14D002

Deterministic Models and Optimization

Fall Term - 6 ECTS

Mandatory Course

Prof. Marc Noy and

Prof. Piotr Zwiernik

Prerequisites to Enroll

None.

Overview and Objectives

The main objective in this course is to give students a thorough grounding in optimization models, theory, and algorithms. The course level is introductory, and the scope is broad, so only the most important and representative models and algorithms will be covered. The presented material will be closely linked to modern statistical methods like network analysis, quantile regression, and high-dimensional statistics. Students will be expected to program as well as use software for optimization.

Prerequisite reading

Students should brush up on their undergraduate calculus and linear algebra before the class. The relevant material is covered in the brush-up course.

Course Outline

Part I. Continuous optimization (20 hours)

1. Linear programming
    a. formulation
    b. the simplex method
    c. duality and complementary slackness
    d. statistical examples: quantile regression, generalized linear models

2. Convex optimization
    a. convex sets and functions
    b. convex duality and KKT conditions
    c. non-differentiable functions and the subgradient
    d. statistical examples: modelling sparsity and other high-dimensional techniques

3. Algorithms for continuous optimization
   a. gradient descent, Newton's method for unconstrained smooth functions
   b. projected gradient descent for constrained smooth functions
   c. coordinate descent and other methods

Part II. Combinatorial optimization algorithms (20 hours)
Graphs and networks
Greedy algorithms
Divide and conquer
Dynamic programming
Bipartite matching
Random and approximate algorithms
Computational complexity

Required Activities

Exercises, lab, project.

Evaluation

Homework exercises (2 x 15%), Programming project (20%), and Final exam (50%).

Competences

☒ Construct a global vision of the situation of the problem based on knowledge of the synergies between advanced statistical methods, computing and business analysis to generate added value.

☒ Communicate with conviction in English the results and implications of the required analytical study using a language related to the receiver.

☒ Own and understand knowledge that provides a basis or opportunity to be original in the development and / or application of ideas, often in a research context.

☒ That students know how to apply the acquired knowledge and their ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts related to their area of study.

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☒ That the students know to communicate their conclusions and the knowledge and last reasons that sustain them to specialized and non-specialized publics in a clear and unambiguous way.

☒ That students have the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

Learning Outcomes

☒ Apply mathematical and computational analysis of social, business and economic networks knowing the theory and optimization algorithms.

☒ Apply search algorithms and estimation methodologies in networks through observation of data.

☒ Apply mathematical and statistical analysis using economic theory in complex problems with high-dimensional data.

☒ Apply mathematical theory and statistics on data sets from disparate disciplines.

Materials

Recommended Books:

J. Matousek and B. Gärtner. *Understanding linear programming*. Springer 2007.

J. Kleinberg and E. Tardos. *Algorithm design*. Addison-Wesley 2005.

S. Boyd and L. Vandenberghe. *Convex optimization*. Cambridge University Press 2004.
(also available online: http://web.stanford.edu/~boyd/cvxbook/)

T. Hastie, R. Tibshirani and M. Wainwright. *Statistical learning with sparsity*. Chapman&Hall 2015.
(also available online: https://web.stanford.edu/~hastie/StatLearnSparsity/)