Course guides
230584 - ML - Machine Learning on Classical and Quantum Data

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Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS (Syllabus 2010). (Optional subject).

Academic year: 2020 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Lewenstein, Maciej

Others: Alexandre Dauphin
Partick Huembeli
Gorka Muñoz

TEACHING METHODOLOGY

- Lectures
- Activities: - Practicals on machine learning algorithms and quantum simulations
- Seminars

LEARNING OBJECTIVES OF THE SUBJECT

Machine learning is becoming an indispensable life skill with countless applications in any field where data is available. In this course, we will start by presenting history of neural network and machine learning methods. We will discuss attractor neural networks and their storage capacity, as well as feed forward multi-layer neural networks and back propagation algorith. We will make a general introduction to machine learning methods. In the second part of the course 3 four hours long seminars will take place in which the state-of-the-art methods of machine leanirng and neural networks will be presented and discussed with details: including feedforward convolution neural networks and recurrent networks. We will put an emphasis on hands-on training on real-life problems. We will discuss the major learning paradigms (supervised, unsupervised, generative, and reinforcement learning) as well as the main types of data (structured, semi-structured, an unstructured). Concrete examples will concern pattern recognition in bio-photonics, recognition of quantum phases and phase transitions, etc.

The pace of development in quantum technologies is akin to the rapid advances made in machine learning. It is natural to ask whether quantum resources could boost learning algorithms: this field of enquiry is called quantum-enhanced machine learning. Recent progress indicates that current and near-future quantum technologies have tangible benefits for machine learning. The second half of the course will focus on these methods, demonstrating the difficulty of the problems by classical simulations. In the last 4 hours we will try to address the question of if quantum neural networks and machine leanring can be realized with cold atoms and ions.

STUDY LOAD

Type	Hours	Percentage
Hours large group	24,0	32.00
Self study	51,0	68.00

Total learning time: 75 h

CONTENTS

Part 1: Machine learning on classical data

Description:
1. Introduction to machine learning. What makes a good hypothesis and the problem of generalization. Shallow architectures and feature engineering.
2. Deep learning. Feedforward neural networks, convolutional layers. Image classification.
3. Deep learning with recurrent neural networks. Long short-term memory and text generation.
4. Unsupervised learning and manifold embedding. Debugging neural networks.
5. Reinforcement learning.

Full-or-part-time: 14h 30m
Theory classes: 7h 30m
Guided activities: 7h

Part 2: Quantum-enhanced machine learning

Description:
1. Thermal state sampling protocols and probabilistic methods.
2. Discrete optimization on quantum hardware.
3. Coherent quantum protocols.

Full-or-part-time: 8h
Theory classes: 4h
Guided activities: 4h

GRADING SYSTEM

- Homework assessments (50%)
- Written exam (35%)
- Oral presentation of a scientific journal paper (15%)

BIBLIOGRAPHY

Basic:
- Hastie, T.; Tibshirani, R. & Friedman, J.. The Elements of statistical learning: data mining, inference, and prediction [on line]. New York: Springer, 2009 [Consultation: 21/05/2020]. Available on: http://dx.doi.org/10.1007/978-0-387-84858-7. ISBN 9780387848570.
- Murphy, K.P. Machine learning: a probabilistic perspective [on line]. Cambridge, MA: MIT Press, 2012 [Consultation: 16/10/2019]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=3339490. ISBN 9780262018029.
- Wittek, P.. Quantum machine learning: what quantum computing means to data mining. Elsevier, 2016. ISBN 9780128100400.