

3. *Non-smooth optimization* (3 hours)
Smooth vs non-smooth optimization, subdifferential and subgradient, optimality conditions for non-differentiable costs, proximal operators and their properties, Moreau decomposition, proximal gradient methods.
4. *Algorithms: Unconstrained minimization* (3 hours)
Quadratic minimization and least squares, descent methods, line search, backtracking, gradient descent method, steepest descent method, Newton's method, non-linear least squares, Gauss-Newton method, implementation and examples.
5. *Algorithms: Constrained minimization* (3 hours)
Primal and dual feasibility conditions, Newton's method with equality constraints, convex-concave games, barrier method, primal-dual interior point methods, practical considerations and examples.
6. *Proximal algorithms* (3 hours)
Proximal gradient methods, proximal gradient methods with line search, acceleration, dual decomposition, dual proximal gradient method, Douglas-Rachford splitting, alternating directions method of multipliers, implementation and examples.
7. *Applications of convex optimization* (6 hours)
Approximation and fitting, least-norm problems, regularized approximation, robust approximation, maximum-likelihood estimation, logistic regression, maximum-a-posteriori probability estimation, optimal detection and hypothesis testing, robust detectors, experiment design, extremal volume ellipsoids, centring, classification, location problems with path constraints.

Part II: Discrete optimization

8. *Graphs and network flow problems* (3 hours)
Graphs and flows, examples of network flow models, an overview of network flow algorithms, algorithm complexity (good, bad, and polynomial algorithms).
9. *Shortest path problems* (3 hours)
Problem formulation and applications, a generic shortest path algorithm, label setting (Dijkstra) methods, label correcting methods, single origin/single destination methods, auction algorithms, dynamic programming.
10. *The max-flow and the min-flow cost problems* (3 hours)
Cuts in a graph, the max-flow/min-cut theorem, the maximal and minimal saturated cuts, decomposition of infeasible network problems, the Ford-Fulkerson algorithm, transformations and equivalences, duality.
11. *Network problems with integer constraints* (3 hours)
Basic formulation, branch-and-bound, Lagrangian relaxation, cutting plane methods, local search methods, genetic algorithm, simulated annealing, rollout algorithms.

Course Textbooks

The students will be provided with copies of lecture slides developed based on:

1. S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press, 2004 (freely available online at <http://stanford.edu/~boyd/cvxbook/>)
2. D. P. Bertsekas, *Network Optimization: Continuous and Discrete Models*, Athena Scientific, 1998 (freely available online at <http://web.mit.edu/dimitrib/www/net.html>)

Marking Scheme

1. Home Assignments (5 assignments \times 5 points): 25%
2. Course project: 35%
3. Final Exam: 40%