200611 - AB - Bayesian Analysis

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 715 - EIO - Department of Statistics and Operations Research
Academic year: 2017
Degree: MASTER'S DEGREE IN STATISTICS AND OPERATIONS RESEARCH (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 5
Teaching languages: English

Teaching staff
Coordinator: JOSEP GINEBRA MOLINS
Others: Segon quadrimestre:
JOSEP GINEBRA MOLINS - A
XAVIER PUIG ORIOL - A

Prior skills
We start from scratch and hence there are no pre-requisites for this course. But having some basic knowledge of
statistics, at the level of what is covered in Chapters 1 to 12 of the 2004 book "All of Statistics" of Larry Wasserman will
help get the best out of the first two thirds of the course. Having some basic knowledge of applied linear and generalized
linear models, at the level of the 2005 book "Applied Linear Regression" by Sanford Weisberg will help get the best out of
the last one third of the course.

Requirements
We start from scratch, without any pre-requisites. But having basic knowledge of statistics will help better understand the
differences between the Bayesian approach to statistical inference and model selection and the non Bayesian approach.
Having some basic knowledge of applied linear and generalized linear models is not required but it will also help get the
best out of this course.

Degree competences to which the subject contributes

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.

Transversal:
1. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of
Abilities to be acquired:
* Knowledge of the difference between Bayesian and non Bayesian statistical modelling, and of the role of the likelihood function.
* Knowledge of the advantages and of the disadvantages of Bayesian statistical modelling with respect to non Bayesian statistical modelling.
* Understand the differences between Bayesian and Non-Bayesian inference.
* 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 Monte Carlo 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.

**Teaching methodology**

There will be two 1,5 hour sessions per week. Two thirds of the sessions will be in a regular classroom and one third of them will be in a computer lab.

**Learning objectives of the subject**

**Study load**

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Hours large group:</th>
<th>30h</th>
<th>24.00%</th>
</tr>
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<tr>
<td></td>
<td>Hours medium group:</td>
<td>0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Hours small group:</td>
<td>15h</td>
<td>12.00%</td>
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<td></td>
<td>Guided activities:</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>80h</td>
<td>64.00%</td>
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</tbody>
</table>
# Bayesian Analysis

## Content

### 1- Bayesian Model

**Learning time:** 18h  
Theory classes: 9h  
Laboratory classes: 4h 30m  
Self study: 4h 30m

**Description:**  
1. What is a statistical model.  
2. The three problems in statistics.  
3. Critique of "frequentist inference".  
4. Likelihood based inference.  
5. Bayesian model.  
6. Posterior distribution.  
7. Prior predictive and posterior predictive distributions.  
8. Choice of the prior distribution.  
9. Bayesian model as a probability model and as a data simulator.  
10. Advantages and disadvantages of going Bayesian.

### 2- Bayesian Inference

**Learning time:** 18h  
Theory classes: 9h  
Laboratory classes: 4h 30m  
Self study: 4h 30m

**Description:**  
1. Posterior distribution as an estimator.  
2. Point estimation.  
3. Interval estimation.  
4. Two-hypothesis test.  
5. More than two-hypothesis test, model comparison and model averaging.  
6. Prediction.  
7. Simulation based inference.  
8. Frequentist asymptotic behavior of the posterior distribution.  
9. Bayesian asymptotic behavior of the posterior distribution.  
10. Decision theory and frequentist (Bayesian) assessment of the Bayesian (frequentist) inference.  
11. Summary

### 3- Hierarchical Models

**Learning time:** 6h  
Theory classes: 3h  
Laboratory classes: 1h 30m  
Self study: 1h 30m

**Description:**  
1. Hierarchical models.  
2. Empirical Bayes.

### 4. Model selection

**Learning time:** 6h  
Theory classes: 3h  
Laboratory classes: 1h 30m  
Self study: 1h 30m

**Description:**  
1. Difference between model checking and model comparison.  
2. Model selection through Bayes factors.  
3. Model selection through predictive checks.
**Qualification system**

Students will have to hand in several assignments and work on a final project that will be graded and will altogether count as 45% of the final grade.

Final grade = 0.2*Assignm + 0.2*Proj + 0.1*Midterm + 0.5*FinalExam

**Regulations for carrying out activities**

The midterm and the final exam will be closed book but you might need to bring a calculator.
Bibliography

Basic:


Complementary:


Ntzoufras, I. Bayesian modeling using WinBUGS. Wiley. 2009.