Course guide
270214 - OM - Mathematical Optimization

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: 2021 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.

General:
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.
3. 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

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours large group</td>
<td>30,0</td>
<td>20.00</td>
</tr>
<tr>
<td>Hours small group</td>
<td>30,0</td>
<td>20.00</td>
</tr>
<tr>
<td>Self study</td>
<td>90,0</td>
<td>60.00</td>
</tr>
</tbody>
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**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:**

**Integer Optimization.**

**Description:**
# ACTIVITIES

## Development of the topic "Unconstrained Optimization"

**Specific objectives:**
1, 2, 4

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

**Full-or-part-time:** 70h
- Theory classes: 14h
- Practical classes: 7h
- Laboratory classes: 7h
- Guided activities: 1h 24m
- Self study: 40h 36m

## Development of the topic "Constrained Optimization"

**Specific objectives:**
1, 2, 4

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

**Full-or-part-time:** 60h
- Theory classes: 12h
- Practical classes: 6h
- Laboratory classes: 6h
- Guided activities: 1h 12m
- Self study: 34h 48m
Development of the topic "Integer Optimization"

Specific objectives:
1, 2, 4

Related competencies:
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.

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.

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

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.

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.

Full-or-part-time: 20h
Theory classes: 4h
Practical classes: 2h
Laboratory classes: 2h
Guided activities: 0h 24m
Self study: 11h 36m

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:

\[ NF = 0.3 \times Pr + 0.35 \times ExP + 0.35 \times ExF \]

Students with NF<5 will be allowed to do a re-evaluation exam. In the re-evaluation the only mark considered will be that of the re-evaluation exam (i.e., the lab mark is not used).

BIBLIOGRAPHY

Basic:
RESOURCES

Hyperlink:
- http://ampl.com/
- https://neos-server.org/neos/