Columbia University

IEOR4703 – Monte Carlo Simulation Methods

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Course Overview

Monte Carlo simulation, also known as the Monte Carlo method, originated in the 1940s at Los Alamos National Laboratory. Physicists Stanislaw Ulman, Enrico Fermi, John von Neumann, and Nicholas Metropolis had to perform repeated simulations of their atomic physics models to understand how these models would behave given a large number of uncertain input variable values. As random samples of the input variables were chosen for each simulation run, a statistical description of the model output emerged that provided evidence as to how the real-world system would behave.

It is the repeated random sampling model of the input variables over many simulation runs that defines Monte Carlo simulation. The result is an artificial model that is meant to closely resemble the real world in all relevant aspects.

They are often used in quantitative, mathematical, and physical problems and are most useful when dealing with problems which are difficult or not possible to use any other methods. Monte Carlo methods are used in generating samples/draws from a probability distribution, numerical integration, optimization, and more. `Monte Carlo` simulation methods can be applied to any single project.

The computational platform for the course will be Python.

Prerequisites:

Core courses in the first semester of MSFE should be sufficient.

Textbook:

There are NO required textbooks for the course. We will provide lecture notes prior to each lecture. Recommended textbooks are:

Monte Carlo Methods in Financial Engineering (Springer) by Paul Glasserman

Monte Carlo methods in finance (J. Wiley) by Peter Jackel

Simulation (Academic Press) by Sheldon M. Ross

Computational Methods in Finance (Chapman & Hall/CRC) by Ali Hirsa (Chapters 6 & 8)

Required Work and Grading Policy (subject to change):

Assignments: 7/8 assignments & a case study

Exams: midterm (Tue 3/22/2022 & Thu 3/24/2022) & final (TBA)

Final Grade is based the following weighting schemes: the higher of

25% assignments, 30% midterm, 45% final exam

or

25% assignments, 25% midterm, 50% final exam

Teaching/Course Assistants:

Yuanzhe Ma (TA)

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Office Hours:

Ali Hirsa (Mudd #322) on Tue&Thu 10:00-11:00 (permanent) and 14:30-15:30 (temporary)

Yuanzhe Ma (TBA)

Zhiman Tang (TBA)

Yuan Tan (TBA)

Statement of academic integrity:

Students are allowed to collaborate on assignments however, they are not allowed to copy one another's work/code. The work/code should be your own. If students are caught copying, all participants would receive zero for that assignment. Use of online sources are allowed with proper citation.

Class Outline (subject to change):

Generating random numbers

Sampling from various different distributions

Simulation output analysis

Variance reduction techniques

Monte Carlo Integration, Quasi Monte-Carlo and low discrepancy sequences (LDS)

Simulating stochastic differential equations (SDEs)

Simulation of various different processes

Pricing derivatives via simulation

American Option Pricing via simulation

Estimating `Greeks` via Monte-Carlo

Statistical Inferences & `Bayesian` Approach

`Markov` Chains

`Markov` Chain Monte-Carlo (`MCMC`) methods including `Metropolis-Hastings` and `Gibbs` sampling

`Hamiltonian` Monte Carlo

Optimization using Monte Carlo