



UNIVERSIDAD
POLITÉCNICA
DE MADRID

PROCESO DE
COORDINACIÓN DE LAS
ENSEÑANZAS PR/CL/001



E.T.S. de Ingenieros de
Telecomunicacion

ANX-PR/CL/001-01

GUÍA DE APRENDIZAJE

ASIGNATURA

93000941 - Aprendizaje Predictivo Y Descriptivo

PLAN DE ESTUDIOS

09AT - Master Universitario En Teoria De La Señal Y Comunicaciones

CURSO ACADÉMICO Y SEMESTRE

2025/26 - Primer semestre

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1. Datos descriptivos

1.1. Datos de la asignatura

Nombre de la asignatura	93000941 - Aprendizaje Predictivo y Descriptivo
No de créditos	6 ECTS
Carácter	Optativa
Curso	Primer curso
Semestre	Primer semestre
Período de impartición	Septiembre-Enero
Idioma de impartición	Inglés/Castellano
Titulación	09AT - Master Universitario en Teoría de la Señal y Comunicaciones
Centro responsable de la titulación	09 - E.T.S. De Ingenieros De Telecomunicacion
Curso académico	2025-26

2. Profesorado

2.1. Profesorado implicado en la docencia

Nombre	Despacho	Correo electrónico	Horario de tutorías *
Eduardo Lopez Gonzalo (Coordinador/a)	C-330	eduardo.lopez@upm.es	Sin horario. Appointment arranged by email
Luis Alfonso Hernandez Gomez	C-330	luisalfonso.hernandez@upm. es	Sin horario. Appointment arranged by email

* Las horas de tutoría son orientativas y pueden sufrir modificaciones. Se deberá confirmar los horarios de tutorías con el profesorado.

3. Conocimientos previos recomendados

3.1. Asignaturas previas que se recomienda haber cursado

El plan de estudios Master Universitario en Teoría de la Señal y Comunicaciones no tiene definidas asignaturas previas recomendadas para esta asignatura.

3.2. Otros conocimientos previos recomendados para cursar la asignatura

- It is mandatory to follow this course simultaneously with the subject Machine Learning Lab
- Previous exposure to a programming language, such as MATLAB, R or Python
- Elementary course in Statistics

4. Competencias y resultados de aprendizaje

4.1. Competencias

CB06 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB07 - Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo

CE01 - Analizar y aplicar técnicas para el diseño y desarrollo avanzado de equipos y sistemas, basándose en la teoría de la señal y las comunicaciones, en un entorno internacional

CE02 - Evaluar y sintetizar los resultados de un trabajo en equipo en proyectos relacionados con la teoría de la señal y las comunicaciones, en un entorno internacional.

CE03 - Valorar y contrastar la utilización de las diferentes técnicas disponibles para la resolución de problemas reales dentro del área de teoría de la señal y comunicaciones.

CT01 - Capacidad para comprender los contenidos de clases magistrales, conferencias y seminarios en lengua inglesa

CT03 - Capacidad para adoptar soluciones creativas que satisfagan adecuadamente las diferentes necesidades planteadas

CT04 - Capacidad para trabajar de forma efectiva como individuo, organizando y planificando su propio trabajo, de forma independiente o como miembro de un equipo

CT05 - Capacidad para gestionar la información, identificando las fuentes necesarias, los principales tipos de documentos técnicos y científicos, de una manera adecuada y eficiente

4.2. Resultados del aprendizaje

RA73 - RA305 - Capability to design, develop and evaluate machine-learning techniques for a wide range of application areas

RA74 - RA336 - Capability to understand, design, develop and evaluate machine-learning, deep-learning and generative AI technologies for a wide range of application areas

5. Descripción de la asignatura y temario

5.1. Descripción de la asignatura

This course covers the principles and methodology for the design, evaluation and selection of a large variety of Machine Learning, Deep Learning and AI technologies for practical applications. The course introduces main principles in Machine Learning: supervised, unsupervised and reinforcement learning, though main emphasis is on predictive and descriptive learning as reinforcement learning is covered in a subsequent course. Methodological issues such as model assessment and selection, and overfitting are discussed.

The course starts introducing the most relevant traditional predictive or supervised techniques: as different types of regression, generalized linear models, k-nearest neighbor classifier, classification and regression trees, ensemble methods (Bagging, Random Forests and Boosting) and kernel methods and Support Vector Machines. Then the

course addresses traditional descriptive or unsupervised techniques: principal components analysis and clustering methods (k-means and hierarchical clustering). In parallel with classical ML, Deep Learning models (Feed-Forward Networks, Convolutional Networks, Recurrent Neural Networks and Transformers) are presented together with new ways of learning (self-supervised, contrastive, zero-shot, in-context, etc.). The course also introduces the main Generative AI models: Autoregressive, VAE, VQ-VAE, GANs, Flow Models, Diffusion models, Consistency Models. Emergent architectures such as Mamba, Kolmogorov-Arnold Networks, etc. are also discussed.

The students will understand the fundamentals and important topics in statistical machine learning, deep learning and artificial intelligence. This outcome represents a fundamental ingredient in the training of a modern AI engineering providing a solid base for its use on a wide range of applications in science and industry.

Through several examples and use cases, worked out in the companion course Machine Learning Lab, students will learn how important is to accurately assess the performance of a model. They will also acquire solid criteria on what could be best model for a given data and task. By the end of the course, students should be able to:

- Understand the fundamentals of the most used models and techniques for predictive and descriptive learning.
- Design a proper methodology for accurately assessing and gaining knowledge from the use of each one of the particular machine learning techniques.
- Know the strengths and weaknesses of the various approaches in order to choose the best models for a given data and application scenario.

5.2. Temario de la asignatura

1. Introduction to Machine Learning
 - 1.1. What is statistical learning?
 - 1.2. Types of Machine Learning
 - 1.3. Assessing Model Accuracy
2. Linear Regression
 - 2.1. Simple and Multiple Linear Regression
 - 2.2. Linear Regression and Distributed Machine Learning Principles
 - 2.3. Interpreting Regression Coefficients
 - 2.4. Model Selection and Qualitative Predictors
 - 2.5. Interactions and Nonlinearity
 - 2.6. Comparison of Linear Regression with KNN
3. Classification
 - 3.1. Logistic Regression
 - 3.2. Bayes classifier and Linear Discriminant Analysis
 - 3.3. Classification error analysis
 - 3.4. Quadratic Discriminant Analysis
 - 3.5. K-Nearest Neighbors
 - 3.6. A Comparison of Classification Methods: Logistic Regression, LDA, QDA and KNN
4. Resampling methods
 - 4.1. Cross-validation
 - 4.2. Bootstrap
5. Linear Model Selection and Regularization
 - 5.1. Feature selection
 - 5.2. Optimal Model selection
 - 5.3. Regularization
 - 5.4. Dimension Reduction
 - 5.5. High-Dimensional Data

6. Moving Beyond Linearity

6.1. Generalized Linear Models and Generalized Additive Models

7. Tree-Based Methods

7.1. Decision trees

7.2. Bagging

7.3. Random Forests

7.4. Boosting

8. Support Vector Machines

8.1. Maximal Margin Classifier

8.2. Support Vector Classifiers

8.3. Kernels and Support Vector Machines

8.4. Relationship to Logistic Regression

9. Descriptive Learning

9.1. Supervised vs Unsupervised learning

9.2. Principal Components Analysis

9.3. Clustering Methods

9.4. K-means

9.5. Hierarchical Clustering

9.6. Practical Issues in Clustering

10. Introduction to Deep Learning

10.1. Feed-forward Networks, Convolutional Networks

10.2. Recurrent Networks and SeqSeq

10.3. Attention Mechanisms and Transformers

10.4. Ablation studies, Interpretability and Explainability

11. Introduction to Deep Generative Models

11.1. Autoregressive Models: Large Language Models and Large Multimodal Models

11.2. VAE, VQ-VAE

11.3. GANs, Flow-based Models

11.4. Diffusion Models and Consistency Models

12. Emergent models and new architectures

6. Cronograma

6.1. Cronograma de la asignatura *

Sem	Actividad tipo 1	Actividad tipo 2	Tele-enseñanza	Actividades de evaluación
1	Activities Chapter 1 Duración: 02:00 LM: Actividad del tipo Lección Magistral Activities Chapter 2 Duración: 02:00 LM: Actividad del tipo Lección Magistral			
2	Activities Chapter 3 Duración: 04:00 LM: Actividad del tipo Lección Magistral			
3	Activities Chapter 4 Duración: 02:00 LM: Actividad del tipo Lección Magistral Activities Chapter 5 Duración: 01:00 LM: Actividad del tipo Lección Magistral Activities Chapter 6 Duración: 01:00 LM: Actividad del tipo Lección Magistral			
4	Activities Chapter 7 Duración: 01:00 LM: Actividad del tipo Lección Magistral Activities Chapter 8 Duración: 03:00 LM: Actividad del tipo Lección Magistral			
5	Activities Chapter 9 Duración: 04:00 LM: Actividad del tipo Lección Magistral			
6	Activities Chapter 10 (10.1 , 10.2) Duración: 04:00 LM: Actividad del tipo Lección Magistral			
7	Activities Chapter 10 (10.3, 10.4) Duración: 04:00 LM: Actividad del tipo Lección Magistral			
8	Activities Use Case Review Duración: 04:00 AC: Actividad del tipo Acciones Cooperativas			
9	Activities Chapter 11 (11.1) Duración: 04:00 LM: Actividad del tipo Lección Magistral			

10	Activities Chapter 11 (11.2) Duración: 04:00 LM: Actividad del tipo Lección Magistral			
11	Activities Chapter 11 (11.3) Duración: 04:00 LM: Actividad del tipo Lección Magistral			
12	Activities Chapter 11 (11.4) Duración: 03:00 LM: Actividad del tipo Lección Magistral Activities Chapter 12 Duración: 01:00 PR: Actividad del tipo Clase de Problemas			
13	Activities Use Case Review Duración: 04:00 AC: Actividad del tipo Acciones Cooperativas			
14	Activities Use Case Review Duración: 04:00 AC: Actividad del tipo Acciones Cooperativas			
15				
16				
17				Final Project Machine Learning Evaluation TI: Técnica del tipo Trabajo Individual Evaluación Progresiva Presencial Duración: 00:15 Final Project Machine Learning Evaluation TI: Técnica del tipo Trabajo Individual Evaluación Global Presencial Duración: 00:15 Final project deep learning evaluation TG: Técnica del tipo Trabajo en Grupo Evaluación Global Presencial Duración: 00:15 Final project deep learning evaluation TG: Técnica del tipo Trabajo en Grupo Evaluación Progresiva Presencial Duración: 00:15

Para el cálculo de los valores totales, se estima que por cada crédito ECTS el alumno dedicará dependiendo del plan de estudios, entre 26 y 27 horas de trabajo presencial y no presencial.

7. Actividades y criterios de evaluación

7.1. Actividades de evaluación de la asignatura

7.1.1. Evaluación (progresiva)

Sem.	Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
17	Final Project Machine Learning Evaluation	TI: Técnica del tipo Trabajo Individual	Presencial	00:15	50%	3.5 / 10	CB06 CB07 CB09 CB10 CT01 CT03 CT04 CT05 CE01 CE02 CE03
17	Final project deep learning evaluation	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:15	50%	3.5 / 10	CB06 CB07 CB09 CB10 CT01 CT03 CT04 CT05 CE01 CE02 CE03

7.1.2. Prueba evaluación global

Sem	Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
17	Final Project Machine Learning Evaluation	TI: Técnica del tipo Trabajo Individual	Presencial	00:15	50%	3.5 / 10	CB06 CB07 CB09 CB10 CT01 CT03 CT04 CT05 CE01 CE02 CE03

17	Final project deep learning evaluation	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:15	50%	3.5 / 10	CB06 CB07 CB09 CB10 CT01 CT03 CT04 CT05 CE01 CE02 CE03
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7.1.3. Evaluación convocatoria extraordinaria

Descripción	Modalidad	Tipo	Duración	Peso en la nota	Nota mínima	Competencias evaluadas
Final Project Machine Learning Evaluation	TI: Técnica del tipo Trabajo Individual	Presencial	00:20	50%	3.5 / 10	CB06 CB07 CB09 CB10 CT01 CT03 CT04 CT05 CE01 CE02 CE03
Final project Deep Learning evaluation	TG: Técnica del tipo Trabajo en Grupo	Presencial	00:20	50%	3.5 / 10	CB06 CB07 CB09 CB10 CT01 CT03 CT04 CT05 CE01 CE02 CE03

7.2. Criterios de evaluación

Evaluation will assess if students have acquired all the competences of the subject. Thus, evaluation through extraordinary assessment will be carried out considering all the evaluation techniques used in ordinary evaluation (EX, ET, TG, etc.).

Progressive evaluation will be the preferred assessment method as it will be suited to the optimum learning process along the course. Progressive evaluation will consist

of:

- A Machine Learning Report describing the activities that demonstrate skills in developing Machine Learning models. The evaluation of this Report will represent 50% of final grade. For progressive evaluation, this report must be due by the 9th week. Several course assignments, which will be announced in Moodle, will be planned to review the students' progress through draft versions of their reports so we can give them feedback. We could also require students to prepare specific presentations to review their work.

- A Deep Learning Report must be prepared by the end of the course to demonstrate skills in developing Deep Learning models. The evaluation of this Deep Learning Report will represent 50% of final grade.

Through several course assignments, announced in Moodle, we will review the students' progress while working in this Report. We could require students to attend to specific presentations to review their work.

Deep Learning activities must be developed in working teams, but each team member must individually clearly describe her/his specific activities in the Report.

One group project subject could be in the form of a challenge in quantitative finance, which may include:

- (1) Quantification of patterns in leading market indicators
- (2) Quantification of patterns in market value.
- (3) Quantification of seasonality in the main market indicators
- (4) Quantification of intra- and inter-day patterns, volatility, etc.

Students in groups of two may request the challenge. The challenge statement will be published at the beginning of the course, including a calendar that will be in accordance

Students may request the challenge as a group or individually to the teacher responsible for the group. In the

latter case, the teachers will be in charge of forming the groups. In both scenarios the groups will be formed by

two students, and the students must meet the requirements to be able to develop the group work. The

challenge statement will be published at the beginning of the course, including a calendar that will be in accordance

with the rest of the course. The development of the challenge will be divided into four phases:

(1) Research: study of the challenge statement and research on possible solutions. The students will have to inform

themselves and formulate questions that will allow them to understand the dimension of the challenge and to approach a possible solution.

(2) Development of the challenge: students will develop in teams small activities leading to identify the most appropriate solution to the problem, all of them proposed by the teacher in view of the previous stages.

(3) Verification and validation: the results obtained and the chosen solution will be contrasted in real

environments.

(4) Elaboration of the report and/or exhibition: the results will be shared through a working report and/or an exhibition, which may be done through a video.

The monitoring of the phases of the activity will be developed in tutorial sessions with the teachers designated for this purpose. The evaluation will be carried out in a coordinated way between the teachers and the participants in the teams. The teachers will carry out a continuous evaluation of the performance and the achievement of the objectives set during the development of the challenge for each student. Likewise, after completing the challenge, students will perform a self-evaluation and a cross evaluation. The weight of the exercise in the grade will be the same as that assigned to the group work.

Final evaluation will consist of:

- A Machine Learning Report describing the activities that demonstrate skills in developing Machine Learning models. The evaluation of this Report will represent 50% of final grade and it must be due by the final exam date, although students can submit draft versions before that date can they can receive feedback on their work.

- A Deep Learning Report must be prepared to demonstrate skills in developing Deep Learning models. The evaluation of this Deep Learning Report will represent 50% of final grade and it must be due by the by the final exam date.

Deep Learning activities must be developed in working teams, but each team member must individually clearly

describe her/his specific activities in the Report.

For both Reports, students can submit draft versions before the final submission date so they can receive feedback

on their work.

Evaluation through extraordinary assessment will consist of:

- A Machine Learning Report describing the activities that demonstrate skills in developing Machine Learning models (50% of final grade)

- A Deep Learning Report describing the activities that demonstrate skills in developing Deep Learning models (50% of final grade)

8. Recursos didácticos

8.1. Recursos didácticos de la asignatura

Nombre	Tipo	Observaciones
An Introduction to Statistical Learning	Bibliografía	An Introduction to Statistical Learning: with Applications in Python (Springer Texts in Statistics) Gareth James, Daniela Witten, Jonathan Taylor, Robert Tibshirani, Trevor Hastie https://www.statlearning.com/

Machine learning: a probabilistic perspective	Bibliografía	Kevin P. Machine learning: a probabilistic perspective. MIT press, 2012
The Elements of Statistical Learning Data Mining, Inference, and Prediction,	Bibliografía	Hastie, Trevor, Tibshirani, Robert and Friedman, Jerome. The Elements of Statistical Learning Data Mining, Inference, and Prediction, Second Edition. Springer Series in Statistics, 2009
Deep learning	Bibliografía	Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning. Cambridge: MIT press.
Neural Networks and Deep Learning	Recursos web	http://neuralnetworksanddeeplearning.com/index.html
Scaling up machine learning: Parallel and distributed approaches.	Bibliografía	Bekkerman, Ron, Mikhail Bilenko, and John Langford, eds. Scaling up machine learning: Parallel and distributed approaches. Cambridge University Press, 2011
Pattern recognition and machine learning (information science and statistics).	Bibliografía	Christopher M. Bishop. Pattern Recognition and Machine Learning (Information Science and Statistics), 2006.
Hands-On Machine Learning with Scikit-Learn, Keras, and tensorflow: Concepts, Tools, and Techniques to Build Intelligent Systems	Bibliografía	Géron, Aurélien. O'Reilly Media 2nd edition
Deep Learning: Foundations and Concepts by Christopher M. Bishop and Hugh Bishop	Bibliografía	Christopher M. Bishop and Hugh Bishop https://www.bishopbook.com/

9. Otra información

9.1. Otra información sobre la asignatura

For on-line learning activities we will use UPM Moodle platform and tools. Moodle, GutHub and Youtube will be the environments to share specific course materials.

The increasing relevance of technological developments based on Machine Learning makes this course an educational activity directed to contribute to Goal 4.4 in Sustainable Development Goals (SDGs) 2030 United Nations Agenda, empowering our students with relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.

Through approaching practical scenarios in our Lab, students will develop relevant skills and in-depth knowledge

on the impact of different Machine Learning techniques on different fields as health, environmental monitoring,

smart energy management, or finance. This will help them to become more aware of how technology can

contribute to several SDGs goals: end poverty (Goal 1), promote well-being (Goal 2), and promote sustainable

management of water, energy, economic growth and industrialization (Goals 5, 6, 7, and 8) as well as to reduce

inequality among countries (Goal 10).