

## Modelling and Inference

Code: 104392  
ECTS Credits: 6

**2024/2025**

| Degree   | Type | Year |
|--|------|------|
| 2503740 Computational Mathematics and Data Analytics | OB   | 2    |

### Contact

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### Teaching groups languages

You can view this information at the [end](#) of this document.

### Prerequisites

Good knowledge of the contents of the courses taken during the first year of the bachelor's degree is considered very important, especially those of probability and calculus.

### Objectives and Contextualisation

This is the first course in the Bachelor's degree that focuses on Statistical Inference, a branch of statistics that uses data from a "representative" sample to acquire information about a population. The course is required throughout the Bachelor's degree, as it covers different concepts and techniques that serve as the basis for many of the topics introduced in upcoming courses within the Bachelor's. In particular, the course will start with a brief introduction to statistics, followed by a chapter on parameter estimation (both point and based on confidence intervals), and finally chapters on frequentist-based significance tests and an introduction to classical linear regression models. Special emphasis will be placed on the statistical methods that can be used to compare machine learning algorithms.

To protect everyone's safety, in-person teaching and evaluable activities will be adjusted in accordance with health authority recommendations.

### Learning Outcomes

1. CM14 (Competence) Implement strategies to confirm or refute hypotheses.
2. CM15 (Competence) Manage the information for validation through statistical processing.
3. CM15 (Competence) Manage the information for validation through statistical processing.
4. CM16 (Competence) Assess, using the data obtained, inequalities on the grounds of sex/gender.
5. KM12 (Knowledge) Identify statistical inference as a tool for forecasting and prediction.
6. KM12 (Knowledge) Identify statistical inference as a tool for forecasting and prediction.
7. KM12 (Knowledge) Identify statistical inference as a tool for forecasting and prediction.
8. KM12 (Knowledge) Identify statistical inference as a tool for forecasting and prediction.
9. KM13 (Knowledge) Describe the basic properties of point and interval estimators.
10. KM13 (Knowledge) Describe the basic properties of point and interval estimators.
11. KM14 (Knowledge) Identify the usefulness of Bayesian methods, applying them appropriately.
12. KM14 (Knowledge) Identify the usefulness of Bayesian methods, applying them appropriately.

13. SM14 (Skill) Use the properties of density and distribution functions.
14. SM14 (Skill) Use the properties of density and distribution functions.
15. SM15 (Skill) Use suitable statistical software to manage databases, to obtain summary indices of the study variables and to analyse data using inference techniques.
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## Content

Preliminaries of Probability (reminder): Probability and random variables. Law concept. Discrete-valued distributions. Density and probability functions. Expectation and variance. Moment generating function. Examples.

Topic 1. Introduction to Statistics.

1. Descriptive statistics and inferential statistics.

1.1. Basic concepts in inference: statistical population and sample; parameters, statistics and estimators.

1.2. Statistical models: parametric and non-parametric.

2. Most common statistics: the sample moments. The order statistics.

3. Distribution of some statistics.

3.1. From a sample of a Normal population: Fisher's theorem.

3.2. The Central Limit Theorem: asymptotic normality of sample moments and proportion.

Topic 2: Point estimation.

1. Point estimators: definition and properties.

1.1. Bias

1.2. Comparison of estimators without bias. Relative efficiency

1.3. Comparison of estimators with bias: the mean square error.

1.4. Consistency of an estimator.

2. Methods to obtain estimators.

2.1. Method of moments.

2.2. Method of maximum likelihood (MLE)

Topic 3. Estimation by confidence intervals.

1. Concept of confidence region and interval.

2. The "pivot" method for the construction of confidence intervals.

3. Confidence intervals for the parameters of a population.

3.1. For the mean of a Normal population with known and unknown deviations.

- 3.2. For the variance of a Normal population with known and unknown means.
- 3.3. Other applications of the pivot method.
- 3.4. Asymptotic confidence intervals.
- 4. Confidence intervals for the parameters of two populations.
  - 4.1. Confidence intervals with independent samples.
  - 4.2. Confidence intervals for the difference of means of two Normal populations with paired data.

#### Topic 4: Significance tests.

- 1. Introduction.
  - 1.1. Type I and II errors.
  - 1.2. Power function.
  - 1.3. Tests consistency.
  - 1.4. p-values.
  - 1.5. Duality between confidence intervals and significance tests.
- 2. Tests for the parameters of a population.
  - 2.1. For the mean of a Normal population with known and unknown deviations.
  - 2.2. Asymptotic tests for the mean of a population when the sample is large.
  - 2.3. For the variance of a Normal population.
- 3. Tests for the parameters of two populations.
  - 3.1. Hypothesis tests with independent samples.
  - 3.2. Tests of hypotheses with paired data.
- 4. Chi-square tests.
  - 4.1. Goodness of fit test.
  - 4.2. Independence test.
- 5. Non-parametric tests to compare machine learning algorithms.

#### Topic 5. Simple linear regression model.

- 1. Purpose of the model.
- 2. Ordinary least squares (OLS) estimators.
- 3. Inference based on the linear regression model.
- 4. Predictions.

**IMPORTANT:** In teaching, the gender perspective involves reviewing androcentric biases and questioning the assumptions and hidden gender stereotypes. This revision involves including the contents of the subject the knowledge produced by scientific women, often forgotten, seeking the recognition of their contributions, as well as that of their works in the bibliographical references.

## Activities and Methodology

| Title               | Hours | ECTS | Learning Outcomes |
|---------------------|-------|------|-------------------|
| Type: Directed      |       |      |                   |
| Practical classes   | 10    | 0.4  |                   |
| Problems class      | 12    | 0.48 |                   |
| Theory classes      | 27    | 1.08 |                   |
| Type: Autonomous    |       |      |                   |
| Exams               | 15    | 0.6  |                   |
| Problems resolution | 33    | 1.32 |                   |
| Workshop resolution | 23    | 0.92 |                   |

The course is organized into lecture, exercise and lab sessions.

In lectures, we will introduce the concepts and techniques outlined in the course program. Given that the content is mostly based on the standard topics of an introduction to statistical inference course, the recommended bibliography can be used to follow the course. Lecture slides and related material will be available in Moodle. The exercise sessions are intended to work through and understand statistical concepts. Each exercise will be available in Moodle. The goal of the lab sessions is to learn how to apply the methods given in lectures using the statistical software R, as well as how to evaluate the findings.

**IMPORTANT:** To work more comfortably with R, it is recommended to use the RStudio interface: it is free, "Open source" and works with Windows, Mac and Linux. <https://www.rstudio.com/>

**OBSERVATION:** The gender perspective in teaching goes beyond the contents of the subjects, since it also implies a revision of the teaching methodologies and of the interactions between the students and the teaching staff, both in the classroom and outside. In this sense, participatory teaching methodologies, where an egalitarian, less hierarchical environment is generated in the classroom, avoiding stereotyped examples in gender and sexist vocabulary, with the aim of developing critical reasoning and respect for the diversity and plurality of ideas, people and situations, tend to be more favorable to the integration and full participation of the students in the classroom, and therefore their effective implementation in this subject will be sought.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

## Assessment

### Continuous Assessment Activities

| Title      | Weighting | Hours | ECTS | Learning Outcomes            |
|------------|-----------|-------|------|------------------------------|
| Final exam | 0,60      | 10    | 0.4  | CM14, KM12, KM13, KM14, SM14 |

|                   |      |    |      |                              |
|-------------------|------|----|------|------------------------------|
| Grading exercises | 0,15 | 12 | 0.48 | CM15, CM16, SM15             |
| Mid-term exam     | 0,25 | 8  | 0.32 | CM14, KM12, KM13, KM14, SM14 |

During the lecture sessions the basic concepts of the subject will be introduced and a wide set of examples will be presented. In the problems and practices sessions, exercises will be solved and practices with R will be carried out. Classroom attendance is recommended to have an idea about the course in general, as well as the exercises and practices.

#### Assessment:

The student's grade will be the weighted average of the following activities:

PAC1: partial exam, which accounts for 25% of the grade.

PAC2: delivery of exercises related to computer practices with R carried out in the classroom, which accounts for 15% of the grade.

Final exam: which will consist of some conceptual questions in the form of short questions and some problems in which you will have to solve a series of exercises similar to those that have been worked on in class sessions. This exam represents the remaining 60% of the grade.

Important: if the grade for any of these activities does not reach 3 out of 10, it will count as 0 in the calculation of the final grade.

Recovery: if this grade does not reach 5, the student has the right to another opportunity to pass the subject through the recovery exam. In this exam, 85% of the grade corresponding to the final exam and PAC1 can be recovered. The practical part with R (PAC2) is not recoverable. In no case can the recovery exam be used to raise the grade if the student has already passed the subject with the first exam.

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#### Single evaluation:

The student who has taken advantage of the single evaluation modality must take a final exam that will consist of some conceptual questions in the form of short questions and some problems in which they will have to solve a series of exercises similar to those that have been worked on in class sessions. Once completed, you will deliver, in addition to the exam, the exercises related to the R computer practices completed throughout the course.

The student's grade will be the weighted average of the two previous activities, where the final exam will account for 85% of the mark, and the evaluation of the answer sheets of the computer practices with R the remaining 15%.

Important: if the grade for any of these activities does not reach 3 out of 10, it will count as 0 in the calculation of the final grade.

If this qualification does not reach 5, the student has the right to another opportunity to pass the subject through the recovery exam that will be held on the date set by the coordination of the degree. In this exam it will be possible to recover 85% of the mark corresponding to the final exam. The practical part with R is not recoverable. In no case can the recovery exam be used to raise the grade if the student has already passed the subject with the first exam.

#### Bibliography

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<https://www.amazon.es/Probabilidad-Estad%C3%ADstica-aplicaciones-Rosario-Delgado/dp/1983376906>
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9. Silvey, S.D.: Statistical Inference. Chapman&Hall. 1975.

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## Software

R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

## Language list

| Name                          | Group | Language | Semester       | Turn          |
|-------------------------------|-------|----------|----------------|---------------|
| (PLAB) Practical laboratories | 1     | Catalan  | first semester | morning-mixed |
| (SEM) Seminars                | 1     | Catalan  | first semester | morning-mixed |
| (TE) Theory                   | 1     | Catalan  | first semester | morning-mixed |