturity and a solid grounding in linear algebra.

Requirements and Grading

Homework assignments will count for 75% of the grade. There will be 4 assignments, which will be proof-based, and are intended to be very challenging. Collaboration and discussion among students is allowed, even encouraged, though students must write up their solutions independently.

The remaining 25% of the grade will be allocated to a final project. Students will have to choose a related research topic, read several papers in that area, and write a survey of the area.

Project Details

The goal of the project is to learn a new area related to the class material by reading 2-4 research papers, and writing a report surveying the area and outlining interesting research directions. Students must form teams of 2-3 students, decide on a topic and a list of papers, and submit a one-page project proposal by the end of the 8th week of class. Exceptions to the 2-3 student rule are at the discretion of the instructor. On the last day of class, each team must submit a project report of up to 10 pages.

Students will be graded on the proposal and the report, with the former worth 5% of the course grade, and the latter worth 20%.

Students must consult with the instructor during the first half of the class for help in forming project teams, selecting a suitable project topic, and selecting a suitable set of research papers. Students are encouraged to choose a topic related to their own research interests, though the instructor will provide suggestions based on recent important work in related areas. Example project topics include, but are not limited to:

- Applications of submodularity in machine learning
- Compressed Sensing
- Matrix completion

- Online convex optimization
- Distributed Convex Optimization
- Online Combinatorial Optimization via Primal-Dual Techniques
- Maximum entropy rounding techniques in combinatorial optimization
- Computation of Market Equilibria

Late Homework Policy

Students will be allowed 3 late days for homework, to be used in integer amounts and distributed as the student sees fit. No additional late days are allowed.

References

We will refer to two main texts: *Convex Optimization* by Boyd and Vandenberghe, available free online at `http://www.stanford.edu/~boyd/cvxbook/bv_cvxbook.pdf`, and *Combinatorial Optimization* by Korte and Vygen, available online through USC libraries. Both books will also be made available at the USC bookstore. Additional recommended references include *Combinatorial Optimization* by Schrijver, *Linear and Nonlinear Programming* by Luenberger and Ye, available online through USC libraries, as well as lecture notes from related courses elsewhere which will be linked on the course website.

Schedule by Week

- Week 1: Introduction to Optimization. Linear Programming and Duality.
  - Reading: B&V Chapter 1, and additional references posted to course website.
- Weeks 2: Convex Sets and Functions
  - Reading: B&V Chapters 2 and 3.
  - Homework 1 released.
- Week 3: Geometric Duality
  - Reading: References posted to course website.
- Week 4: Convex Optimization Problems
  - Reading: B&V Chapter 4.
  - Homework 1 due
  - Homework 2 released
- Week 5: Convex Optimization Duality
  - Reading: B&V Chapter 5.

- Week 6-7: Combinatorial Problems as Linear Programs
  - Reading: References posted to course website.
  - Homework 2 due by end of week 7.
- Weeks 8-9: Algorithms: simplex method, ellipsoid method and its consequences
  - Reading: K&V Chapters 3 and 4, as well as references posted to course website.
  - Project team selection and proposal due by end of week 8.
  - Homework 3 released in week 8
- Weeks 10-11: Matroid theory. Optimization over matroids and matroid intersections
  - Reading: K&V Chapter 13, as well as references posted to course website.
  - Homework 3 due in week 11.
  - Homework 4 released in week 11.
- Weeks 12-13: Submodular functions and optimization
  - Reading: References posted to course website.
- Week 14: Semidefinite programming and constraint satisfaction problems
  - Reading: References posted to course website.
  - Homework 4 due.
- Week 15: Additional topics at the discretion of the instructor
  - Project reports due.

Statement for Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m - 5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

Statement on Academic Integrity

USC seeks to maintain an optimal learning environment. General principles of academic honesty include the concept of respect for the intellectual property of others, the expectation that individual work will be submitted unless otherwise allowed by an instructor, and the obligations both to protect one'ss own academic work from misuse by others as well as to avoid using another's work as one's own. All students are expected to understand and abide by these principles. Scampus, the Student Guidebook, contains the Student Conduct Code in Section 11.00, while the recommended sanctions are located in Appendix A: http://www.usc.edu/dept/publications/SCAMPUS/gov/. Students will be referred to the Office of Student Judicial Affairs and Community Standards for further review, should there be any suspicion of academic dishonesty. The Review process can be found at: http://www.usc.edu/student-affairs/SJACS/..

Emergency Preparedness/Course Continuity in a Crisis

In case of a declared emergency if travel to campus is not feasible, USC executive leadership will announce an electronic way for instructors to teach students in their residence halls or homes using a combination of Blackboard, teleconferencing, and other technologies.