Monte Carlo Simulation (MA323)

Introduction

Dr. Palash Ghosh

Indian Institute of Technology Guwahati

July-Nov 2023

Syllabus

- Principles of Monte Carlo; Generation of random numbers from a uniform distribution - linear congruential generators and its variations; Generation of discrete and continuous random variables - inverse transform and acceptance-rejection method;
- Simulation of univariate normally distributed random variables - Box-Muller and Marsaglia methods; Generation of multivariate normally distributed random variables - Cholesky factorization;
- Generation of geometric Brownian motion and jump-diffusion sample paths; Variance reduction techniques; Quasi Monte Carlo - general principles and low discrepancy sequences.

Books

- Text Books
  - P. Glasserman, Monte Carlo Methods in Financial Engineering, Springer, 2004.
  - R. U. Seydel, Tools for Computational Finance, 5th Ed., Springer, 2012.

Grading Policy

- Weights in different examination are as follows:
  - Lab Assignments: 20% [**If you copy codes/reports in any of the Lab assignments, you (all who involved) will start from -10 marks.**]
  - Mid-semester Lab Examination: 30%
  - End-semester Lab Examination: 50%
- An **F** grade will be awarded if you obtain less than 20% of total marks after the end semester examination.

Why should we study Monte Carlo Simulation?

Why should we study Monte Carlo Simulation?

- **Large Hadron Collider (LHC)**: To study the fundamental building blocks of matter. Monte Carlo simulations are used to design and optimize the LHC, and to predict the results of experiments.
- **Human Genome Project**: To sequence the entire human genome. Monte Carlo simulations were used to estimate the cost and time of the project, and to identify the most difficult parts of the genome to sequence.
- **Climate change research**: Monte Carlo simulations are used to model the effects of climate change on the environment, and to predict how climate change is likely to impact the planet in the future.
- As the world becomes increasingly complex, and the need for **accurate predictions becomes more essential**, Monte Carlo simulation is likely to become an **even more valuable tool for scientists**.

Why should we study Monte Carlo Simulation?

- Some other examples of high-impact science projects that have used Monte Carlo simulation:
  - The search for dark matter
  - The development of new drugs
  - The design of new materials
  - The study of the brain
  - The exploration of space
- These projects all involve complex systems with uncertainty, and Monte Carlo simulation has been used to help scientists make better decisions and to achieve their goals.

Monte Carlo Simulation: Roulette Wheel

Source: From Wikimedia Commons, the free media repository

Monte Carlo Simulation: Roulette Wheel

Source: From Wikimedia Commons, the free media repository

- This image shows a roulette wheel, which is a classic example of a random process. Monte Carlo simulation can be used to simulate the outcome of a roulette wheel by repeatedly spinning the wheel and recording the results. This can be used to estimate the probability of different outcomes, such as the probability of landing on red or black.

Monte Carlo Simulation: Rocket Science

- **Designing rockets:** MCS is used to model the behavior of rockets in different environments.
- **Planning launches:** MCS can be used to plan launches by considering a variety of possible outcomes.
- **Analyzing data:** MCS to identify trends and to improve the understanding of the rocket's performance.
- To estimate the probability of launch success
- To determine the optimal trajectory for a rocket
- To predict the effects of weather on a launch
- To model the performance of a new rocket engine
- To test the robustness of a rocket's software

Monte Carlo Simulation: Digital Twin

Source: Erol T, Mendi AF, Dogan D. The digital twin revolution in healthcare. In2020 4th international symposium on multidisciplinary studies and innovative technologies (ISMSIT) 2020 Oct 22 (pp. 1-7). IEEE.