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

Last modified: 04/02/2025

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: 2024 **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.

Generical:
CG3. Capacity for mathematical modeling, calculation and experimental designing in technology and companies engineering centers, particularly in research and innovation in all areas of Computer Science.

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.

Basic:
CB6. Ability to apply the acquired knowledge and capacity for solving problems in new or unknown environments within broader (or multidisciplinary) contexts related to their area of study.
CB8. Capability to communicate their conclusions, and the knowledge and rationale underpinning these, to both skilled and unskilled public in a clear and unambiguous way.

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

Type	Hours	Percentage
Hours large group	54,0	36.00
Self study	96,0	64.00

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 cluttering methods with k-means, hierarchical clustering, mixture of Gaussians and the expectation maximization algorithmm.

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 including multilayer perceptron (MLP), convolutional neural networks (CNN), recurrent neural networks(RNN) and autoencoders.

ACTIVITIES

Convex Optimization basics

Specific objectives:
1, 2, 3

Related competencies :
CB8. Capability to communicate their conclusions, and the knowledge and rationale underpinning these, to both skilled and unskilled public in a clear and unambiguous way.
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Full-or-part-time: 33h
Self study: 15h
Theory classes: 18h

Applications to machine learning topics

Specific objectives:
3, 4

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Neural networks and deep learning

Specific objectives:
3, 6

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Delivery of project on programming exercises on non-linear optimization

Specific objectives:
1, 2

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Full-or-part-time: 12h
Self study: 12h

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

Specific objectives:
2, 3

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Full-or-part-time: 12h
Self study: 12h

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

Specific objectives:
3, 4, 5

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Full-or-part-time: 13h
Self study: 13h

Delivery of the project using a neural network

Specific objectives:
3, 6, 7

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Full-or-part-time: 14h
Self study: 14h

GRADING SYSTEM

The evaluation is based on the development of 4 projects (each project is worth the same) and 2 written exams. The final grade for the course (FM) will be:

FM = 0.6*(P1+P2+P3+P4) + 0.15*Ex1 + 0.25*Ex2.

For each project, a research report is submitted where the proposed problem is analysed, the resolution methodology is described and the results and conclusions are described. Students will be assessed on their ability to demonstrate understanding and comprehension of the theory, ability to reason and communicate results (competences CG3, CEE2.2, CEE2.3, CEE2.1, CB8, CTR6).

In the written exams, they will be given a list of theoretical concepts related to the subject topics on which they have to demonstrate an understanding and comprehension. In the exam they will be asked to explain their understanding of these concepts (competences CG3, CEE2.3, CB6, CTR6).

BIBLIOGRAPHY

Basic:
- Bishop, Christopher M. Pattern recognition and machine learning. New York: Springer, 2006. ISBN 0387310738.
- Theodoridis, S. Machine learning : a bayesian and optimization perspective. 2nd ed. London: Elsevier Academic Press, 2020. ISBN 9780128188033.
- Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron. Deep learning. Cambridge, Massachusetts: The MIT Press, [2016]. ISBN 9780262035613.

RESOURCES

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