COMILLAS
UNIVERSIDAD PONTIFICIA
ICAI ICADE CIHS

COURSE SYLLABUS 2025-2026

GENERAL INFORMATION

Course information	
Name	Deep Learning
Code	DTC-MIINT-512
Main program	Official Master's Degree in Industrial Engineering
Offered in	Máster Universitario en Ingeniería Industrial + Máster en Industria Inteligente [2nd year] Máster en Industria Inteligente [1st year]
Level	Master's Degree
Semester	1st (Fall)
Credits	6.0 ECTS
Type	Elective (MII), Compulsory (MIINT)
Department	Telematics and Computer Science
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Instructor	
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COURSE SPECIFIC INFORMATION

Contextualization of the course

Contribution to the professional profile of the degree

Currently, artificial intelligence (AI) techniques are found in all types of applications, among which those related to industry stand out. Their implementation and development involve a relatively low cost and minimum time provided that you have the appropriate knowledge and, therefore, the demand for professionals with this profile is growing at a rate that cannot be satisfied today.

This subject prepares the student to develop, implement, and analyze some of the most advanced AI systems currently available, including image classifiers, as well as forecasting models based on time series. This knowledge is presented in three major blocks: learning with shallow and deep neural networks, convolutional neural networks, and recurrent neural networks.

Python is the vehicular programming language and is mainly supported by PyTorch.

Prerequisites

This subject requires solid foundations of machine learning as well as statistics, calculus, and algebra. Knowledge of Python, Git, and data science environments is desirable but not mandatory.

Competences[1] - Objectives

Competences

General

CG1.	Have acquired advanced knowledge and demonstrated, in a research and technological or highly specialized context, a detailed and well-founded understanding of the theoretical and practical aspects, as well as of the work methodology in one or more fields of study. *Haber adquirido conocimientos avanzados y demostrado, en un contexto de investigación científica y tecnológica o altamente especializado, una comprensión detallada y fundamentada de los aspectos teóricos y prácticos y de la metodología de trabajo en uno o más campos de estudio.*
CG2.	Know how to apply and integrate their knowledge, understanding, scientific rationale, and problem-solving skills to new and imprecisely defined environments, including highly specialized multidisciplinary research and professional contexts. *Saber aplicar e integrar sus conocimientos, la comprensión de estos, su fundamentación científica y sus capacidades de resolución de problemas en entornos nuevos y definidos de forma imprecisa, incluyendo contextos de carácter multidisciplinar tanto investigadores como profesionales altamente especializados.*
CG3.	Know how to evaluate and select the appropriate scientific theory and the precise methodology of their fields of study in order to formulate judgements based on incomplete or limited information, including, when necessary and pertinent, a discussion on the social or ethical responsibility linked to the solution proposed in each case. *Saber evaluar y seleccionar la teoría científica adecuada y la metodología precisa de sus campos de estudio para formular juicios a partir de información incompleta o limitada incluyendo, cuando sea preciso y pertinente, una reflexión sobre la responsabilidad social o ética ligada a la solución que se proponga en cada caso.*
CG4.	Be able to predict and control the evolution of complex situations through the development of new and innovative work methodologies adapted to the scientific/research, technological or specific professional field, in general multidisciplinary, in which they develop their activity. *Ser capaces de predecir y controlar la evolución de situaciones complejas mediante el desarrollo de nuevas e innovadoras metodologías de trabajo adaptadas al ámbito científico/investigador, tecnológico o profesional concreto, en general multidisciplinar, en el que se desarrolle su actividad.*
CG5.	Be able to transmit in a clear and unambiguous manner, to specialist and non-specialist audiences, results from scientific and technological research or state-of-the-art innovation, as well as the most relevant foundations that support them. *Saber transmitir de un modo claro y sin ambigüedades, a un público especializado o no, resultados procedentes de la investigación científica y tecnológica o del ámbito de la innovación más avanzada, así como los fundamentos más relevantes sobre los que se sustentan.*
CG6.	Have developed sufficient autonomy to participate in research projects and scientific or technological collaborations within their thematic area, in interdisciplinary contexts and, where appropriate, with a high knowledge transfer component. *Haber desarrollado la autonomía suficiente para participar en proyectos de investigación y colaboraciones científicas o tecnológicas dentro de su ámbito temático, en contextos interdisciplinares y, en su caso, con una alta componente de transferencia del conocimiento.*
CG7.	Being able to take responsibility for their own professional development and their specialization in one or more fields of study. *Ser capaces de asumir la responsabilidad de su propio desarrollo profesional y de su especialización en uno o más campos de estudio.*

[1] Competences in English are a free translation of the official Spanish version.

Specific	
CE3.	Be able to design and train systems that learn automatically, mastering both supervised and unsupervised learning techniques. Understand the potential application of these systems in the improvement of industrial processes, relations with clients, etc. *Ser capaces de diseñar y entrenar sistemas que aprendan de manera automática, dominando tanto las técnicas de aprendizaje supervisado como no supervisado. Entender el potencial de aplicación de estos sistemas en la mejora de procesos industriales, relación con clientes, etc.*
Learning outcomes	
RA1.	Understand the mathematical foundations that support deep learning algorithms.
RA2.	Be able to implement shallow and deep neural networks with PyTorch.
RA3.	Know how to use the AutoDiff framework to build deep learning models.
RA4.	Apply convolutional neural networks to solve image classification problems, both building the model from scratch and through transfer learning from a pretrained model.
RA5.	Design and implement advanced time series forecasting systems and apply them to different fields of knowledge.
RA6.	Be aware of the latest trends in deep learning.

CONTENTS

Contents
Theory
Unit 1. Deep learning frameworks
1.1 Introduction to PyTorch 1.2 Introduction to vectorized computing 1.3 Introduction to Autograd
Unit 2. Foundations of neural networks
2.1 Types of neural networks 2.2 General problem statement 2.3 Foundations 2.4 Classification and regression 2.5 Activation functions 2.6 Loss functions
Unit 3. Convolutional neural networks (CNN)
3.1 Introduction 3.2 Image ingestion 3.3 Convolution 3.4 Data augmentation 3.5 Transfer learning
Unit 4. Optimization and regularization
4.1 Introduction to optimization algorithms 4.2 Regularization 4.3 Dropout 4.4 Normalization

Unit 5. Recurrent neural networks (RNN)

5.1 Introduction
5.2 Basic concepts
5.3 Core architectures (RNN)
5.4 Long short-term memory (LSTM)
5.5 Gated recurrent unit (GRU)
5.6 Applications: Time series forecasting (LSTM, GRU)
5.7 Applications: Natural language processing (LSTM, GRU)

Unit 6. Advanced deep learning

6.1 Introduction
6.2 Basic concepts
6.3 Variational deep learning
6.4 Generative adversarial networks (GAN)
6.5 Attention
6.6 Current trends in natural language processing
6.7 Current trends in computer vision

Laboratory

Lab 1. Introduction to deep learning

In this first lab assignment, the student will learn the fundamentals of PyTorch and deep learning. They will address a basic problem with deep learning, having an overview of the different parts of a project.

Lab 2. Convolutional neural networks (CNN)

In this assignment, students will learn about CNNs, how to use them, and how to address an image project, exploring the processing of the data and how we can tune and optimize a model.

Lab 3. Optimization and regularization

In this lab students will learn about optimization and regularization techniques. They will have a complete set of tools that they can use to enhance the performance of the models.

Lab 4. Recurrent neural networks (RNN)

In this lab students will dive into recurrent neural networks (RNNs) addressing a forecasting problem. Moreover, the difference in dataset processing, optimization and regularization with these models will be studied.

Lab 5. Natural language processing (NLP)

In this final lab assignment, students will be able to combine the knowledge they have gained in deep learning and apply it in the natural language processing (NLP) domain, in a real application.

TEACHING METHODOLOGY

General methodological aspects	
The methodology of this course is inspired by the "learning by doing" paradigm. All units will incorporate a practical component during or after the lectures. The knowledge acquired will be evaluated at the end of each unit with graded quizzes.	
In-class activities	**Competences**
▪ **Lectures:** Theoretical sessions will introduce the fundamental aspects to be mastered in each unit. These sessions will be complemented with practical examples. Active participation is expected from the students, who will finally show their mastery of the subject by solving theoretical and practical cases.	CG1, CG3, CE3
▪ **Lab sessions:** Organized in small groups and under the supervision of the instructor, students will learn how to build deep learning models using PyTorch. Every individual will be required to contribute to the solution of the problem. Whenever possible, once the essence of the problem has been unraveled, the different groups will compete to achieve the best model.	CG2, CG3, CG4, CG5, CG6, CG7, CE3
▪ **Tutoring** for groups or individual students will be organized upon request.	–
Out-of-class activities	**Competences**
▪ Study and understand the material covered in class and complement it with additional recommended bibliography.	CG1, CG3, CE3
▪ Resolution of exercises proposed during the sessions.	CG1, CG3, CE3

STUDENT WORK-TIME SUMMARY

IN-CLASS HOURS	
Lectures	**Lab sessions**
30	30
OUT-OF-CLASS HOURS	
Self-study	**Lab preparation and model refinement**
60	60
ECTS credits:	**6.0 (180 hours)**

EVALUATION AND GRADING CRITERIA

The use of AI to produce entire assignments or significant parts of them, without citing the source or tool used, or without explicit permission in the assignment description, will be considered plagiarism and will be subject to the University's General Regulations.

Evaluation activities	Grading criteria	Weight
Mini tests	▪ Understanding of the theoretical concepts.	15%
Midterm	▪ Theoretical concepts (50%). ▪ Coding exercises (50 %).	20%
Final exam	An overall mark of at least 4 out of 10 is required to pass the course. ▪ Theoretical concepts (50%). Minimum grade of 4 out of 10 points. ▪ Coding exercises (50%). Minimum grade of 4 out of 10 points.	40%
Lab assignments	▪ Application of theoretical concepts to real problem-solving. ▪ Ability to use and develop deep learning software. ▪ Attitude and effort: Initiative and proactive work will be encouraged ▪ Teamwork.	25%

Grading

Regular assessment

To pass the course, students must achieve a weighted average grade of at least 5 out of 10 points, obtain a minimum of 4 out of 10 on the final exam, and earn at least 4 out of 10 in each exam block (theory and coding exercises). If these conditions are not met, the final grade will correspond to the lowest value among the weighted average and the scores of the exam blocks.

Retake

There will be a retake exam that will replace the final exam of the regular assessment period. All the remaining marks will be preserved. The final grade will be computed as in the regular assessment period and under the same restrictions.

Course rules

- Class attendance is mandatory according to Article 93 of the General Regulations (Reglamento General) of Comillas Pontifical University and Article 6 of the Academic Rules (Normas Académicas) of the ICAI School of Engineering. Not complying with this requirement may have the following consequences:
  - Students who fail to attend more than 15% of the lectures may be denied the right to take the final exam during the regular assessment period.
  - Regarding laboratory, absence to more than 15% of the sessions can result in losing the right to take the final exam of the regular assessment period and the retake. Missed sessions must be made up for credit.
- Students who commit an irregularity in any graded activity will receive a mark of zero in the activity and disciplinary procedures will follow (cf. Article 168 of the General Regulations (Reglamento General) of Comillas Pontifical University).

Guidelines for the use of generative artificial intelligence (AI)

- **Exams.** The use of generative artificial intelligence models or programming assistants is strictly prohibited in the exams. These activities must reflect exclusively the student's own knowledge and individual work.
- **Laboratory.** The use of AI-based programming assistants and generative language models is permitted under the following conditions:
  - These tools may be used as support for understanding technical concepts, obtaining suggestions on how to approach the proposed exercises, and generating code snippets or initial drafts of reports.
  - Their use must always be complementary and must not replace the student's individual work. Submitting automatically generated content as one's own, without proper understanding, review, and adaptation, is not allowed.
  - Any relevant content generated wholly or partially using these tools must be explicitly cited, clearly indicating which parts were generated with AI and which tools were used. The sequence of prompts must be included as an annex at the end of the report.
  - Instructors reserve the right to ask oral questions regarding content generated with AI assistance to assess the student's understanding. Failure to explain or justify such content may negatively impact the grade for the activity.

  The responsible use of these tools is encouraged as a means of supporting individual study (e.g., to clarify concepts, generate additional exercises, or receive feedback). However, students should be aware that responses generated by AI models may contain errors, and it is their responsibility to critically assess and verify the information provided.

WORK PLAN AND SCHEDULE

Activities	Date/Periodicity	Deadline
Mini tests	At the end of every unit	–
Midterm	Mid-October	–
Final exam	After the lecture period	–
Review and self-study of the concepts covered in the lectures	After each lesson	–
Lab sessions	Weekly	–

BIBLIOGRAPHY AND RESOURCES

Basic references

- Slides and videos prepared by the lecturer (available in Moodle).
- A. Zhang, Z. C. Lipton, M. Li, and A. J. Smola, *Dive into deep learning*, 1st Ed., Cambridge University Press, 2024. ISBN-13: 978-1-009-38943-3
- F. Chollet, *Deep Learning with Python*, 1st Ed., Manning, 2017. ISBN-13: 978-1-617-29443-3
- E. Stevens, L. Antiga, and T. Viehmann, *Deep Learning with PyTorch*, 1st Ed., Manning, 2020. ISBN-13: 978-1-617-29526-3
- I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*, 1st Ed., MIT Press, 2016. ISBN-13: 978-0-262-03561-3 [Online]. Available: https://www.deeplearningbook.org/

Complementary references

- S. Weidman, *Deep Learning from Scratch: Building with Python from First Principles*, 1st Ed., O'Reilly Media, 2019. ISBN-13: 978-9-352-13902-6
- J. Howard, *Deep Learning for Coders with fastai and PyTorch: AI Applications Without a PhD*, 1st Ed., O'Reilly Media, 2020. ISBN-13: 978-1-492-04552-6