Advanced Optimization Techniques for Communications and Signal Processing

First Quarter, Course 2009 - 2010

Professor

	Email	Office	Tel.
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Time and location of Lectures

Days	Time	Classroom
Fridays	12:00 - 13:30	Seminar Room (IRTIC)
Fridays	15:00 - 16:30	Seminar Room (IRTIC)

Day off: October 9th (Festivity day of Valencia Community)

Last session (Final exam): December 18th

Total number of sessions: 12 (11 lectures + Final exam)

Tutorships

Days	Time	Office
Mondays	16:00 - 17:00	IRTIC

General description of the course

The focus of the course is to provide a deep study of optimization tools in the context of important problems related to point-to-point and Networked Communications, as well as Signal Processing. On the one hand, these are very useful tools in order to understand, model and analyze correctly real problems and on the other hand, these are also the key tools to design solutions for these problems. The course will cover both classic results and also more recent results.

Main objectives

- Acquire correctly the mentality and language of Optimization.
- Know how to model and formulate real communication and signal processing problems as optimization problems.
- Understand well the underlying theory, concepts and properties related to each of the optimization tools.
- Design, implement and simulate practical (centralized and distributed) algorithms to solve the various optimization problems.

- Analyze the structures/decompositions of problems and solutions, as well as the relationship between different problems

Of course, I also expect you to: be willing to learn, enjoy the class and to be participative!

Prerequisites

You are expected to have knowledge on Algebra, Calculus, Probability and Random Processes, Basic Digital Communications and Matlab Programming.

Class material and Web access

- Slides, which will be distributed periodically and posted at http://pizarra.uv.es.
- Homework assignments. Although in-group discussion can be done and is ok, you should try to solve all the problems individually. When preparing the exam, I will assume that you have done all the problems. The general type of problems will not be plug-and-chug, that is, it will require time and thinking, not just applying straightforward or standard methods. Each homework assignment will have also a given due date and no late homeworks will be accepted. Doing the homeworks will be the best possible preparation for the final exam. The homework assignments will be also posted at http://pizarra.uv.es
- Research papers and other complementary material (refreshers, tutorials, papers, etc...), which will be posted at http://pizarra.uv.es.

Project

- Either original research or extensive comparative study between existing solutions
- A list of topics and papers will be provided (students can also propose topics ;))
- Groups of two students (individual projects are also possible)
- Presentation during last week of Quarter
- Project report due on 23/12/09 (Wednesday), both content and presentation will be evaluated.
- There will be several project progress meetings to interact

Final Exam

There will be a Final exam on (tentatively) 18/12/09 (Friday). The set of problems and questions in the exam will be of similar level to the homework assignments.

Grading

The final grade for this course will be calculated as follows:

$$\text{Grade} = 0.2 \times (\text{Homeworks}) + 0.4 \times (\text{Project}) + 0.4 \times (\text{Final Exam}).$$

The grading of the project will be based both on the Report (25%) and on the Presentation (15%).

Approximate Outline of topics

- Introduction, Motivation and Course Overview
- Theory and Algorithms:
  - Convex Sets and Convex Functions
  - Classification of Convex problems: LP, QP, SOCP, SDP, GP
  - Convex Optimization and Lagrange Duality
  - Pareto Optimization
  - Dynamic Programming and Sequential Optimization
  - Geometric Programming for Communication Systems
  - Gradient Optimization Algorithms
  - Interior Point Optimization Algorithms
  - Alternating Projections & Composite Mappings
  - Decomposition Optimization Methods/Structures and Distributed Algorithms
  - Non-convex Optimization
- Applications (interlaced between theoretical lectures):
  - Approximation and fitting
  - Waterfilling solutions
  - Network Flow Problems
  - Statistical Estimation
  - Classification
  - Robust Beamforming
  - Transceiver Design for MIMO Communications
  - Power Control Optimization in Wireless systems
  - Multi-user Maximum-Likelihood Detection and Decoding
  - Code duality between rate-distortion and channel capacity
  - Network Utility Maximization
  - Internet TCP Congestion Control

Bibliography

Unfortunately, there is not a single book covering all the material of the course, thus, we will use several books at the same time. There will be also periodic reading assignments from some of these books.

- Basic Bibliography:
  - S. Boyd and L. Vandenberghe, *Convex Optimization*, Cambridge University Press 2004.
- Complementary Bibliography:
  - D. P. Bertsekas, *Nonlinear Programming*, Athena Scientific, 2nd Edition, 1999.

- D. Bertsimas, J. N. Tsitsiklis, *Introduction to Linear Optimization*, Athena Scientific, 1997
- D. G. Luenberger, *Linear and Non-Linear Programming*, Springer, 2003.
- D. P. Bertsekas, *Network Optimization: Continuous and Discrete Models (Optimization, Computation, and Control)*, Athena Scientific, 1998.
- D. P. Bertsekas, *Convex Analysis and Optimization*, Athena Scientific, 2003.
- M. Chiang, *Geometric programming for communication systems*, Foundations and Trends in Communications and Information Theory, vol. 2, no. 1-2, pp. 1-154, July 2005.
- S. Shakkottai, R. Srikant, *Network Optimization and Control*, Foundations and Trends in Networking, vol. 2, no. 3, 2007
- D. P. Bertsekas, *Dynamic Programming and Optimal Control*, Volume I, Athena Scientific, 2007.
- G. L. Nemhauser, L. A. Wolsey, *Integer and Combinatorial Optimization*, Wiley-Interscience (series in discrete mathematics and optimization), 1999.
- L. A. Wolsey, *Integer Programming*, Wiley-Interscience (series in discrete mathematics and optimization), 1998.
- T. K. Moon, W. C. Stirling, *Mathematical Methods and Algorithms for Signal Processing*, Prentice Hall, 2000.
- W. Kocay, D. L. Kreher, *Graphs, Algorithms and Optimization*, Chapman & Hall/CRC Press, 2005.
- Several tutorials and journal papers to be distributed in class.