ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

93000939 - Statistical Modelling

DEGREE PROGRAMME

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

ACADEMIC YEAR & SEMESTER

2024/25 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	93000939 - Statistical Modelling
No of credits	3 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 *
Pedro Jose Zufiria Zatarain (Subject coordinator)	A-306	pedro.zufiria@upm.es	Tu - 12:00 - 13:00 Additional tutoring hours to be agreed between professor and students.

* 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

- The student should have a fundamental undergraduate level knowledge of: 1) linear algebra, 2) mathematical analysis and 3) probability theory.

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

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

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

CT06 - Capacidad para emitir juicios sobre implicaciones económicas, administrativas, sociales, éticas y medioambientales ligadas a la aplicación de sus conocimientos

4.2. Learning outcomes

RA13 - Capability to construct parameter estimators, hypothesis tests and linear regression models.

RA14 - Capability to model real phenomena using probability theory.

RA15 - Capability to relate the foundations of statistical inference with standard machine learning schemes.

RA12 - Capability to construct probabilistic models from experimental data using inference tools.

* 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

The course covers the fundamental aspects of frequentist statistical inference (parameter estimation, hypothesis tests, linear regression), and their application to solve engineering problems.

In addition, the Montecarlo and Bootstrap techniques, together with some fundamental aspects of Bayesian inference are also addressed.

Finally, some relationships among fundamentals of statistical inference, principal elements of causal inference and some basic machine learning paradigms are also outlined.

5.2. Syllabus

1. Introduction.
   1.1. Engineering and statistical modelling.
   1.2. Course general overview.
2. Brief review of probability theory.
   2.1. Probability spaces. Conditional probability. Bayes theorem.
   2.2. Discrete and continuous random variables.
   2.3. Joint probability distributions.
3. Descriptive Statistics.
   3.1. Random sampling. Sample mean, median, range and variance.
   3.2. Histograms, blox-plots and time-series graphical representations.
4. Sample distribution and parameter point estimation.
   4.1. Point estimation.
   4.2. Sample distribution and Central Limit Theorem.
   4.3. Unbiased estimators. Variance and mean square error of a point estimator.
   4.4. Frequentist methods of point estimation: method of moments and method of maximum likelihood.
   4.5. Bayesian reasoning. Bayesian point estimation.
5. Statistical intervals.
   5.1. Confidence intervals for the mean and variance of a normal distribution.
   5.2. Confidence intervals for the proportion of a population.
   5.3. Tolerance and prediction intervals.
   5.4. Montecarlo and Bootstrap techniques.
6. Hypothesis tests for a single sample.
   6.1. Definition of hypothesis tests.
   6.2. Tests for mean and variance of a normal distribution.
   6.3. Tests for a population proportion.
   6.4. Bayesian tests.
7. Linear regression and correlation.

7.1. Linear simple regression.

7.2. Correlation.

7.3. Linear multiple regression.

7.4. Bayesian linear regression.

8. Towards machine learning: fundamental problems and tools.

6. Schedule

6.1. Subject schedule*

Week	Type 1 activities	Type 2 activities	Distant / On-line	Assessment activities
1	**Sections 1.1, 1.2 and 2.1 of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
2	**Sections 2.2 and 2.3 of syllabus.** Duration: 01:00 Lecture **Exercices.** Duration: 01:00 Problem-solving class			
3	**Section 3.1 of syllabus.** Duration: 01:30 Lecture **Exercices** Duration: 00:30 Problem-solving class			
4	**Section 3.2 of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
5	**Sections 4.1, 4.2 and 4.3 of syllabus..** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
6	**Section 4.4 of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			

7	**Section 5.1 of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
8	**Sections 5.2 and 5.3 of syllabus.** Duration: 01:00 Lecture **Section 5.4 of syllabus.** Duration: 01:00 Lecture			**Online evaluation exam 1.** Online test Progressive assessment Not Presential Duration: 01:00 **Homework 1.** Group work Progressive assessment Not Presential Duration: 06:00
9	**Sections 6.1 and 6.2 (part) of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
10	**Sections 6.2 and 6.3 of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
11	**Section 6.4 of syllabus..** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
12	**Section 7.1 and 7.2 of syllabus.** Duration: 01:30 Lecture **Exercices.** Duration: 00:30 Problem-solving class			
13	**Sections 7.3 and 7.4 of syllabus.** Duration: 01:00 Lecture **Section 8 of syllabus.** Duration: 01:00 Lecture			
14	**Evaluation** Duration: 02:00 Additional activities			**Presential evaluation exam.** Written test Progressive assessment Presential Duration: 02:00 **Online evaluation exam 2.** Online test

				Progressive assessment Not Presential Duration: 01:00
15				**Homework 2.** Group work Progressive assessment Not Presential Duration: 07:00 **Final project.** Individual work Progressive assessment Not Presential Duration: 15:00
16				
17				**Global evaluation.** Other assessment Global examination Presential Duration: 04:00

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.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
8	Online evaluation exam 1.	Online test	No Presential	01:00	10%	0 / 10	CB07 CT01
8	Homework 1.	Group work	No Presential	06:00	15%	0 / 10	CB07 CT01 CT04 CT05
14	Presential evaluation exam.	Written test	Face-to-face	02:00	20%	0 / 10	CB06 CB07 CT01
14	Online evaluation exam 2.	Online test	No Presential	01:00	10%	0 / 10	CB07 CT01
15	Homework 2.	Group work	No Presential	07:00	15%	0 / 10	CB07 CB10 CT04 CT05
15	Final project.	Individual work	No Presential	15:00	30%	0 / 10	CB06 CB07 CB10 CT01 CT04 CT05 CT06

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Global evaluation.	Other assessment	Face-to-face	04:00	100%	5 / 10	CB06 CB07 CB10 CT01 CT04 CT05 CT06

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Extraordinary evaluation.	Other assessment	Face-to-face	04:00	100%	5 / 10	CB06 CB07 CB10 CT01 CT04 CT05 CT06

7.2. Assessment criteria

By default, students will be progresively evaluated along the course. Nevertheless, the students can also be evaluated via a global examination procedure which includes the possibility of making up the evaluation exams, homeworks and project.

The course extraordinary evaluation will also include the possibility of making up the evaluation exams, homeworks and project.

Regular progresive evaluation will be performed as follows:

- Homeworks and proposed classroom exercises (30%). Besides the proposed exercises in class, the professor will propose 2 homeworks to be solved by the students and submitted at the established dates. Such exercises and homeworks will have to be solved using the theoretical foundations and the software tools presented in the course.

- 2 online exams each having a weight of 10% of the final grade. The first exam will cover from Section 1 to Section 5. The second part will cover from Section 5 to Section 8.

- 1 presential exam having a weight of 20% of the final grade, covering all course Sections.

- Final Project (30% of final grade).

Any work submitted by the student may require an oral complementary evaluation by the professor in order to

guarantee that such work has been done by the student without the aid of an AI system.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Douglas C. Montgomery and George C. Runger. Applied Statistics and Probability for Engineers. Fifth Edition. Wiley & Sons.	Bibliography	Fundamental.
Mariano García Otero. Probability and Random Variables. (Notes)	Bibliography	Fundamental.
R programming language tutorial.	Web resource	Fundamental.
Moodle.	Web resource	Links to homeworks, documents and videos related to the course.
Python programming language tutorial.	Web resource	Complementary.
J. Grus. Data Science from Scratch. First principles with Python. O'Reilly 2019.	Bibliography	Complementary.
G. Casella and R.L. Berger. Statistical Inference. 2nd Edition. Thomson Learning, 2002.	Bibliography	Complementary.
William Mendenhall, R.J. Beaver and B.M. Beaver. Introduction to Probability and Statistics. 14nth Edition. Brooks/Cole, 2013.	Bibliography	Complementary.
Peyton Z. Peebles and Bertram Emil Shi. Probability, random variables, and random signal principles. New York : McGraw-Hill, 2015.	Bibliography	Complementary.

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning (Vol. 112). New York: springer.	Bibliography	Complementary.
Vladimir N. Vapnik. The Nature of Statistical Learning Theory. Springer, 2000.	Bibliography	Complementary.
Judea Pearl et al. Causal inference in Statistics. A primer. Wiley 2016	Bibliography	Complementary.

9. Other information

9.1. Other information about the subject

The course will be taught in English.

Besides the use of the Moodle platform, in case of need, the communication between professors and students will be carried out using Zoom.

Relationship with Sustainable Development Goals:

On the one hand, the course contributes to SDG 4 (sub-objetive 4.4): Increase the number of young and adult people having professional and technical competences necessary to have access to employment and entrepreneurship.

On the other hand, the course studies fundamental mathematical and statistical tools to be employed in the modelling of different types of systems such as biological ones (SDG 3), data processing ones for industrial innovation and sustainable cities/communities (SDGs 9 and 11), climate ones (SDG 13) or ecosystems (SDGs 14 and 15).