# Course guide
# 230856 - MLN - Machine Learning with Neural Networks

**Last modified:** 14/12/2023

**Unit in charge:** Barcelona School of Telecommunications Engineering
**Teaching unit:** 723 - CS - Department of Computer Science.

**Degree:** MASTER'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2018). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN BIO & PHARMACEUTICAL MATERIALS SCIENCE (Syllabus 2021). (Optional subject).

**Academic year:** 2023 **ECTS Credits:** 4.0 **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

## PRIOR SKILLS

Strong Mathematical ans Statistical background
Basic programming skills

## REQUIREMENTS

None

## DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

**Basic:**
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

MD1 - Master classes: The contents of the course are exposed in the classroom by a teacher without the active participation of the students.
MD4 - Group work: Learning activity that has to be done through collaboration between the members of a group.
MD6 - Problem solving: In the problem solving activity, the teaching staff presents an exercise / problem that the students must solve, whether working individually or in a team.
MD8 - Search for information: The search for information, organized as actively seeking information on the part of the students, allows the acquisition of knowledge directly, but also the acquisition of skills and attitudes related to the obtaining of information.
MD10 - Practice: They allow to apply and configure, at a practical level, the theory of a field of knowledge in a specific context.

## LEARNING OBJECTIVES OF THE SUBJECT

- Neural Networks Introduction
- Introduction to Machine Learning
- Introduction to multi-layer perceptrons
- To know the Backpropagation learning algorithm
- To face the student with the practical problems implied in using a neural network
- To understand the Rosenblatt Perceptron
- To understand how the basic ideas of the Perceptron can be extended to more sophisticated machines: The Support Vector Machines
- To understand Convolutional Neural Networks
- To learn how to solve practical problems that may appear in the training of Neural Networks
- To understand the difference between a recurrent network and a feed-forward network
- To understand the Hopfield model as a simple example of a recurrent network
- To understand the Boltzmann Machines (BM) and the concept of learning a distribution of probability
- To understand the Boltzmann Restricted Machines (RBM) and the advantages they have over BMs
- To know the Contrastive Divergence learning algorithm to train RBMs
- To understand the connection between BMs and some relevant physical systems
- To understand the management of sequential data by means of Recurrent Networks
- To relate the previously mentioned models to Deep Learning.

## STUDY LOAD

| Type | Hours | Percentage |
|---|---|---|
| Hours large group | 36,0 | 36.00 |
| Self study | 64,0 | 64.00 |

**Total learning time:** 100 h

## CONTENTS

### General Concepts of Learning and Neural Networks

**Description:**
Students will receive general knowledge related to neural networks, that is, the knowledge common to any type of network, plus the biological and mathematical justification of these concepts. The classification of neural networks will be motivated and the different networks will be described in general terms. The basic concepts of machine learning and its specific implementation associated with neural networks are described (the functionality of a network is achieved through the learning of the network, given some data associated with a specific problem).

**Specific objectives:**
- Understanding the concept of Neural Network and where it comes from
- Understanding the different types of network
- Understanding the concept of Machine Learning and its experimental particularities
- Understanding how Machine Learning relates to neural networks and how they are implemented

**Related activities:**
The Formal Neuron and Neuronal Networks: Introduction
General Machine Learning Issues
Laboratory: Fundamentals of Python and Introduction to practices: BP and CD-k

**Full-or-part-time:** 8h
Theory classes: 5h
Self study : 3h

**Feed-forward Neural Networks: Multi-layer Perceptrons, Support Vector Machines and Convolutional Networks.**

**Description:**
This first block of the course will revolve around feed-forward networks and the Backpropagation training algorithm. The three most commonly used architectures will be explained: The Perceptron and its generalization (Support Vector Machines), the multi-layer perceptrons and the convolutional networks. We will emphasize the practical aspects of the subject matter, putting much detail on the problems that may appear when training these networks with real problems. A practice related to the content of this block will be assessed.

**Specific objectives:**
- Introduction to multi-layer perceptions
- Detail the Backpropagation learning algorithm so that students can implement it
- To face the student with the practical problems implied in using a neural network
- Understanding the Rosenblatt Perceptron
- Understanding how the basic ideas of the Perceptron can be extended to more sophisticated machines: The Support Vector Machines
- Offering a detailed explanation of Convolutional Neural Networks
- Show how to solve practical problems that may appear in the training of Neural Networks

**Related activities:**
- Multilayer Perceptrons and Backpropagation
- Laboratory: Practical work Backpropagation
- Perceptron and Support Vector Machines
- Convolutional Neural Networks
- Experimental Issues

**Full-or-part-time:** 45h
Theory classes: 15h
Self study : 30h

**Recurrent Neural Networks: Hopfield networks, Boltzmann Machines and LSTM**

**Description:**
This second block of the course will focus on recurrent networks, where we will see Hopfield networks and Boltzmann Machines as classic examples of recurrent network and Restricted Boltzmann Machines (RBM) and the LSTM as examples of networks used in practical problems. A practical work will be done on RBMs learning algorithm, called Contrastive Divergence (CD-k).

**Specific objectives:**
- To understand the difference between a recurrent network and a feed-forward network
- To understand the Hopfield model as a simple example of a recurrent network
- To understand the Boltzmann Machines (BM) and the concept of learning a distribution of probability
- To understand the Boltzmann Restricted Machines (RBM) and the advantages they have over BMs
- To understand the details of the Contrastive Divergence algorithm to train RBMs
- To understand the management of sequential data by means of LSTMs
- To relate the previously mentioned models to Deep Learning

**Related activities:**
Hopfield Networks
Máquinas de Boltzmann y Contrastive-Divergence
Laboratory: Practical work CD-k
LSTM Networks
Deep Learning: Introduction

**Full-or-part-time:** 39h
Theory classes: 13h
Self study : 26h

## GRADING SYSTEM

There will be a final exam.
The mark of the course will be that of the final exam, possibly moderated by laboratory practical works and/or a final report depending on the course evolution.
There will be no re-evaluation.

## EXAMINATION RULES.

Will be decided along the course

## BIBLIOGRAPHY

**Basic:**
- Graves, A. Supervised sequence labelling with recurrent neural networks [on line]. Berlin, Heidelberg: Springer, 2012 [Consultation: 07/06/2021]. Available on: http://dx.doi.org/10.1007/978-3-642-24797-2. ISBN 978-3-642-24796-5.
- Goodfellow, I.; Bengio, Y.; Courville, A. Deep learning [on line]. Cambridge, Massachusetts: MIT Press, 2016 [Consultation: 19/10/2022]. Available on: http://www.deeplearningbook.org/. ISBN 978-0262035613.
- Hertz, J.; Krogh, A.; Palmer, R.G. Introduction to the theory of neural computation. Redwood City: Addison-Wesley, 1991. ISBN 0201503956.
- Bishop, C.M. Neural networks for pattern recognition. Oxford: Clarendon Press, 1995. ISBN 0198538642.
- Coolen, A.C.C.; Kühn, R.; Sollich, P. Theory of neural information processing systems. Oxford: Oxford University Press, 2005. ISBN 9780198530244.

## RESOURCES

**Hyperlink:**
- Curs Xarxes Neuronals (Hugo Larochelle). https://www.youtube.com/watch?v=SGZ6BttHMPw&list=PL6Xpj9I5qXYEcOhn7TqghAJ6NAPrNmUBH

**Other resources:**
None