TRAINING COURSE

MONTE CARLO AND ADVANCED SIMULATION METHODS

PROVIDED BY JOHN VON NEUMANN INSTITUTE - VNUHCM

I. COURSE INTRODUCTION

Monte Carlo methods are the main ingredients of many numerical algorithms widely used in Econometrics, Finance, Biology and more generally in all domains that are linked with Statistics and Machine Learning. In Bayesian Statistics for example, inference on the model is done from an a priori knowledge on the parameter and from a given family of observations. To obtain numerical expressions of any quantity expressed as an expectation of a particular function of interest under a posteriori distribution, some efficient computational algorithms are then crucially requested.

In this course, we provide several ways of sampling either exactly or approximately from a target distribution. The performance of these algorithms is usually measured in terms of the variance of the error and we also provide classical variants that allow to reduce, sometimes dramatically, the variance of the error, enhancing therefore the quality of the approximation. Throughout the course, many illustrations in Python help to grasp the different introduced algorithms.

II. WHAT YOU WILL LEARN

- Propose several ways for providing approximate samples from a target distribution.
- Understand the basis of Monte Carlo methods and identify the main factors that influence the quality of the approximations.
- Propose some variants that reduce the variance of the error.

III. LEARNING OUTCOMES

At the end of this course,

- Monte Carlo and advanced simulation methods can be used by financial analysts to estimate cash flows and potential new products.
- Portfolio managers and financial advisors can use Monte Carlo models to assess how investments affect portfolio risk and performance.
- Insurance firms use Monte Carlo to calculate policy prices and claim potential.

IV. WHO THIS COURSE IS FOR?

- Business analysts, risk analysts, data analysts;
- Evaluation engineers, planners, and economists;
- risk managers within banks, insurance companies, mutual funds, as well as finance departments of non-financial organizations.

V. LECTURERS

- Lecturer in charge of the course:

- Prof. Randal Douc
  Full Professor in Applied Mathematics in the engineering school Télécom Sudparis, France.
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- Lecturers participating in the course:
  - Dr. Tran Trung Minh, John von Neumann Institute, Vietnam National University of Ho Chi Minh City.

APPENDIX 1: COURSE CONTENT

1. **Preliminaries**
2. **Refresh on Measure theory and Lebesgue integration**
   2.1. Sigma-fields, Measures and Probability
   2.2. Integrals, random variables, expectation
   2.3. Convergence
   2.4. Some usual distributions
3. **Introduction to the Monte Carlo methods**
   3.1. Principle of the method
   3.2. On the use of the CLT for Monte Carlo methods
4. **Exact or approximate sampling**
   4.1. Exact Sampling
   4.2. Approximate sampling
   4.3. Take-home message
5. **Metropolis-Hastings algorithms**
   5.1. Canonical space
   5.2. Metropolis-Hastings algorithms
   5.3. Invariant probability measure: uniqueness
6. **Variance reduction techniques**
   6.1. Importance Sampling
   6.2. Antithetic variates
   6.3. Control Variates
   6.4. Conditioning
   6.5. Stratified sampling
   6.6. Quasi Monte Carlo methods
7. **Exercises**

APPENDIX 2: COURSE SCHEDULE

Day	Date	8.30-10.00	10.15-11.45	13.00-14.30
1	Monday, 19 June	Lecture	Tutorial	Computer Session
2	Tuesday, 20 June	Lecture	Tutorial	Computer Session
3	Wednesday, 21 June	Lecture	Tutorial	
4	Thursday, 22 June	Lecture	Tutorial	Computer Session
5	Friday, 23 June	Lecture	Tutorial	Computer Session
6	Saturday, 24 June	Lecture	Tutorial	

- Day 1: 4H30
  - Lecture 1H30: Recap on Measures, Integration, Random Variables, independence, LLN.
  - Tutorial 1H30: Exercises
  - Computer 1H30: Histograms and sampling of random variables. LLN.
- Day 2: 4H30
  - Lecture 1H30: Central Limit Theorem, Confidence interval, Slutsky's lemma.
  - Tutorial 1H30: Exact sampling, quantile function. Rejection sampling: exercise.
  - Computer 1H30. CLT and confidence intervals. Exact sampling.
- Day 3: 3H
  - Lecture 1H30: Approximate sampling, Importance sampling. Monte Carlo by Markov chains.
  - Tutorial 1H30: Approximate sampling, Markov chains, exercises.
- Day 4: 4H30
  - Lecture 1H30: Variance reduction (I): antithetic and control variates.
  - Tutorial 1H30: Markov chains and antithetic variables.
  - Computer 1H30: Importance sampling and MCMC.
- Day 5: 4.30h
  - Lecture 1H30: Variance reduction (II): conditioning, stratified sampling
  - Tutorial 1H30: Exercises on variance reduction.
  - Computer 1H30: Variance reduction (II)
- Day 6: 3H
  - Lecture 1H30: Other approximate sampling methods (Variational Inference).
  - Tutorial 1H30: Exercise.