IE 539: Convex Optimization, Fall 2022

TTh(화목) 4:00-5:30 pm, E2 (산업경영학동) #1122

Instructor: Dabeen Lee, dabeenl@kaist.ac.kr, E2-2 #2109.
Lectures: Tuesdays and Thursdays 4:00-5:30 pm.
Office hours: To be announced.
Teaching assistant: To be announced.
Course webpage: https://dabeenl.github.io/IE539
Assignments and lecture notes will be uploaded to the webpage.

Course description The availability of big data has introduced many opportunities to make better decision-making based on a data-driven approach, and many of the relevant decision-making problems can be posed as optimization models that have special properties such as convexity and smoothness. From this course, a graduate-level student will learn fundamental and comprehensive convex optimization knowledge in theory (convex analysis, optimality conditions, duality) and algorithms (gradient descent and variants, Frank-Wolfe, and proximal methods). We will also cover some application areas including statistical estimation, finance (e.g., portfolio optimization), machine learning, and data science.

Key topics Theory and algorithms for convex optimization, Applications.

- Theory: Convex analysis (sets, functions, operations), Optimality Conditions, Duality.
- Algorithms: First-order methods (gradient descent and variants), Second-order methods (Newton's method, Quasi-Newton method), Frank-Wolfe, ADMM, and more.
- Applications: Statistical estimation, Finance (e.g., portfolio optimization), Machine learning and data science, Economics.

Texts There is no required textbook for this course, but students may find the following list of materials useful to follow the topics covered in this course:

- Convex Optimization, *Boyd and Vandenberghe*, https://stanford.edu/~boyd/cvxbook/
- Convex Optimization: Algorithms and Complexity, *Bubeck*, https://arxiv.org/abs/1405.4980
- Lectures on Modern Convex Optimization, *Ben-Tal and Nemirovski*, https://www2.isye.gatech.edu/~nemirovs/LMCOBookSIAM.pdf

Prerequisites There are no formal prerequisites but you should be comfortable making mathematical arguments, writing proofs, and programming. You should also be comfortable with the background knowledge from previous courses. Such topics include

- linear algebra (vectors, matrices, inner products, eigenvalues, eigenvectors, singular value decomposition),
- basic multivariate calculus (partial derivatives, gradient), and
- basic mathematical analysis (open and closed sets, inf and sup definitions).

Assessment structure There will be bi-weekly assignments (50%), a coding project (20%), and a take-home final exam (30%). **Typesetting in Latex is required for all submissions**.

Course outline What follows is a tentative outline of this course.

- Convex sets and functions.
- Operations preserving convexity
- Quadratic functions, positive semidefinite matrices, differentiable convex functions
- Subgradients of convex functions
- Convex optimization problems and projected subgradient descent
- Mirror descent
- Problems with functional constraints and Lagrange duality
- Saddle point problems and the primal-dual subgradient algorithm
- Conic programming
- Conic programming duality
- Newton's method and Quasi-Newton methods
- Semidefinite programming relaxations of quadratic programs
- Frank-Wolfe algorithm
- Alternating direction method of multipliers
- Modelling optimization problems under uncertainty
- Algorithms for optimization under uncertainty