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

Last modified: 02/02/2024

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: 2023 **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

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 :
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.
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.

Full-or-part-time: 20h
Theory classes: 20h

Applications to machine learning topics

Specific objectives:
3, 4

Related competencies :
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.
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.

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

Neural networks and deep learning

Specific objectives:
3, 6

Related competencies :
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.
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.

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

Related competencies :
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.
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.

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

Related competencies :
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.
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.

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

Project on neural networks and deep learning

Specific objectives:
7

Related competencies :
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.
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.

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

Project on programming exercises on non-linear optimization

Specific objectives:
1, 2

Related competencies :
CEE2.3. Capability to understand models, problems and mathematical tools to analyze, design and evaluate computer networks and distributed systems.
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.

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

Related competencies :
CEE2.3. Capability to understand models, problems and mathematical tools to analyze, design and evaluate computer networks and distributed systems.
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.

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

Specific objectives:
2, 3

Related competencies :
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.
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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.

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

Specific objectives:
3, 4, 5

Related competencies :
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.
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.

Delivery of the project using a neural network

Specific objectives:
3, 6, 7

Related competencies :
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.
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.

GRADING SYSTEM

The evaluation is based on the development of several projects. Each of the projects will be evaluated (0=
FM = Sum_i (Wi*Mi)

Where:

Wi = is the weight of each project i = 1, ... N
Mi = 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:
- Bishop, Christopher M. Pattern recognition and machine learning. New York: Springer, 2006. ISBN 0387310738.
- Theodoridis, S. Machine learning : a bayesian and optimization perspective [on line]. 2nd ed. London: Elsevier Academic Press, 2020 [Consultation: 08/03/2024]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=6118601. ISBN 9780128188033.
- Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron. Deep learning [on line]. Cambridge, Massachusetts: The MIT Press, [2016] [Consultation: 08/03/2024]. Available on: https://www.deeplearningbook.org/. ISBN 9780262035613.

RESOURCES

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