Course guide
200618 - OGD - Large Scale Optimization

Last modified: 01/06/2023

Unit in charge: School of Mathematics and Statistics
Teaching unit: 715 - EIO - Department of Statistics and Operations Research.

Degree: MASTER'S DEGREE IN STATISTICS AND OPERATIONS RESEARCH (Syllabus 2013). (Optional subject).

Academic year: 2023 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JORDI CASTRO PÉREZ

Others: Segon quadrimestre:
JORDI CASTRO PÉREZ - A
ESTEVE CODINA SANCHO - A

PRIOR SKILLS

Basic knowledge of Operations Research / Optimization / Modelling in Mathematical Programming / Basic Linear Algebra.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
3. CE-2. Ability to master the proper terminology in a field that is necessary to apply statistical or operations research models and methods to solve real problems.
4. CE-3. Ability to formulate, analyze and validate models applicable to practical problems. Ability to select the method and / or statistical or operations research technique more appropriate to apply this model to the situation or problem.
5. CE-5. Ability to formulate and solve real problems of decision-making in different application areas being able to choose the statistical method and the optimization algorithm more suitable in every occasion.
Translate to english
6. CE-6. Ability to use appropriate software to perform the necessary calculations in solving a problem.
7. CE-9. Ability to implement statistical and operations research algorithms.

Transversal:
1. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

2. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

TEACHING METHODOLOGY

Both lectures about theory and practice:

* Theoretical sessions: The contents of the course will be presented and discussed by combining explanations on the board and with transparencies.

* Problem-solving sessions: Interspersed with theory classes; problems and case studies are introduced and solved.

* Practicals: Lab sessions in which software for solving large-scale problems are studied.

* Language: the course can be imparted in either English, Catalan or Spanish.

LEARNING OBJECTIVES OF THE SUBJECT

The objective of this course is to introduce students to the solution of large-scale problems as well as the different existing methodologies, specially decomposition methods for structured problems and interior-point methods. On completion of the course, students should be familiar with different types of structured problems and should be able to identify the most appropriate methodology for each problem, in addition to obtaining the solution to the optimization problem in an efficient way.

Skills to be learned
* Given an optimization model, identify whether or not it is suitable to use a decomposition technique.
* Learn the main role played by Lagrangian duality and its relation with different decomposition techniques.
* Implement decomposition methods using algebraic languages for mathematical programming in different models with the aim of resolving them.
* Learn the differences between the simplex method for Linear Programming and the interior-point methods, as well as when it is suitable to use the former or the latter.
* Learn the foundations of the interior point methods, for LP, QP and convex NLP.
* Implement simple versions of interior-point methods with high-level languages (matlab),as well as learning the required linear albegra tools.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	24.00
Self study	80,0	64.00
Hours small group	15,0	12.00

Total learning time: 125 h

CONTENTS

DUALITY

Description:
1.1 Duality in Linear Programming. Duality Theorems and complementary slackness. Dual-simplez algoritm and sensitivity analysis. Vertexes and extreme directions in polyhedra. Farkas Minkowsky's theorem. Farkas' lemma.

1.2 Duality in mathematical programming and lagrangian duality. Dualization and relaxation. dualization and convexification. Optimiality conditions and Karush-Kuhn and Tucker conditions. Lagrangian relaxation and duality. Introduction to non-differentiable optimization. Subgradient optimization.

Full-or-part-time: 6h
Theory classes: 6h

DECOMPOSITION METHODS

Description:
2.1 Decomposition methods in Mathematical Programming. Dantzig's cutting plane algorithm and generalized linear preogramming. Dantzig-Wolfe's decomposition algorithm. Resource based decomposition. Benders decomposition algorithm. Vertex generating methods in non-linear programming problems with linear constraints

Full-or-part-time: 13h 30m
Theory classes: 13h 30m

INTERIOR-POINT METHODS

Description:
Basic elements of convexity. Perturbed KKT conditions. The barrier problem. The central path. Primal-dual path following interior point algorithms. Short and long step versions. Implementation details. Augmented system and normal equations. Second order directions. Extensions to quadratic and convex problems.

Full-or-part-time: 19h 30m
Laboratory classes: 19h 30m

GRADING SYSTEM

Two practical assignments for each part of the course (1. Duality and decomposition; 2 interior-point methods). Each assignment is a 50% of the overall mark.

BIBLIOGRAPHY

Basic:
- Bradley, S. P.; Hax, A.C.; Magnanti, T.L. Applied mathematical programming. Addison-Wesley, 1977. ISBN 020100464X.
- Chvátal, Vasek. Linear programming. Freeman, 1983. ISBN 0716715872.
- Wright, Stephen J. Primal-dual interior-point methods. Society for Industrial and Applied Mathematics, 1997. ISBN 089871382X.
- Minoux, M. Vajda, S. Mathematical programming : theory and algorithms. John-Wiley, 1986. ISBN 0471901709.
- Bazaraa, M.S.; Sheraly, H.D.; Shetty, C.M. Nonlinear programming : theory and algorithms [on line]. 3ª. John-Wiley, 2006 [Consultation: 05/07/2023]. Available on: https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/0471787779.

Complementary:
- Conejo, A.J.; Castillo, E.; Minguez, R. ; Garcia-Bertrand, R. Decomposition techniques in mathematical programming : engineering and science [on line]. Springer, 2006 [Consultation: 05/07/2023]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/3-540-27686-6. ISBN 9786610625628.
- Bertsekas, Dimitri P.. Nonlinear programming. Athena Scientific, 1999.
- Sierksma, Gerard. Linear and integer programming theory and practice [on line]. 2nd ed. Marcel Dekker, 1996 [Consultation: 05/07/2023]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=1683099. ISBN 0824796950.
- Shapiro, Jeremy F. Mathematical programming. Structures and algorithms. John Wiley, 1979. ISBN 0471778869.