# Simulation in probability and statistics

**Academic Year: ( 2023 / 2024 )** **Review date: 09/02/2024 13:54:13**

**Department assigned to the subject: Statistics Department**

**Coordinating teacher: CASCOS FERNANDEZ, IGNACIO**

**Type: Compulsory ECTS Credits : 3.0**

**Year : 4 Semester : 2**

## REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Probability (Year 2 - Semester 2)
Statistics (Year 3 - Semester 1)
Stochastic Processes (Year 4 - Semester 1) - at least partial knowledge

## LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG1. Students are able to demonstrate knowledge and understanding of concepts in mathematics, statistics and computation and to apply them to solve problems in science and engineering with an ability for analysis and synthesis.
CG2. Students are able to formulate in mathematical language problems that arise in science, engineering, economy and other social sciences.
CG4. Students are able to show that they can analyze and interpret, with help of computer science, the solutions obtained from problems associated to real world mathematical models, discriminating the most relevant behaviours for each application.
CG5. Students can synthesize conclusions obtained from analysis of mathematical models coming from real world applications and they can communicate in verbal and written form in English language, in an clear and convincing way and with a language that is accessible to the general public.
CG6. Students can search and use bibliographic resources, in physical or digital support, as they are needed to state and solve mathematically and computationally applied problems arising in new or unknown environments or with insufficient information.
CE1. Students have shown that they know and understand the mathematical language and abstract-rigorous reasoning as well as to apply them to state and prove precise results in several areas in mathematics.
CE4. Students have shown that they understand the fundamental results from the theory of ordinary differential equations as well as the theory of partial derivative and stochastic equations.
CE8. Students are able to discretize mathematical models associated to real world problems using interpolation and approximation techniques, in order to solve them numerically by means of direct or iterative methods and to interpret the obtained solutions.
CE22. Students have shown that they understand the concept of random phenmena, and that they can apply the basic principles of probability calculus and the statistic inference, recognizing their applicability to real problems.
CE23. Students have shown that they understand the concepts of stochastic processes and queuing theory to model real world processes as well as to simulate them in a computer.

RA1. Students must have acquired advanced cutting-edge knowledge and demonstrated indepth understanding of the theoretical and practical aspects of working methodology in the area of applied mathematics and computing.
RA2. Through sustained and well prepared argument and procedures, students will be able to apply their knowledge, their understanding and the capabilities to resolve problems in complex specialized professional and work areas requiring the use of creative and innovative ideas.
RA3. Students must have the capacity to gather and interpret data and information on which they base their conclusions, including where relevant and necessary, reflections on matters of a social, scientific, and ethical nature in their field of study.
RA4. Students must be able to perform in complex situations that require developing novel solutions in the academic as well as in the professional realm, within their field of study.
RA5. Students must know how to communication with all types of audiences (specialized or not) their knowledge, methodology, ideas, problems and solutions in the area of their field of study in a clear and precise way.
RA7. Students must possess the professional maturity necessary to choose and evaluate their work objectives in a reflexive, creative, self-determined and responsible way, for the betterment of society.

## DESCRIPTION OF CONTENTS: PROGRAMME

* R programming and introduction to R Markdown
* Probability refresher
* Statistics refresher

1. Random numbers (Monte Carlo tecniques)
1.1 Probability and inference refresher
1.2 Statistical validation techniques
1.3 (Pseudo)random number generation
1.4 Approximation of probabilities and volumes
1.5 Monte Carlo integration
2. Simulating random variables and vectors
2.1 Inverse transform
2.2 Aceptance-rejection
2.3 Composition approach
2.4 Multivariate distributions
2.5 Multivariate normal distribution
3. Discrete event simulation
3.1 Poisson processes
3.2 Gaussian processes
3.3 Single- and multi-server Queueing systems
3.4 Inventory model
3.5 Insurance risk model
3.6 Repair problem
3.7 Exercising a stock option
4. Efficiency improvement (variance reduction) techniques
4.1 Antithetic variables
4.2 Control variates
4.3 Stratified sampling
4.4 Importance sampling
5. MCMC
5.1 Markov chains
5.2 Metropolis-Hastings
5.3 Gibbs sampling
6. Introduction to the bootstrap
6.1 The bootstrap principle
6.2 Estimating standard errors
6.3 Bootstrap Inference (Confidence Intervals)

## LEARNING ACTIVITIES AND METHODOLOGY

- Lectures and problem sessions with a computer: introducing the theoretical concepts and developments with examples, and solving problems: 25 on-site hours

- Homework: 49 non on-site hours
- Evaluation sessions (continuous evaluation and final exam): 5 on-site hours
- Specific exam preparation: 49 non on-site hours

## ASSESSMENT SYSTEM

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|---|---|
| **% end-of-term-examination/test:** | 0 |
| **% of continuous assessment (assigments, laboratory, practicals…):** | 100 |

100% of the course grade will be obtained by continuous evaluation:

- Simulation project: 35%
- Classroom presentation of the simulation project: 10%
- Resampling project: 25%
- Classroom problems: 30%

The students that do not follow the continuous evaluation will be allowed to write a final exam with a total weight of 60%.

Any student that has not followed the continuous evaluation process has the right to take an extraordinary exam with a total weight of 100% of the course grade. Alternatively, she/he can complete a Simulation project (35%) with its presentation (10%) and a Resampling project (25%) with its presentation (5%) having a total weight of 75%.

## BASIC BIBLIOGRAPHY

- Bradley Efron, Robert Tibshirani An introduction to the Bootstrap, Chapman & Hall, 1993

- Sheldon M. Ross Simulation, Academic Press, 2013 (5th ed)

## ADDITIONAL BIBLIOGRAPHY

- Christian P. Robert, George Casella Introducing Monte Carlo methods with R, Springer, 2010