ORF 363/COS 323, Fall 2018

Computing and Optimization for the Physical and Social Sciences

http://aaa.princeton.edu/orf363

Course description

An introduction to several fundamental and practically-relevant areas of numerical computing with an emphasis on the role of modern optimization. Topics include convex optimization, computational linear algebra, linear and semidefinite programming, optimization for statistical regression and classification, computational complexity theory, and techniques for dealing with uncertainty and intractability in optimization problems. Extensive hands-on experience with high-level optimization software. Applications drawn from operations research, statistics and machine learning, finance, economics, and engineering.

Course website

- The course will be on Blackboard and we will have Piazza.
- Lecture notes and problem sets will also be posted here: http://aaa.princeton.edu/orf363

Class schedule and location

T, Th 1:30 pm-2:50 pm. McCosh Hall 28.

Distribution area

Quantitative reasoning.

Certificate programs

The course counts towards the certificates in

- Applications of Computing
- Statistics and Machine Learning
- Engineering and Management Systems
- Robotics and intelligent systems

Instructor

Amir Ali Ahmadi, Assistant Professor at ORFE. Web: http://aaa.princeton.edu/ Email: a_a_a@p...
Office hours: Tuesdays, 5:30-7:30 PM, Sherrerd 329 (overflow room: Sherrerd 125).

Other official or volunteer members of the teaching staff

- **Thomas Pumir** (official TA)
- Office hours: **Mon 4-6pm, Sherrerd 005**
- tpumir@p...

- **Cemil Dibek** (volunteer)
- Office hours: **Mon 6-8pm, Sherrerd 005**
- cdibek@p...

- **Francesca Tang** (official TA)
- Office hours: **Tue 9-11am, Sherrerd 005**
- frtang@p...

- **Benjamin Mirabelli** (official TA)
- Office hours: **Tue 7:30-9:30pm, Sherrerd 005**
- bpm2@p...

- **Zheng Yu** (official TA)
- Office hours: **Wed 5-7pm, Sherrerd 005**
- zhengy@p...

- **Bachir El Khadir** (volunteer)
- Office hours: **Wed 7-9pm, Sherrerd 005**
- bkhadir@p...

- **Yaqi Duan** (official TA)
- Office hours: **Thu 9-11am, Sherrerd 006**
- yaqid@p...

- **Wenyan Gong** (official TA)
- Office hours: **Fri 3-5pm, Sherrerd 005**
- wenyang@p...

- **Jeffrey Zhang** (volunteer)
- Piazza Guru
- jeffz@p...

Prerequisites

- Multivariable Calculus: MAT201 or MAT203
- Linear Algebra: MAT202 or MAT204
- Familiarity with MATLAB

Textbooks

Recommended as reference:

- *An Introduction to Optimization,* K. P. Chong & S. H. Zak, *4th ed.*
- *Algorithms,* S. Dasgupta, C. Papadimitriou, and U. Vazirani.
- *Introduction to Applied Linear Algebra – Vectors, Matrices, and Least Squares*
  https://web.stanford.edu/~boyd/vmls/
- *Linear Programming: Foundations and Extensions,* R.J. Vanderbei.
  Available for free download to Princeton students:
  http://link.springer.com/book/10.1007/978-1-4614-7630-6
- *Convex Optimization,* S.Boyd, and L. Vandenberghe.
  Available for free download:
  http://web.stanford.edu/~boyd/cvxbook/

Software

Students will use the MATLAB-based optimization software CVX (http://cvxr.com/cvx/) to solve a variety of real-world (but simplified) problems having to do with optimization and computing in operations research, machine learning, finance, economics, and engineering.

Course grade

- 50% homework (around 8 problem sets; will drop the lowest score); almost all problem sets will involve a computational component
- 20% midterm (in-class, date TBA)
- 30% final (take-home); involves a computational component

Homework

Homework will be due in class, at 1:30 pm. If you cannot make it to class one day, you can drop it off (before 1:30 pm) in Sherrerd 123 (ORFE undergraduate lounge) in the box designated for ORF 363. Unless there is an *extremely valid* reason, requests for extension on homework will not be accepted. To help stick with this policy, we drop your lowest homework score.

Midterm

Midterm will be in-class, for the entire length of a regular lecture. Midterm is closed-book and closed-notes. However, you can take a single sheet of A4 paper with you (double-sided) with anything you want written on it. No electronic devices are allowed; no calculators, no phones, etc. There will be no computer exercises on the midterm.

Final

There will be a take-home final exam. This will be a cumulative exam but with more focus on the second half of the course. You cannot discuss the exam with anyone other than the professor and the TAs. The

date of the exam is to be announced. The final (just like the homework) will have both a mathematical component and a computational component.

Collaboration policy

Homework: You are allowed and in fact encouraged to collaborate on the homework. You have to turn in your individual assignment and you have to write the name of the students with whom you worked with on the first page of your homework. Full credit will be given to all members of the team.

Midterm and final exam: No collaboration allowed.

Tentative list of lectures and problem sets:

- Lec1: Let's play two games! (Optimization, P and NP.)
- Lec2: What you should remember from linear algebra and multivariate calculus.
- HW1: Brush up on linear algebra, multivariate calculus, and MATLAB.
- Lec3: Unconstrained optimization, least squares, optimality conditions.
- Lec4: Convex optimization I.
- HW2: Image compression and SVD, optimality conditions, convex sets.
- Lec5: Convex optimization II.
- Lec6: Applications in statistics and machine learning: LASSO+SVMs.
- HW3: Convex analysis and convex optimization.
- Lec7: Root finding and line search: bisection, Newton, and the secant method.
- Lec8: Gradient descent methods, analysis of steepest descent, rates of convergence.
- HW4: Support vector machines.
- Lec9: Quadratic convergence of Newton's method, nonlinear least squares and Gauss-Newton.
- Lec10: Conjuagate direction methods, solving linear systems, Leontief economy.
- HW5: New gym and movie theater for Princeton + Newton fractals.
- Lec11: Linear programming: applications, geometry, and the simplex algorithm.
- Lec12: Duality and robust linear programming.

- HW6: Leontief economy + conjuagate gradients + radiation treatment planning.
- Lec13: Semidefinite programming, SDP relaxations for nonconvex optimization.
- Lec14: A working knowledge of computational complexity for an optimizer.
- HW7: Optimal control + linear programming.
- Lec15: William Pierson Field Lecture by Sanjeeb Dash: Optimization at IBM Research.
- Lec16: Limits of computation, course recap.
- HW8: End-of-semester party at AAA's + Doodle and scheduling + SDP + NP-completeness.

Honor code

We strictly adhere to Princeton University's Undergraduate Honor System.