# Bayesian Statistics and Simulation Methods

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## Overview

This course will provide the introduction to the Bayesian approach in statistics both from the theoretic and the computational perspective using R and WinBUGS.

## Key Outcomes

By completing the course, the students will understand the fundamental differences between the Frequentist and Bayesian approach to statistics, know how to implement them in practice and be able to perform statistical analysis from a purely Bayesian perspective.

## Requirements and Prerequisites

The students should have a good quantitative background. Specifically, knowledge in the fields of calculus, probability/distribution theory and statistics will be necessary for this course.

## Bibliography

Books:

- Ntzoufras, I. (2009). Bayesian Modeling Using WinBUGS. Wiley. Hoboken. USA.
- Carlin B. and Louis T. (2008), Bayes and Empirical Bayes Methods for Data Analysis. 3rd Edition, London: Chapman and Hall.
- Gelman A., Carlin J.B., Stern H.S., Dunson, D.B., Vehtari, A. and Rubin D.B. (2013). Bayesian Data Analysis. Third Edition. Chapman and Hall/CRC.

Lecture Notes:

- P. Dellaportas and P. Tsiamyrtzis, “Introduction to Bayesian Statistics” (in Greek)

## Grading

There will be a total of 3 homework assignments that will contribute 70% in the final grade.

- Two minor assignments (10% each)
- One major homework project on Bayesian data analysis of a dataset

The remaining 30% will be determined by the in class final exam.

Please note that one needs to write at least 5 (out of 10) in the final exam (independently of the grades in the homework assignments and project) not to fail the course.

## Course Syllabus

The course comprises of ten units of three hours each.

### Unit 1: Introduction to Bayesian Statistics and MCMC

Introduction to Bayesian Inference. Prior and Posterior. Conjugate Analysis. Introduction to MCMC (Gibbs Sampling and Metropolis Hastings). Illustration of MCMC mobility using R animations. Motivation about Bayesian models.

### Unit 2: Introduction to WinBUGS

Scripting with WinBUGS. The Deviance Information Criterion. Details about the Syntax of WinBUGS. Simple Examples. Running WinBUGS from R (R2WinBUGS). RJUGS.

### Unit 3: Bayesian Modeling and Normal Regression Using WinBUGS

Deviance Information Criteria (and BIC and AIC), Predictive distribution, Prediction and Handling of missing data, Normal regression, ANOVA using dummies

### Unit 4: Bayesian Generalized Linear Models

Models for poisson counts, Modelling Football Data with Poisson log-linear models, Binomial regression models

### Unit 5: Hierarchical Models

Introduction, reasons for using hierarchical models, exchangeability, simple examples, more realistic applications.

### Unit 6 : Introduction to Bayesian Model Comparison

Posterior odds, Posterior model probabilities and Bayes Factors; marginal likelihood; The Lindley-Bartlett paradox, Variable Selection Indicators, Prior distributions for Variable Selection in GLMs, Criteria for Objective Priors, Hyper-g priors, Using BAS package in R for variable selection, Marginal likelihood computation (short discussion), Model Search using Gibbs variable selection methods, GVS in WinBUGS (with independent priors and g-priors), Implementing GVS using hyper-g priors in WinBUGS. Other packages in R. Variable Selection using JASP.

### Unit 7: The Philosophy Behind the Bayesian Theory

Three schools of thought in Statistics: Fiducial – Frequentist – Bayesian. Subjective probability. Bayes theorem, as an updating mechanism of prior to posterior distribution and examples.

### Unit 8: Prior Distributions and Multivariate Bayesian Analysis

Prior distributions: conjugate, non-informative, improper, Jeffreys prior, prior elicitation, mixtures and hyperpriors. Sensitivity analysis. Empirical Bayes approach. Sequential updating of the posterior distribution. Multivariate Bayesian Analysis.

### Unit 9: Bayesian Inference from a Decision Theory perspective

Basic elements of decision theory. Loss function, frequentist, posterior and Bayes risk. Bayes and minimax rule. Bayesian inference (point/interval estimation and hypothesis testing) from a Bayesian perspective: Bayes rules, credible sets, Highest Posterior Density sets.

## Unit 10: Predictive Inference and Bayesian Asymptotic Methods

Conjugate Analysis for Regression Models. Posterior distributions. Estimation. Using R packages for Bayesian Regression. Examples in R. Implementing Conjugate Analysis for Model Comparison in Regression. Example in R using full enumeration with small p.