

## Course guide

### 200611 - AB - Bayesian Analysis

**Last modified:** 09/06/2023

<b>Unit in charge:</b>	School of Mathematics and Statistics		
<b>Teaching unit:</b>	715 - EIO - Department of Statistics and Operations Research.		
<b>Degree:</b>	MASTER'S DEGREE IN STATISTICS AND OPERATIONS RESEARCH (Syllabus 2013). (Optional subject).		
<b>Academic year:</b> 2023	<b>ECTS Credits:</b> 5.0	<b>Languages:</b> Spanish	

#### LECTURER

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<b>Coordinating lecturer:</b>	XAVIER PUIG ORIOL
<b>Others:</b>	Segon quadrimestre: JESUS CORRAL LOPEZ - A XAVIER PUIG ORIOL - A

#### PRIOR SKILLS

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We start from scratch and hence there are no pre-requisites for this course. But having some basic knowledge of statistics and R will help get the best out of the course.

#### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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##### Specific:

3. CE-1. Ability to design and manage the collection of information and coding, handling, storing and processing it.
4. CE-3. Ability to formulate, analyze and validate models applicable to practical problems. Ability to select the method and / or statistical or operations research technique more appropriate to apply this model to the situation or problem.
5. CE-4. Ability to use different inference procedures to answer questions, identifying the properties of different estimation methods and their advantages and disadvantages, tailored to a specific situation and a specific context.
6. CE-6. Ability to use appropriate software to perform the necessary calculations in solving a problem.
7. CE-7. Ability to understand statistical and operations research papers of an advanced level. Know the research procedures for both the production of new knowledge and its transmission.
8. CE-8. Ability to discuss the validity, scope and relevance of these solutions and be able to present and defend their conclusions.
9. CE-9. Ability to implement statistical and operations research algorithms.

##### Transversal:

1. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

#### TEACHING METHODOLOGY

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Our goal is to focus the learning goals on the student and adapt the teaching to the achievement of the goals. That's why we want classes to be valuable for learning and tasks to be well thought out and defined. Half of the sessions will be theoretical and half will be based on computer use.

Theoretical concepts are presented in theory classes and are usually expository classes, where exercises or discussions between students are often interspersed. These classes also work on learning through case studies.

In the practical classes, the practical cases are solved with the help of the statistical software R, WinBugs, JAGS and STAN.

## LEARNING OBJECTIVES OF THE SUBJECT

The main objective of this subject is that the student ends up with a good knowledge and mastery of Bayesian modeling in terms of both theoretical and practical knowledge. This knowledge must allow, in the face of an objective or question, to intervene in the design of the experiment necessary to obtain the study data, to analyze them satisfactorily in order to reach the conclusions according to the initial objective.

And as specific objectives (abilities to be acquired):

- \* Knowledge of the difference between Bayesian and non Bayesian statistical modelling, and of the role of the likelihood function.
- \* Understand the role of the prior distribution, the role of reference priors and how to go from prior to posterior distributions.
- \* Understand the difference between hierarchical and non-hierarchical Bayesian models.
- \* Understand how to check a Bayesian model, how to compare Bayesian models and how to use them for prediction.
- \* Understand the Montecarlo methods that allow one to simulate from the posterior and how to make inferences from those simulations.
- \* Posing and solving Bayesian inference problems analytically with exponential family statistical models and conjugate prior distributions.
- \* Posing and solving Bayesian inference problems numerically under complex situations using WinBugs, JAGS or STAN.

## STUDY LOAD

Type	Hours	Percentage
Hours small group	15,0	12.00
Hours large group	30,0	24.00
Self study	80,0	64.00

**Total learning time:** 125 h

## CONTENTS

### 1- Bayesian Model

#### Description:

1. What is a statistical model. 2. The four problems in statistics. 3. The Likelihood function. 4. Bayesian model. 5. Posterior distribution. 6. Prior predictive and posterior predictive distributions. 7. Choice of the prior distribution.

**Full-or-part-time:** 45h

Theory classes: 14h

Laboratory classes: 6h

Self study : 25h

### 2- Bayesian Inference

#### Description:

1. Posterior distribution as an estimator. 2. Point estimation. 3. Interval estimation 4. Prediction 5. Hypothesis test

**Full-or-part-time:** 39h

Theory classes: 10h

Laboratory classes: 4h

Self study : 25h



### 3- Bayesian computation

**Description:**

1. The need for integration and for simulation. 2. Markov chain monte Carlo simulation. 3. Monitoring Convergence

**Full-or-part-time:** 13h

Theory classes: 2h

Laboratory classes: 1h

Self study : 10h

### 4- Hierarchical Models

**Description:**

1. Hierarchical Models

**Full-or-part-time:** 14h

Theory classes: 2h

Laboratory classes: 2h

Self study : 10h

### 5. Checking and defining the model

**Description:**

Checking and defining the model

**Full-or-part-time:** 14h

Theory classes: 2h

Laboratory classes: 2h

Self study : 10h

## GRADING SYSTEM

Final grade =  $0.4 \cdot \text{Assignments} + 0.2 \cdot \text{Exam} + 0.4 \cdot \text{Project}$

where,

Assignments is the grade obtained from the resolution of exercises delivered to both practical and theoretical classes,

Project is the grade of a group work, and

Exam is the grade of the exam that will take place in the second half of the course

## BIBLIOGRAPHY

**Basic:**

- Gelman, Andrew. Bayesian data analysis. 3rd ed. London: Chapman & Hall, 2014. ISBN 9781439840955.
- Kruschke, J.K. Doing bayesian data analysis : a tutorial with R, JAGS and STAN. Academic Press, 2015. ISBN 9780124058880.
- Bolstad, W. Introduction to Bayesian statistics. 2nd. John Wiley, 2007. ISBN 9780470141151.

**Complementary:**

- Leonard, Thomas; Hsu, John S. J. Bayesian methods. Cambridge: Cambridge University Press, 1999. ISBN 0521594170.
- Bernardo, José Miguel; Smith, Adrian F. M. Bayesian theory. Chichester: Wiley, 1994. ISBN 0471924164.
- Carlin, Bradley P; Louis, Thomas A. Bayes and empirical bayes and methods for data analysis. London: Chapman and Hall, 1996. ISBN 0412056119.
- Gill, Jeff. Bayesian methods : a social and behavioral sciences approach. Boca Raton, Fla: Chapman & Hall/CRC, 2002. ISBN 1584882883.

- Kendall, Maurice G. Kendall's Advanced Theory of Statistics : Bayesian inference. 6th ed. London: Edward Arnold, 1994. ISBN 0340529229.
- Berger, James O. Statistical decision theory and Bayesian analysis. 2nd ed. New York: Springer-Verlag, 1985. ISBN 0387960988.
- Congdon, Peter. Bayesian statistical modelling. 2nd ed. Chichester: John Wiley & Sons, 2006. ISBN 0471496006.
- Congdon, Peter. Applied bayesian modelling. West Sussex: John Wiley & Sons, 2003. ISBN 0471486957.
- Congdon, Peter. Bayesian models for categorical data. Chichester: John Wiley, 2005. ISBN 0470092378.
- Robert, Christian P.; Casella, George. Monte Carlo statistical methods. 2nd ed. New York: Springer, 2004. ISBN 0387212396.
- Tanner, Martin Abba. Tools for statistical inference : methods for the exploration of posterior distributions and likelihood functions. 3rd ed. New York: Springer-Verlag, 1996. ISBN 0387946888.
- Gilks, W. R. Markov chain Monte Carlo in practice. London: Chapman & Hall, 1996. ISBN 0412055511.
- Wasserman, Larry. All of statistics : a concise course in statistical inference. New York: Springer Verlag, 2010. ISBN 9781441923226.
- Robert, Christian P. The Bayesian choice : from decision-theoretic foundations to computational implementation. 2nd ed. New York: Springer, 2001. ISBN 0387952314.
- Carlin, Bradley P.; Louis, Thomas A. Bayesian methods for data analysis. 3rd ed. Boca Raton: CRC Press, 2009. ISBN 9781584886976.
- Hoff, Peter D. A First course in bayesian statistical methods [on line]. New York: Springer, 2009 [Consultation: 28/06/2023]. Available on : <https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=450680>. ISBN 9780387922997.
- Jackman, Simon. Bayesian analysis for the social sciences. Chichester: John Wiley and Sons, 2009. ISBN 9780470011546.
- McElreath, R. Statistical rethinking : a Bayesian course with examples in R and Stan. Chapman Hall, 2016. ISBN 9781482253443.
- Ntzoufras, I. Bayesian modeling using WinBUGS. Wiley. 2009. ISBN 9780470141144.
- Gelman, Andrew; Carpenter, Bob; Lee, Daniel. Stan modeling language: user's guide and reference manual. Version 2.17.0 [on line]. Creative Commons Attribution 4.0 International License (CC BY-ND 4.0), 2017 [Consultation: 07/07/2023]. Available on: <https://github.com/stan-dev/stan/releases/download/v2.17.0/stan-reference-2.17.0.pdf>.