CS 599: Convex and Combinatorial Optimization
Fall 2013

Basic information

- Lecture time: Tuesdays and Thursdays, 2:00-3:20pm.
- Lecture place: KAP 147
- Instructor: Shaddin Dughmi
  - Email: shaddin@usc.edu
  - Office: SAL 234
  - Office Hours: TBD
- Course Homepage: http://www-bcf.usc.edu/~shaddin/cs599fa13

Course Description

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 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 seemlessly 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

The main prerequisites for this class are mathematical maturity, as well as exposure to algorithm design and analysis at the beginning graduate level. Specifically, knowledge of algorithms at the level of CS570 or CS670, or permission of the instructor, is required.

Requirements and Grading

Homework assignments will count for 70% of the grade. There will be 3-4 assignments, roughly 3 weeks apart each. The homeworks 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 30% 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, write a survey of the area, and make an in-class presentation.

Late Homework Policy

Students will be allowed one late homework, at most two days from the due date. No additional late homework will be accepted.

References

We will refer to two main texts: *Convex Optimization* by Boyd and Vandenberghe, and *Combinatorial Optimization* by Korte and Vygen. For topics not covered in these texts, the instructor will provide lecture notes. Additional references include *Combinatorial Optimization* by Schrijver, as well as lecture notes from related courses elsewhere.

Additionally, we will refer to research papers throughout the course, which will be linked on the course homepage.

Schedule by Week

- Week 1-2: Linear Programming and Duality. Connection to zero-sum games.
- Week 2: Convex Sets and Functions
- Week 3-4: Convex Optimization Problems and Duality
- Week 5: Algorithms: Simplex method, ellipsoid method, interior point methods
- Weeks 6-7: Combinatorial problems as linear and convex programs
  - Illustrative examples: shortest paths, spanning trees, flows, traveling salesman, matching, max cut ...
  - Integrality of polyhedra (e.g. Birkhoff von Neumann Theorem, ...)
  - Edmonds' algorithm for non-bipartite matching.

- Week 8: Consequences of the ellipsoid method: Separation oracles, equivalence of separation and optimization.
- Weeks 9-10: Matroid theory. Optimization over matroids and Matroid intersections.
- Weeks 11-12: Submodular functions and optimization.
  - Submodular minimization via convex minimization of the lovasz extension.
  - Approximate Submodular maximization, unconstrained.
  - Approximate submodular maximization subject to a matroid constraint.
- Weeks 13-14: Additional topics at the discretion of instructor, taking into account preferences of students. Possibilities: semidefinite programming and constraint satisfaction problems, computing correlated equilibria, market equilibria, ...
- Week 15: Student presentations

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.