



Course guide

230584 - ML - Machine Learning on Classical and Quantum Data

Last modified: 24/05/2024

Unit in charge: Barcelona School of Telecommunications Engineering

Teaching unit: 1004 - UB - (ENG)Universitat de Barcelona.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).

Academic year: 2024 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here:
<https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura>

Others: Consultar aquí / See here:
<https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma>

TEACHING METHODOLOGY

- Lectures
- Practicals on machine learning algorithms and 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 algorithm. 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 learning 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 learning 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

1. A Practical Introduction to Neural Networks

Description:

- 1.1 Neural networks as function approximators
- 1.2 Layout of neural networks
- 1.3 Training: cost function and stochastic gradient descent
- 1.4 Backpropagation
- 1.5 Applications: Image recognition etc
- 1.6 Unsupervised learning

Full-or-part-time: 10h

Theory classes: 10h

2. Advanced Concepts

Description:

- 2.1 Reinforcement learning;
- 2.2 Networks with memory;
- 2.3 Boltzmann machine

Full-or-part-time: 6h

Theory classes: 6h

3. Applications of Neural Networks and Machine Learning for Quantum Devices

Description:

- 3. Applications of Neural Networks and Machine Learning for Quantum Devices

Full-or-part-time: 4h

Theory classes: 4h

4. Towards Quantum-Enhanced Machine Learning

Description:

- Towards Quantum-Enhanced Machine Learning

Full-or-part-time: 4h

Theory classes: 4h

GRADING SYSTEM

- Homework assessments and quizzes (45%)
- Final exam (45%)
- Oral presentation and participation (10%)



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: 18/07/2023]. Available on: <https://link-springer-com.recursos.biblioteca.upc.edu/book/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.