

## Course Description:

Bayesian methodology and advanced Monte Carlo simulations (such as MCMC and ABC) with applications to finance and network data  
3 ECTS

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The goal of this course is to develop tools for data analysis, probabilistic (hierarchical) modeling, forecasting and model choice from the Bayesian perspective. Financial, social and economic applications are considered.

The Bayesian approach to statistical inference is illustrated, with examples highlighting the differences, pros and contras relative to the likelihood based approach.

The decision theoretical approach to statistical inference is also considered. Simulation algorithms such as Monte Carlo integration, Importance sampling, Markov chain Monte Carlo, Approximate Bayesian Computation and other advanced techniques used to estimate Bayesian models, construct credible intervals and conduct hypothesis testing and model selection, will be illustrated and the code to run such algorithms will be provided.

### **Course Main Topics:**

Theory:

- The Bayesian paradigm: priors and posteriors. Some examples
- Prior specification, credible intervals, hypothesis testing and model comparison/selection
- Monte Carlo integration and Importance sampling
- Markov chain theory

- Markov chain Monte Carlo (MCMC) algorithms
- The Metropolis-Hastings algorithm, the Gibbs sampler, the Independence sampler, the Random Walk algorithm, Reversible Jumps
- Burn-in, convergence diagnostics, starting point of the simulation
- Algorithm performance comparison and Monte Carlo variance reduction techniques
- Adaptive MCMC
- Approximate Bayesian Computation
- Financial, Social and Economic applications will be discussed with a focus on relational data and network models

**Software:** The R statistical software will be used and can be downloaded at [www.r-project.org](http://www.r-project.org) Most of the routines and the code illustrated during the lectures is also available in Matlab.

**Evaluation:** Course evaluation is based on homework and a final project where the student is required to conduct a Bayesian analysis on his/her own data.

**Prerequisites:** Introduction to probability and basics knowledge of statistical inference. Basic knowledge of a statistically oriented software (such as R or Matlab) is strongly recommended.

**Reference papers for MCMC simulation (in order of suggested reading):**

- L. Tierney, *Markov Chains for Exploring Posterior Distributions*, The Annals of Statistics, Vol. 22, n. 4., pp. 1701-1728, 1994  
<http://projecteuclid.org/euclid.aos/1176325750>
- P. J. Green, *Reversible Jump Markov-chain Monte Carlo computation and Bayesian model determination*, Biometrika, Vol. 82, n. 4, pp. 711-732, 1995  
<http://www.maths.bris.ac.uk/~mapjg/papers/RJMCMCBka.pdf>
- G.O. Roberts and J.S. Rosenthal, *Optimal Scaling for Various MetropolisHastings Algorithms*, Statist. Sci. Vol. 16, n. 4, 351-367, 2001
- G.L. Jones, J.P. Hobert, *Honest Exploration of Intractable Probability Distributions via Markov Chain Monte Carlo*, Statistical Science, Vol. 16, n. 4, pp. 312-334, 2001
- G.L. Jones, *On the Markov Chain Central Limit Theorem*, Probab. Surveys, Vol. 1, 299-321, 2004
- C. Andrieu and J. Thoms, *A tutorial on adaptive MCMC*, Statistics and Computing, 18, pp. 343-373, 2008

[http://www2.maths.bris.ac.uk/~maxca/preprints/Andrieu08\\_AdaptiveMCMC.pdf](http://www2.maths.bris.ac.uk/~maxca/preprints/Andrieu08_AdaptiveMCMC.pdf)

- J. Rosenthal and G.O. Roberts, *Examples of adaptive MCMC*, Journal of Computational and Graphical Statistics, 18(2), pp. 349-367, 2009  
<http://probability.ca/jeff/ftplib/adaptex.pdf>
- J.M. Marin JM, P. Pudlo, C.P. Robert, R.J. Ryder, *Approximate Bayesian computational methods*, Statistics and Computing, 22(6), pp. 1167-1180, 2012

**Reference books on Bayesian modeling:**

- A. Gelman, J. Carlin, H. Stern, and D. Rubin, *Bayesian Data Analysis (2nd Edition)*, Chapman & Hall/CRC, 2004
- Berger, J. O. (1985). *Statistical Decision Theory and Bayesian Analysis*. Springer Series in Statistics (Second ed.). Springer Verlag
- Robert, C. P. (2001). *The Bayesian Choice A Decision-Theoretic Motivation* (second ed.). Springer Verlag
- Bauwens, L., M. Lubrano and J.F. Richard (1999) *Bayesian Inference in Dynamic Econometric Models*, Oxford University Press.
- Murray, I., Ghahramani, Z. and MacKay, D. J. C. (2006). *MCMC for doubly-intractable distributions*. In: Dechter, R and Richardson, TS, (eds.) (Proceedings) Uncertainty in Artificial Intelligence. (pp. 359 - 366). AUAI Press
- Durbin, J. and Koopman S. J. (2001). *Time series analysis by state-space methods*, Oxford University Press.
- Greenberg, E. (2008), *Introduction to Bayesian Econometrics*, Cambridge University Press.
- Kim, C. J. and Nelson C. R.(1999). *State-space models with regime switching: classical and Gibbs-sampling approaches with applications*, MIT press.
- Koop, G. (2003). *Bayesian Econometrics*, J. Wiley.
- Koop, G., Dale J. P., Tobias, J. L. (2007) *Bayesian Econometric Methods*, Cambridge University Press
- West, M. and Harrison, P. J. (1997). *Bayesian Forecasting and Dynamic Models*, Springer-Verlag.
- Zellner, A. (1971) *Introduction to Bayesian Inference in Econometrics*, Wiley and Sons

**Reference books on Simulation algorithms:**

- J. Liu, *Monte Carlo Strategies in Scientific Computing*, Springer, 2001
- C.P. Robert and G. Casella, *Monte Carlo Statistical Methods*, New York: Springer-Verlag, 2004
- W. R. Gilks and S. Richardson and D. J. Spiegelhalter, *Markov chain Monte Carlo in practice*, London: Chapman and Hall, 1996
- C.P. Robert and G. Casella, *Introducing Monte Carlo Methods with R*, Springer-Verlag, 2009