Course guides
2706320 - TOML - Topics on Optimization and Machine Learning

Unit in charge: Barcelona School of Informatics
Teaching unit: 701 - DAC - Department of Computer Architecture.
Degree: MASTER'S DEGREE IN INNOVATION AND RESEARCH IN INFORMATICS (Syllabus 2012). (Optional subject).
Academic year: 2021 ECTS Credits: 6.0 Languages: English

LECTURER
Coordinating lecturer: JOSE MARIA BARCELÓ ORDINAS
Others: Segon quadrimestre:
JOSE MARIA BARCELÓ ORDINAS - 10
JORGE GARCÍA VIDAL - 10

PRIOR SKILLS
Recommended to have previously followed the course "Statistical Analysis of Networks and Systems (SANS-MIRI)"

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEE2.1. Capability to understand models, problems and algorithms related to distributed systems, and to design and evaluate algorithms and systems that process the distribution problems and provide distributed services.
CEE2.2. Capability to understand models, problems and algorithms related to computer networks and to design and evaluate algorithms, protocols and systems that process the complexity of computer communications networks.
CEE2.3. Capability to understand models, problems and mathematical tools to analyze, design and evaluate computer networks and distributed systems.

Transversal:
CTR6. REASONING: Capacity for critical, logical and mathematical reasoning. Capability to solve problems in their area of study. Capacity for abstraction: the capability to create and use models that reflect real situations. Capability to design and implement simple experiments, and analyze and interpret their results. Capacity for analysis, synthesis and evaluation.

TEACHING METHODOLOGY
During the initial sessions of each topic, the main results will be explained in the blackboard. The student will solve some exercises to prove their skills in the topic. Finally, the students develop projects according to the topics studied.

LEARNING OBJECTIVES OF THE SUBJECT
1. Capacity to formulate a convex optimization problem
2. Capacity to solve non linear optimization problems.
3. Capacity to apply to a real problem topics related to optimization
4. Capacity to understand basic machine learning algorithms
5. Capacity to apply machine learning algorithms to real scenarios.
6. Capacity to understand neural networks and deep learning algorithms
7. Capacity to apply neural networks and deep learning algorithms to real scenarios
STUDY LOAD

<table>
<thead>
<tr>
<th>Type</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical classes</td>
<td>12,0</td>
<td>8.00</td>
</tr>
<tr>
<td>Guided activities</td>
<td>6,0</td>
<td>4.00</td>
</tr>
<tr>
<td>Theory classes</td>
<td>24,0</td>
<td>16.00</td>
</tr>
<tr>
<td>Laboratory classes</td>
<td>12,0</td>
<td>8.00</td>
</tr>
<tr>
<td>Self study</td>
<td>96,0</td>
<td>64.00</td>
</tr>
</tbody>
</table>

**Total learning time:** 150 h

CONTENTS

**Convex Optimization basics**

**Description:**
In this topic we will introduce the main concepts of non-linear optimization with special emphasis in convex optimization. Specifically we will see: convex sets, convex functions, convex optimization problems (COP) and duality (Lagrange dual function, KKT optimality conditions), methods for solving COP’s (General Descent Methods, Interior Point Methods)

**Applications to machine learning topics**

**Description:**
Examples of how optimization is applied in the field of machine learning in computer networks and distributed networks. Specifically, we will explain supervised methods such as multiple linear regression with regularization (ridge regression and lasso), nearest neighboring methods, kernel regression (RKHS) and Gaussian processes, support vector machines, bootstrapping, random forest, and unsupervised methods such as clustering methods with k-means, hierarchical clustering, mixture of Gaussians and the expectation maximization algorithm.

**Neural networks and deep learning**

**Description:**
In this chapter we study the basic concepts related to neural networks and deep learning applied to computer networks and distributed systems. Specifically, introduction to neural networks, back propagation algorithm, SGD, regularization techniques and review of the most important NN architectures.

ACTIVITIES

**Convex Optimization basics**

**Specific objectives:**
1, 2, 3

**Full-or-part-time:** 20h
Theory classes: 20h
### Applications to machine learning topics

**Specific objectives:**
3, 4

**Full-or-part-time:** 18h  
Theory classes: 18h

### Neural networks and deep learning

**Specific objectives:**
3, 6

**Full-or-part-time:** 12h  
Theory classes: 12h

### Programming project for the optimisation of a media access control protocol (MAC) in a wireless sensor network,

**Specific objectives:**
3

**Full-or-part-time:** 26h  
Theory classes: 1h  
Self study: 25h

### Sensor calibration project using machine learning techniques (MLR, KNN, SVR, RF, GP),

**Specific objectives:**
5

**Full-or-part-time:** 42h  
Theory classes: 2h  
Self study: 40h

### Project on neural networks and deep learning

**Specific objectives:**
7

**Full-or-part-time:** 25h  
Self study: 25h

### Project on programming exercises on non-linear optimization

**Specific objectives:**
1, 2

**Full-or-part-time:** 11h  
Theory classes: 1h  
Self study: 10h
Delivery of project on programming exercises on non-linear optimization

Specific objectives:
1, 2

Delivery of the programming project for the optimisation of a media access control protocol (MAC) in a wireless sensor network,

Specific objectives:
2, 3

Delivery of the sensor calibration project using machine learning techniques (MLR, KNN, SVR, RF, GP),

Specific objectives:
3, 4, 5

Delivery of the project using a neural network

Specific objectives:
3, 6, 7

GRADING SYSTEM

The evaluation is based on the development of several projects. Each of the projects will be evaluated (0=<mark=<10) and weighted according to the complexity of the project. The final mark for the course (FM) will be:

FM = \sum_{i} (W_i \cdot M_i)

Where:

W_i = is the weight of each project i = 1, ..., N
M_i = is the mark of each project i = 1, ..., N

The number of projects may vary over time, but in general the following projects are foreseen:
* P1 (10%): Programming of non-linear optimisation exercises,
* P2 (25%) Programming project for the optimisation of a media access control protocol (MAC) in a wireless sensor network,
* P3 (40%): Sensor calibration project using machine learning techniques (MLR, KNN, SVR, RF, GP),
* P4 (25%): Project using a neural network

BIBLIOGRAPHY

Basic:
RESOURCES

Hyperlink:
- http://www.stanford.edu/~boyd/cvxbook/
- https://www.deeplearningbook.org