Syllabus – PhD Course Proposal

Course Title:

Monte Carlo random sampling methods with application to Bayesian analysis

Instructor:

Luca Martino – Email: luca.martino@unict.it

Course Description:

This course provides an introduction to the principles and methods of random number generation and their applications in statistical computation. We begin with the fundamentals of pseudo-random and true random number generation, discussing algorithms, properties, and reproducibility. We then explore random sampling techniques used in Monte Carlo simulation and Bayesian inference, highlighting their role in numerical integration and uncertainty quantification. Finally, the course covers advanced methods for stochastic approximation, including advanced Markov Chain Monte Carlo (MCMC) and advanced importance sampling, emphasizing both theoretical foundations and practical implementation aspects

Learning Outcomes:

At the end of the course, students will be able to:

1. Knowledge of the basic Random Number Generation and Pseudo-Random Numbers.

2. Application to Monte Carlo quadratures for integral approximations

3. Ability of programming direct transformation methods, rejection sampling, advanced MCMC methods and advaaced importance sampling schemes

Prerequisites:

Basic statistics.

Course Structure and Schedule (15 hours):

Session	Topic	Key Readings
1	Intro to Pseudo Random Number and Random number generation	- L. Martino, D. Luengo, J. Míguez, "Independent Random Sampling Methods", Springer, 2018;
2	Random sampling methds for Monte Carlo and Bayesian inference	- C. P. Robert and G. Casella. Monte Carlo Statistical Methods. Springer, 2004
3	Direct methods and Rejection sampling with applications	- L. Martino, D. Luengo, J. Míguez, "Independent Random Sampling Methods", Springer, 2018; - C. P. Robert and G. Casella. Monte

		Carlo Statistical Methods. Springer, 2004
4	Basics of Markov Chain Monte Carlo (MCMC), and Importance Sampling with applications	- C. P. Robert and G. Casella. Monte Carlo Statistical Methods. Springer, 2004 - D. Luengo, L. Martino, M. Bugallo, V. Elvira, S. S arkka, "A Survey of Monte Carlo Methods for Parameter Estimation", EURASIP Journal on Advances in Signal Processing, Article number: 25, 2020
5	Advanced MCMC methods, advanced Importance Sampling (as particle filtering) with applications	- L. Martino, V. Elvira. "Metropolis Sampling", Wiley StatsRef: Statistics Reference Online, 2017. - V. Elvira, L. Martino, "Advances in Importance Sampling", Wiley StatsRef: Statistics Reference Online, 2020. - L. Martino, J. Read, V. Elvira, F. Louzada, "Cooperative Parallel Particle Filters for on-Line Model Selection and Applications to Urban Mobility" Digital Signal Processing, Vol. 60, Pages: 172-185, 2017.

Teaching Methods:

Lectures and coding classes with practical exercises

Assessment:

Presentation and coding in MATLAB

Bibliography:

- L. Martino, D. Luengo, J. Míguez, "Independent Random Sampling Methods", Springer, 2018;
- C. P. Robert and G. Casella. Monte Carlo Statistical Methods. Springer, 2004
- L. Martino, J. Read, V. Elvira, F. Louzada, "Cooperative Parallel Particle Filters for on-Line Model Selection and Applications to Urban Mobility" Digital Signal Processing, Vol. 60, Pages: 172-185, 2017.
- D. Luengo, L. Martino, M. Bugallo, V. Elvira, S. Sarkka, "A Survey of Monte Carlo Methods for Parameter Estimation", EURASIP Journal on Advances in Signal Processing, Article number: 25, 2020.
- L. Martino, V. Elvira. "Metropolis Sampling", Wiley StatsRef: Statistics Reference Online, 2017.
- V. Elvira, L. Martino, "Advances in Importance Sampling", Wiley StatsRef: Statistics Reference Online, 2020.

Preferred Bimester:

Select one: November–December (or May–June)