# Course guide
# 230584 - ML - Classical and Quantum Machine Learning

**Last modified:** 27/05/2026

**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:** 2026 **ECTS Credits:** 3.0 **Languages:** English

## LECTURER

**Coordinating lecturer:** DAVID MALUENDA NIUBÓ

**Others:** Segon quadrimestre:
ALESSIO CELI - 10
DAVID MALUENDA NIUBÓ - 10

## DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

**Specific:**
CE2. Demonstrate the understanding of the peculiarities of the quantum model for light-matter interaction.
CE9. Ability to synthesize and present photonics research results according to the procedures and conventions of scientific presentations in English.

**Generical:**
CG1. Ability to project, design and implement products, processes, services and facilities in some areas of photonics, such as photonic engineering, nanophotonics, quantum optics, telecommunications and biophotonics.
CG2. Ability to modeling, calculate, simulate, develop and implement in research and technological centers and companies, particularly in research, development and innovation tasks in all areas related to Photonics.
CG4. Ability to understand the generalist and multidisciplinary nature of photonics, seeing its application, for example, to medicine, biology, energy, communications or industry

**Transversal:**
CT1. ENTREPRENEURSHIP AND INNOVATION. Knowing and understanding the mechanisms on which scientific research is based, as well as the mechanisms and instruments for transferring results between the different socioeconomic agents involved in R&D&I processes.
CT3. TEAMWORK. Be able to work as a member of an interdisciplinary team, either as another member, or performing management tasks in order to contribute to developing projects with pragmatism and a sense of responsibility, assuming commitments taking into account the available resources.
CT4. SOLVENT USE OF INFORMATION RESOURCES. Manage the acquisition, structuring, analysis and visualization of data and information in the field of the specialty and critically assess the results of this management.
CT5. ENGLISH. Accredit an adequate level of this language, both orally and in writing, in line with the needs that the graduates will have.

**Basic:**
CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of ¿¿study.
CB8. Students should be able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgment.
CB10. Students should possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

## 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 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

### 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 recogniction 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

F: Final project (base grade)
L: Weekly practical exercises (grade boost, up to 50%)

The final grade is computed as F + 0.5L(1-F)

## BIBLIOGRAPHY

**Basic:**
- Hastie, T.; Tibshirani, R. & Friedman, J.. The Elements of statistical learning: data mining, inference, and prediction [on line]. 2nd ed. New York: Springer, 2009 [Consultation: 10/09/2025]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-0-387-84858-7. ISBN 0387952845.
- 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.