Bayesian statistics

Introduction to the course

Matilde Trevisani, Leonardo Egidi

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Università di Trieste

Lecturers

- **Matilde Trevisani**: 16 hours. Mail: matilde.trevisani@deams.units.it. Room 2.16, Building D (DEAMS). Office hours: see website.
- **Leonardo Egidi**: 22 hours. Mail: legidi@units.it. Room 2.10, Building D (DEAMS). Office hours: tuesday 15-17, thursday 11-13.

  See website for eventual changes. Personal page https://leoegidi.github.io/.
- **Jonah Sol Gabry**: 10 hours. Visiting professor from Columbia University, Stan developer. He will provide some lectures in the month of May.

Lectures' schedule

- Monday, 16-18, room 4B, H2BIS building
- Friday, 15-17, room 4A, H2BIS building

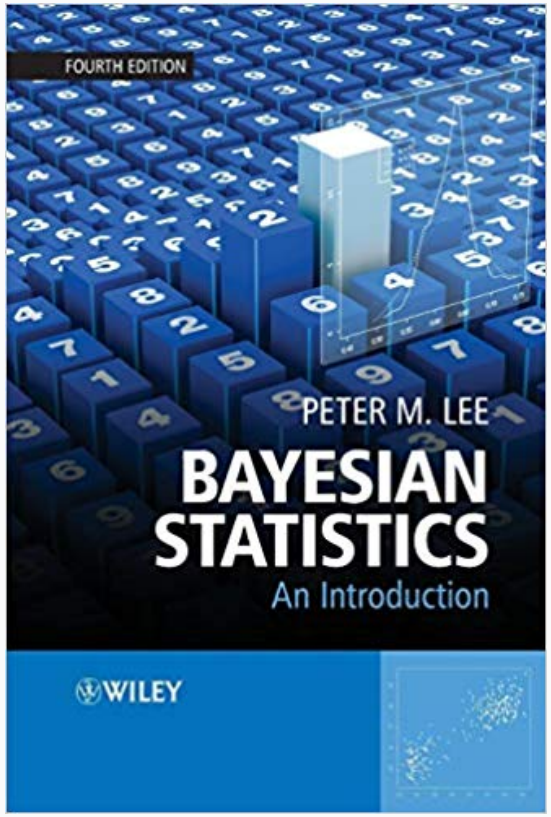
It is likely that, starting from the mid of April, another slot of lectures will be provided within the week.

Textbook and reference books

Lee

Bayesian Statistics: an introduction

Wiley

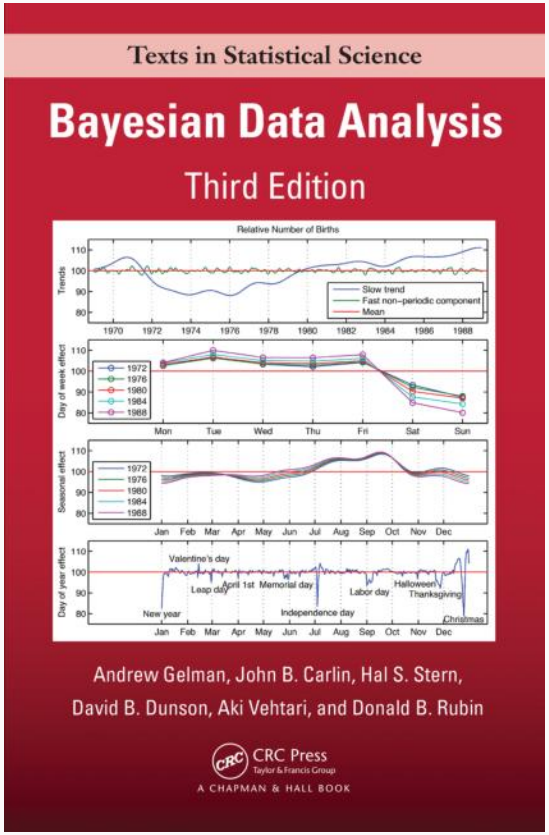


Textbook and reference books

Gelman, Carlin, Stern, Dunson, Vehtari, Rubin

Bayesian Data Analysis

CRC press

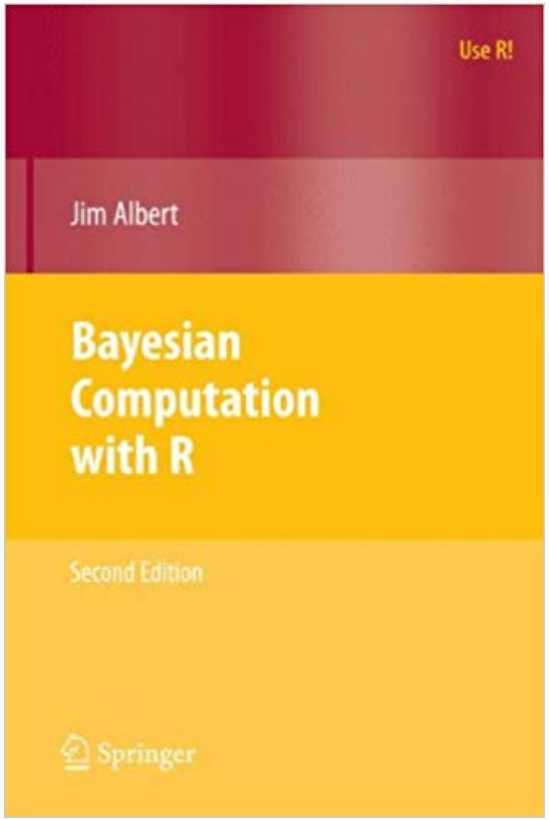


Textbook and reference books

Albert

Bayesian Computation with R

Springer

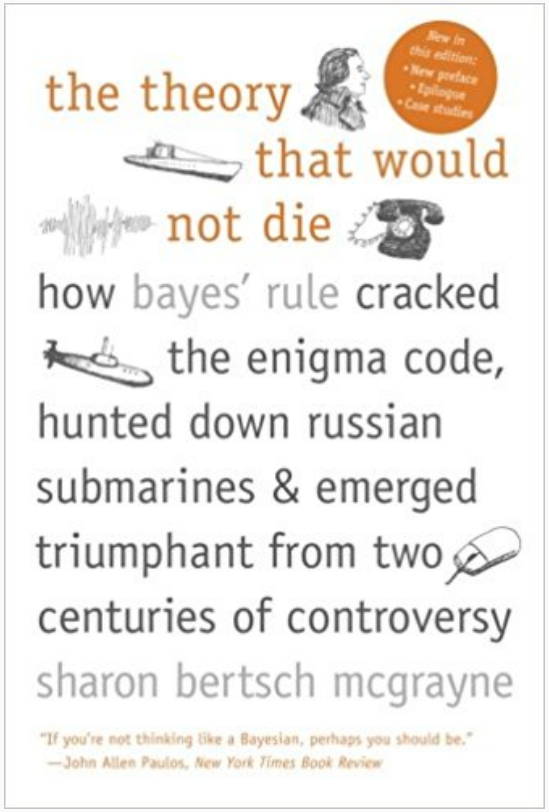


Additional readings

Sharon Bertsch Mcgrayne

The Theory That Would Not Die: How Bayes' Rule Cracked the Enigma Code

Yale University Press



Moodle

Course slides and additional material on moodle2.units.it

Moodle web-page will be used also to communicate variations in the lecture schedules.

Please, subscribe to the course!

Recordings will be available on MS-Teams on the Team of the course.

Exam

- Written exam and submission of a practical exercise.
- In the written examination, during about one hour, the student will have to prove knowledge of theoretical results illustrated in the course (3/4 questions)
- The practical exercise, to be submitted two/three days before the written exam takes place, will serve the purpose of assessing his/her capacity of applying the methods taught in the course.

Aims and Syllabus i

- *Knowledge and understanding*: the student will understand the Bayesian inferential paradigm and its difference with respect to classical inferential paradigm.
- *Applying knowledge and understanding*: the student will be able to specify and estimate a range of models within the Bayesian approach, assess the quality of the models and interpret the results. Specifically, the student is required to have a very good use of the Stan software and of the 'rstan' and 'cmdstan' libraries available in R.

Aims and Syllabus ii

- *Making judgements*: the student must be able to navigate in the context of the analysis of real data according to a Bayesian approach, with always priority and vigilant attention to the sampling scheme of the data, to their possible hierarchical/multilevel structure and to their granularity.
- *Communication skills*: the student will be able to effectively communicate the results of data analysis using appropriate tools (including modern techniques for compiling dynamic documents, such as RMarkdown). In addition, the student is also required to make a 'visualization' effort, suitable for the production of graphical tools that summarize complex trends (above all, for example, the use of R libraries such as 'ggplot2').
- *Ability to learn*: at the end of the course the student will be able to consult theoretical and applied scientific works that use Bayesian statistical techniques, critically analyze the application of the models and algorithms explained in class, and illustrate case studies through the use of probabilistic scientific programming.

Aims and Syllabus iii

Syllabus

- Introduction to Bayesian inference (with comparison to classic/frequentist approach to inference)
- Single parameter models: binomial, normal, Poisson and other standard models
- Bayesian estimate, credibility interval
- Predictive distribution, exchangeability
- Non informative/weakly informative /reference priors
- Multiparameter models: normal (univariate and multivariate), multinomial
- Asymptotic approximations (parallel with classical inference)
- Hierarchical models
- Regression models
- MCMC general introduction (Gibbs-Metropolis)
- Programming an MCMC algorithm in R
- Introduction to Stan and use of Stan for estimation.

Aims and Syllabus iv

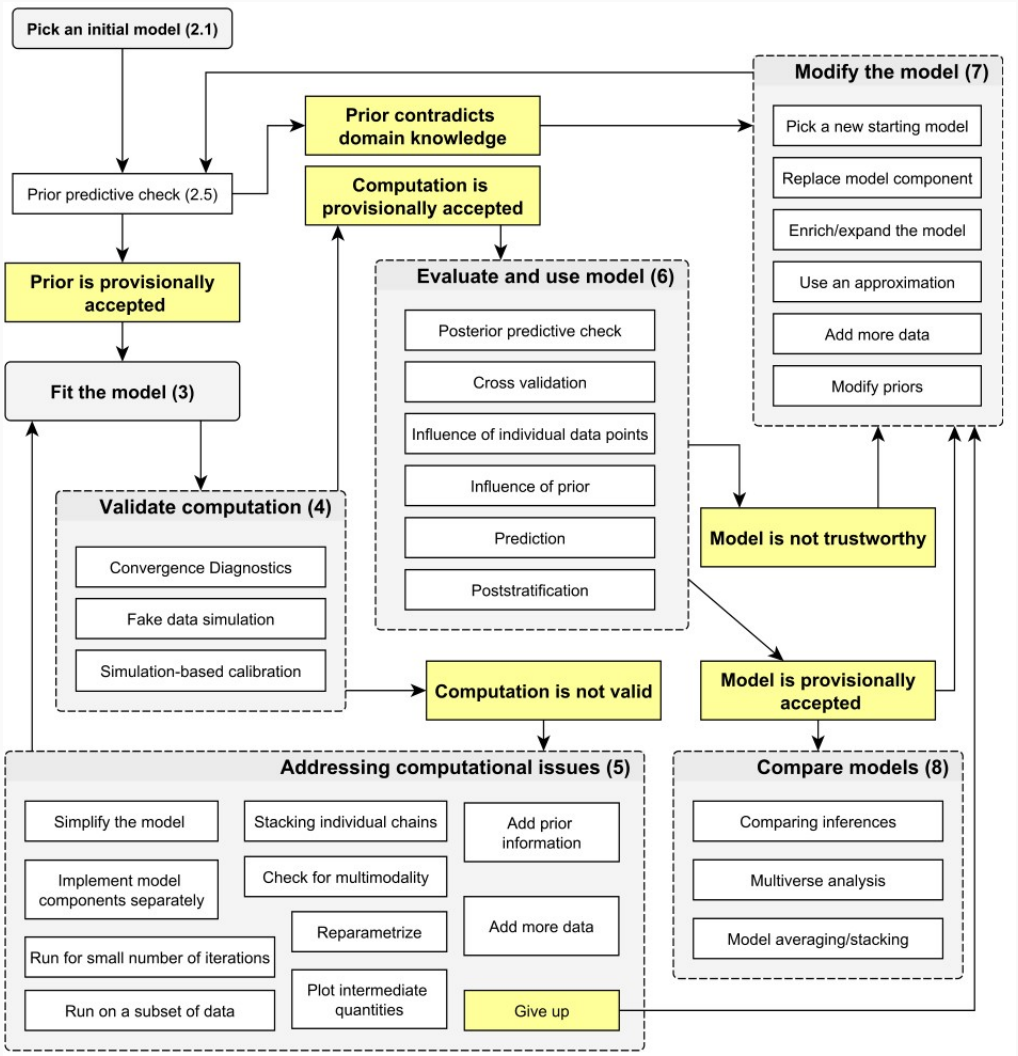
- Variational inference methods in Stan and the CAVI algorithm.
- Expectation-Maximization algorithm
- Mixture models
- Model checking
- Model comparisons

Methods

The course will be delivered by traditional lectures and practical computer sessions. Students will be encouraged to participate at discussion on selected topics during the lectures. In the practical sessions the softwares R and Stan will be used to illustrate some of the main ideas and techniques by analysing some real datasets.

Prerequisites: Probability calculus, statistical inference

Bayesian workflow



Bayesian inference and Bayesian Workflow

Bayesian inference is just the formulation and computation of conditional probability or probability densities.

Bayesian workflow includes the three steps of model building, inference, and model checking/improvement

- model specification
- model fitting and computational issues
- model checking
- model comparison and selection

This is not very different from a general Data Analysis workflow (save for the prior-related issues, although the same issues may be there, more or less under the carpet).