ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000940 - Time Series Analysis

DEGREE PROGRAMME

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

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 1

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1. Description

1.1. Subject details

Name of the subject	93000940 - Time Series Analysis
No of credits	4.5 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	09AT - Master Universitario en Teoria de la Señal y Comunicaciones
Centre	09 - Escuela Tecnica Superior De Ingenieros De Telecomunicacion
Academic year	2024-25

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Eduardo Lopez Gonzalo (Subject coordinator)	C-330	eduardo.lopez@upm.es	Sin horario. Appointment arranged by email

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Deterministic Signals and Systems Theory

- Probability, Random Variables, and Stochastic Processes for Engineers

- Working knowledge of MATLAB or R

4. Skills and learning outcomes *

4.1. Skills to be learned

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

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

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. Learning outcomes

RA17 - Capacidad para aplicar conocimientos de modelado estadístico, técnicas de optimización y modelos de series temporales en el análisis de datos y como base para el desarrollo de algoritmos de aprendizaje automático

RA18 - Knowledge of tools for description, analysis and modeling of discrete-time random processes

RA20 - Capability to choose the appropriate modeling and filtering tools in order to extract useful information from a time series

RA19 - Knowledge of tools to design optimal filtering and signal processing structures

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This course is an introduction to the theory and practice of time series analysis, providing statistical tools to analyze random data that are ordered in time. It begins with a review of the theory of stochastic processes, which are the underlying mathematical description of time-varying random phenomena. Then, some classical parametric models for time series are presented, along with techniques to estimate their parameters. Time series are often analyzed in the frequency domain, so the course also covers topics on spectral estimation. Finally, the theory of optimal filtering and prediction is also presented, developed under the general framework of Bayesian estimation.

5.2. Syllabus

1. Random processes and sequences
   1.1. Basic definitions. Classification.
   1.2. Probabilistic descriptions.
   1.3. Special classes of processes.
   1.4. Stationarity. Power spectra.
   1.5. Linear systems.
   1.6. Ergodicity.
2. Time series modeling
   2.1. Linear stationary models: AR, MA, ARMA.
   2.2. Linear nonstationary models: ARIMA.
   2.3. Nonlinear models. ARCH, GARCH
   2.4. Parameter estimation.
3. Spectral estimation
   3.1. Autocorrelation estimation.
   3.2. Classic spectral estimation.
   3.3. Parametric methods.
4. Optimal filtering
   4.1. Bayesian estimation.
   4.2. Wiener filter.
   4.3. Linear prediction.
   4.4. Recursive estimation.
   4.5. Machine Learning for regression and forecasting

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1				
2				
3				
4		**Topic 1: Random processes and sequences** Duration: 02:00 Lecture		
5		**Topic 1: Random processes and sequences** Duration: 03:00 Lecture **Topic 1: Random processes and sequences** Duration: 01:00 Problem-solving class		
6		**Topic 1: Random processes and sequences** Duration: 03:00 Lecture **Topic 1: Random processes and sequences** Duration: 01:00 Problem-solving class		
7		**Topic 2: Time series modeling** Duration: 03:00 Lecture **Topic 2: Time series modeling** Duration: 01:00 Problem-solving class		
8		**Topic 2: Time series modeling** Duration: 03:00 Lecture **Topic 2: Time series modeling** Duration: 01:00 Problem-solving class		
9		**Topic 2: Time series modeling** Duration: 03:00 Lecture **Topic 2: Time series modeling** Duration: 01:00 Problem-solving class		

10		**Topic 3: Spectral estimation** Duration: 03:00 Lecture **Topic 3: Spectral estimation** Duration: 01:00 Problem-solving class		
11		**Topic 3: Spectral estimation** Duration: 01:00 Problem-solving class **Topic 3: Spectral estimation** Duration: 03:00 Lecture		
12		**Topic 4: Optimal filtering** Duration: 03:00 Lecture **Topic 4: Optimal filtering** Duration: 01:00 Problem-solving class		
13		**Topic 4: Optimal filtering** Duration: 03:00 Lecture **Topic 4: Optimal filtering** Duration: 01:00 Problem-solving class		
14		**Topic 4: Optimal filtering** Duration: 03:00 Lecture **Topic 4: Optimal filtering** Duration: 01:00 Problem-solving class		**Homework exercises** Individual work Progressive assessment Not Presential Duration: 00:00 **Computer assignments** Individual work Progressive assessment Not Presential Duration: 00:00
15				
16				
17				**Final examination** Written test Progressive assessment Presential Duration: 02:00 **Final examination** Written test Global examination Presential Duration: 02:00 **Computer assignment** Individual work Global examination Not Presential Duration: 00:00 **Challenge in quantitative finance which validates the final exam and the**

				homework exercises Group work Progressive assessment Not Presential Duration: 00:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
14	Homework exercises	Individual work	No Presential	00:00	25%	3.5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03
14	Computer assignments	Individual work	No Presential	00:00	25%	3.5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03
17	Final examination	Written test	Face-to-face	02:00	50%	3.5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03
17	Challenge in quantitative finance which validates the final exam and the homework exercises	Group work	No Presential	00:00	75%	5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Final examination	Written test	Face-to-face	02:00	75%	5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03
17	Computer assignment	Individual work	No Presential	00:00	25%	5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Final examination	Written test	Face-to-face	02:00	75%	5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03
Computer assignment	Individual work	No Presential	00:00	25%	5 / 10	CB06 CB07 CB10 CT01 CT03 CT04 CT05 CE01 CE03

7.2. Assessment criteria

Progressive assessment

Several homework assignments will be proposed to be delivered throughout the semester. Some of them will be exercises to be solved by the students (25% of final grade). Others will require the students to develop computer code (in Matlab or R) to analyze more complex problems (25% of final grade).

There is also a final examination at the end of the semester (50% of final grade).

A minimum grade of 3.5 (in a 0 to 10 scale) on every item (final examination, homework exercises and computer assignments) and a global average of 5.0 (in a 0 to 10 scale) will be required to pass the course.

The final examination and the exercises solved by the students (75% of the grade) can be validated by the realization of a challenge in quantitative finance, which may include:

(1) Forecasting of leading market indicators

(2) Forecasting of 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 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.

Global assessment test

Students who do not pass the progressive assessment may opt for a global assessment test (75% of final grade) and also submit the computer assignments (25% of final grade).

A minimum grade of 5.0 (in a 0 to 10 scale) both on the test and on the computer assignments will be required to pass the course.

Extraordinary examination

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

Students taking the extraordinary examination (75% of final grade) should also submit the computer assignments (25% of final grade).

A minimum grade of 5.0 (in a 0 to 10 scale) both on the extraordinary examination and on the computer assignments will be required to pass the course.

Those students who had previously submitted the computer assignments throughout the semester and obtained the minimum grade of 5.0 are not required to resubmit them.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Lecture slides and exercises.	Bibliography	Course material available on Moodle
M. García Otero. Notes on Probability and Random Variables. SSR-ETSIT-UPM, 2020.	Bibliography	Background material available on Moodle
C. W. Therrien. Discrete Random Signals and Statistical Signal Processing. Prentice-Hall, 1992.	Bibliography	
H. Kobayashi et al. Probability, Random Processes, and Statistical Analysis. Cambridge University Press, 2011.	Bibliography	
M. H. Hayes. Statistical Digital Signal Processing and Modeling. Wiley, 1996.	Bibliography	
K. Sam Shanmugan, A. M. Breipohl. Random Signals: Detection, Estimation and Data Analysis. Wiley, 1988.	Bibliography	

R. H. Shumway, D. S. Stoffer. Time Series Analysis and Its Applications: With R Examples. Springer, 2017. (http://www.stat.pitt.edu/stoffer/tsa4/)	Bibliography	
M. Falk et al. A First Course on Time Series Analysis: Examples with SAS. University of Würzburg, 2012. (http://www.mathematik.uni-wuerzburg.de/appliedstochastics/forschung/time-series/)	Bibliography	
P. J. Brockwell, R. A. Davis. Introduction to Time Series and Forecasting. Springer, 2002.	Bibliography	
D.C. Cryer, K. Chan. Time Series Analysis with Application in R. Springer, 2008.	Bibliography	
G. E. P. Box, G. M. Jenkins, G. C. Reinsel, G. M. Ljung. Time Series Analysis: Forecasting and Control. Wiley, 2015. (https://ebookcentral.proquest.com/lib/upmes/reader.action?docID=2064681)	Bibliography	
Ben Auffarth, Machine Learning for Time-Series with Python, 2021 Packt Publishing	Bibliography	
Aileen Nielsen, Practical Time Series Analysis, 2020, O'Reilly	Bibliography	
Terence C. Mills, Applied Time Series Analysis, 2019 Academic Press	Bibliography	
Jason Brownlee, Deep Learning for Time Series Forecasting,2019, Machine Learning Mastery	Bibliography	

Avishek Pal, PKS Prakash, Practical Time Series Analysis, 2017 Packt Publishing	Bibliography	
Francesca Lazzeri, Machine Learning for Time Series Forecasting with Python, 2021, Wiley	Bibliography	
N.D Lewis, Deep Time Series Forecasting with Python, 2016	Bibliography	
Philip Hans Franses, Dick van Dijk, Non-linear time series models in empirical finance, 2000, Cambridge University Press	Bibliography	

9. Other information

9.1. Other information about the subject

This subject is related to the Sustainable Development Goals (SDG) 4 and 9:

- Target 4.4: Increase the number of people who have relevant skills, including technical and vocational skills, for employment and entrepreneurship.
- Target 9.5: Enhance scientific research and upgrade the technological capabilities of industrial sectors.