Course guide
270214 - OM - Mathematical Optimization

Last modified: 30/01/2024

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

Degree: BACHELOR'S DEGREE IN DATA SCIENCE AND ENGINEERING (Syllabus 2017). (Compulsory subject).

Academic year: 2023 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: JORDI CASTRO PÉREZ

Others: Segon quadrimestre:
JORDI CASTRO PÉREZ - 11, 12
FRANCISCO JAVIER HEREDIA CERVERA - 11, 12

PRIOR SKILLS

A first course on calculus and linear algebra. To implement algorithms in some programming language.

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE3. Analyze complex phenomena through probability and statistics, and propose models of these types in specific situations. Formulate and solve mathematical optimization problems.

Generical:
CG1. To design computer systems that integrate data of provenances and very diverse forms, create with them mathematical models, reason on these models and act accordingly, learning from experience.
CG2. Choose and apply the most appropriate methods and techniques to a problem defined by data that represents a challenge for its volume, speed, variety or heterogeneity, including computer, mathematical, statistical and signal processing methods.

Transversal:
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.
CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

TEACHING METHODOLOGY

Theoretical lectures where the concepts will be introduced, including exercises to fix these concepts (75%)
Problems and lab sessions (25%).

LEARNING OBJECTIVES OF THE SUBJECT

1.To solve data science problems previously formulated as mathematical optimization problems.
2.To know what a mathematical optimization problem is, what types of problems are there, and to have a basic knowledge of optimization algorithms.
4.To model mathematical optimization problems and to formulate them through modeling languages. To know how to choose the best method or "solver" according to the type of problem.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	20.00
Hours small group	30,0	20.00
Self study	90,0	60.00

Total learning time: 150 h

CONTENTS

Unconstrained Optimization.

Description:
Problem modeling. Optimality conditions. Convexity. Descent directions. Line search methods. The gradient or steepest descent method, and variants (stochastic gradients, etc.); convergence rate of the gradient method. The Newton method and globally convergent variants (e.g., modified Newton); Newton's convergence rate. Quasi-Newton Methods. Applications: neural networks, LASSO regression, etc.

Constrained Optimization.

Description:
Problem modeling. Convexity. Optimality conditions (Karush-Kuhn-Tucker conditions). Particular cases: linear optimization and quadratic optimization. Simplex method for linear optimization. Duality in optimization. Dual linear and quadratic problems. Applications: support vector machines, etc.

Integer Optimization.

Description:
Modeling of problems with binary and/or integer variables.. Combinatorial problems Properties of integer and combinatorial optimization problems. Solution methods: branch-and-bound, and cutting plans. Applications: clustering, k-median, classification, etc.

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ACTIVITIES

Development of the topic "Unconstrained Optimization"

Specific objectives:
1, 2, 4

Related competencies :
CG1. To design computer systems that integrate data of provenances and very diverse forms, create with them mathematical models, reason on these models and act accordingly, learning from experience.
CG2. Choose and apply the most appropriate methods and techniques to a problem defined by data that represents a challenge for its volume, speed, variety or heterogeneity, including computer, mathematical, statistical and signal processing methods.
CE3. Analyze complex phenomena through probability and statistics, and propose models of these types in specific situations. Formulate and solve mathematical optimization problems.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.
CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

Full-or-part-time: 70h
Theory classes: 14h
Practical classes: 7h
Laboratory classes: 7h
Self study: 42h

Development of the topic "Constrained Optimization"

Specific objectives:
1, 2, 4

Related competencies :
CG1. To design computer systems that integrate data of provenances and very diverse forms, create with them mathematical models, reason on these models and act accordingly, learning from experience.
CG2. Choose and apply the most appropriate methods and techniques to a problem defined by data that represents a challenge for its volume, speed, variety or heterogeneity, including computer, mathematical, statistical and signal processing methods.
CE3. Analyze complex phenomena through probability and statistics, and propose models of these types in specific situations. Formulate and solve mathematical optimization problems.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.
CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

Full-or-part-time: 60h
Theory classes: 12h
Practical classes: 6h
Laboratory classes: 6h
Self study: 36h

Development of the topic "Integer Optimization"

Specific objectives:
1, 2, 4

Related competencies :
CG1. To design computer systems that integrate data of provenances and very diverse forms, create with them mathematical models, reason on these models and act accordingly, learning from experience.
CG2. Choose and apply the most appropriate methods and techniques to a problem defined by data that represents a challenge for its volume, speed, variety or heterogeneity, including computer, mathematical, statistical and signal processing methods.
CE3. Analyze complex phenomena through probability and statistics, and propose models of these types in specific situations. Formulate and solve mathematical optimization problems.
CT5. Solvent use of information resources. Manage the acquisition, structuring, analysis and visualization of data and information in the field of specialty and critically evaluate the results of such management.
CT6. Autonomous Learning. Detect deficiencies in one's own knowledge and overcome them through critical reflection and the choice of the best action to extend this knowledge.

Full-or-part-time: 20h
Theory classes: 4h
Practical classes: 2h
Laboratory classes: 2h
Self study: 12h

GRADING SYSTEM

There will be 3 marks (each in [0,10]):

Pr: lab mark.
ExP: midterm exam mark (for the 1st part of the course).
ExF: final exam mark (for the 2nd part of the course). The 1st part of the course is not evaluated in the final exam.

The final grade (NF) will be calculated as follows:

NF= 0.3 * Pr + 0.35 * ExP + 0.35 * ExF

Students with NF

BIBLIOGRAPHY

Basic:
- Nocedal, J.; Wright, S.J. Numerical optimization. 2nd ed. Berlin: Springer, 2006. ISBN 9780387303031.
- Luenberger, D.G.; Ye, Y. Linear and nonlinear programming. 5th ed. Cham: Springer, 2021. ISBN 9783030854492.
- Wolsey, L.A. Integer programming. 2nd ed. Hoboken, New Jersey: Wiley, 2021. ISBN 9781119606536.
- Fourer, R.; Gay, D.M.; Kernighan, B.W. AMPL: a modeling language for mathematical programming. 2nd ed. Pacific Grove, CA: Thomson/Brooks/Cole, 2003. ISBN 0534388094.
- Cristianini, N.; Shawe-Taylor, J. An introduction to support vector machines: and other kermel-based learning methods. New York: Cambridge University Press, 2000. ISBN 0521780195.

RESOURCES

Hyperlink:
- http://ampl.com/- http://www-eio.upc.es/teaching/ple/pfc_ing.html- https://neos-server.org/neos/