

Metropolis type algorithms and applications

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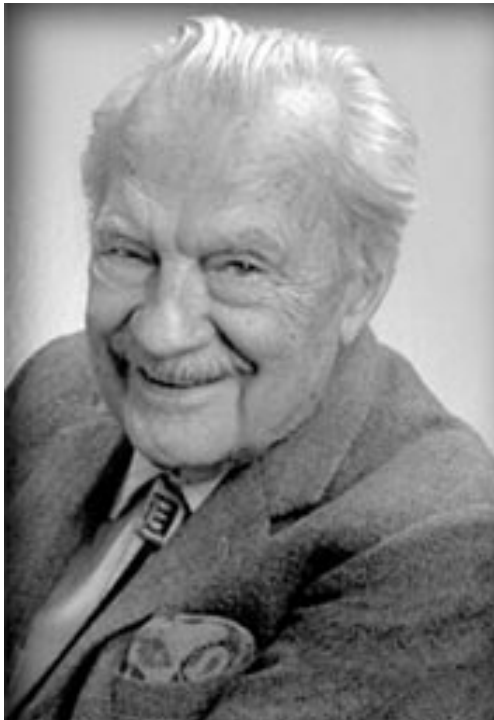
“Spiru Haret” University



Abstract

- This work is dedicated to N. Metropolis, after 100 years since he was born on June 11, 1915.
- The material reviews the characteristics of Metropolis type algorithms, and outline the application fields which used and use what is called, in general, "Monte Carlo methods".
- **keywords:** *Monte Carlo methods, simulation, random numbers, Metropolis, MCMC*

Nicholas Metropolis (June 11, 1915 – October 17, 1999)



- Nicholas Constantine Metropolis was born on June 11th, 1915, in Chicago. In 1936 he received his bachelor's degree, and in 1941, his doctorate, both from the University of Chicago, and both in experimental physics. While at Chicago, Metropolis worked at the Met Lab as an assistant to Enrico Fermi.
- Enrico Fermi was an Italian physicist, best known for his work on Chicago Pile-1 (the first nuclear reactor), and for his contributions to the development of quantum theory, nuclear and particle physics, and statistical mechanics.

<http://manhattanprojectvoices.org/oral-histories/nicholas-metropolis-interview>

Collaborating on ...

- Working under Metropolis' supervision were John von Neumann and Stanislaw Ulam. Metropolis recalls collaborating with von Neumann and Ulam and developing the Monte Carlo method.
- The Monte Carlo method is a statistical approach to solve many-body problems.

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Another case illustrating this situation is as follows: Consider the problem of evaluating the volume of a region in, say, a twenty-dimensional space. The region is defined by a set of inequalities

$$f_1(x_1, x_2 \cdots x_{20}) < 0; f_2(x_1, x_2 \cdots x_{20}) < 0; \cdots f_{20}(x_1, x_2 \cdots x_{20}) < 0.$$

This means that we consider all points $(x_1, x_2, x_3, \cdots x_{20})$ satisfying the given inequalities. Suppose further that we know that the region is located in the unit cube and we know that its volume is not vanishingly small in general. The multiple integrals will be hardly evaluable. The procedure based on the definition of a volume or the definition of an integral, i.e., the subdivision of the whole unit cube, for example, each coordinate x_1 into ten parts, leads to an examination of 10^{20} lattice points in the unit cube. It is obviously impossible to count all of them.

THE MONTE CARLO METHOD

NICHOLAS METROPOLIS AND S. ULAM

Los Alamos Laboratory

We shall present here the motivation and a general description of a method dealing with a class of problems in mathematical physics. The method is, essentially, a statistical approach to the study of differential equations, or more generally, of integro-differential equations that occur in various branches of the natural sciences.

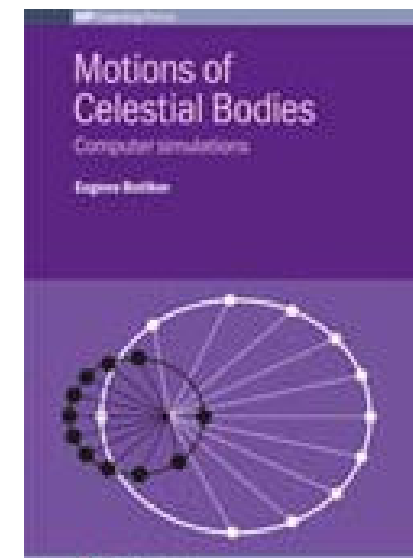
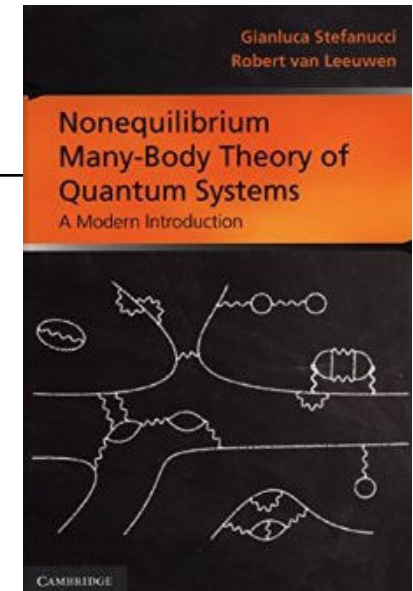
MANIAC

- ❑ The **MANIAC** (*Mathematical Analyzer, Numerical Integrator, and Computer* or *Mathematical Analyzer, Numerator, Integrator, and Computer*) was an early computer built under the direction of Nicholas Metropolis at the Los Alamos Scientific Laboratory. It was based on the von Neumann architecture of the IAS, developed by John von Neumann. As with all computers of its era, it was a one of a kind machine that could not exchange programs with other computers (even other IAS machines).
- ❑ The MANIAC ran successfully in March 1952 and was shut down on July 15, 1958.
- ❑ It was succeeded by MANIAC II in 1957.
- ❑ In 1957, Dr. Metropolis returned to the University of Chicago and founded the Institute for Computer Research. A third version MANIAC III was built at the Institute for Computer Research at the University of Chicago in 1964. In 1965, he returned to Los Alamos
- ❑ A computer named MANIAC I was featured in the science fiction film *The Magnetic Monster*

https://www.youtube.com/watch?v=M_HaWKNnz-I

Many-Body Theory

- The **many-body theory** (or **many-body physics**) is an area of physics which provides the framework for understanding the collective behavior of vast assemblies of interacting particles. In general terms, the many-body theory deals with effects that manifest themselves only in systems containing large numbers of constituents. While the underlying physical laws that govern the motion of each individual particle may (or may not) be simple, the study of the collection of particles can be extremely complex.
- **Many-body systems in celestial mechanics**



Simulated Annealing

- **Simulated annealing (SA)** is a generic probabilistic metaheuristic for the global optimization problem of locating a good approximation to the global optimum of a given function in a large search space.
- The name and inspiration come from annealing in metallurgy, a technique involving heating and controlled cooling of a material to increase the size of its crystals and reduce their defects.
- The method is an adaptation of the Metropolis–Hastings algorithm, a Monte Carlo method to generate sample states of a thermodynamic system, invented by M.N. Rosenbluth and published in a paper by N. Metropolis et al. in 1953.

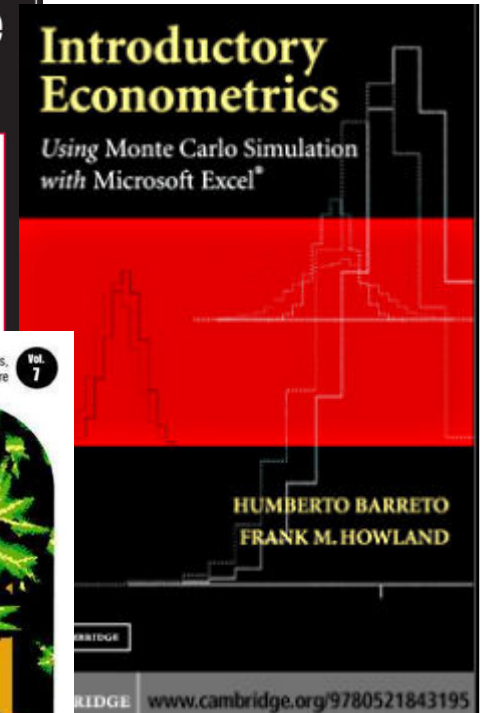
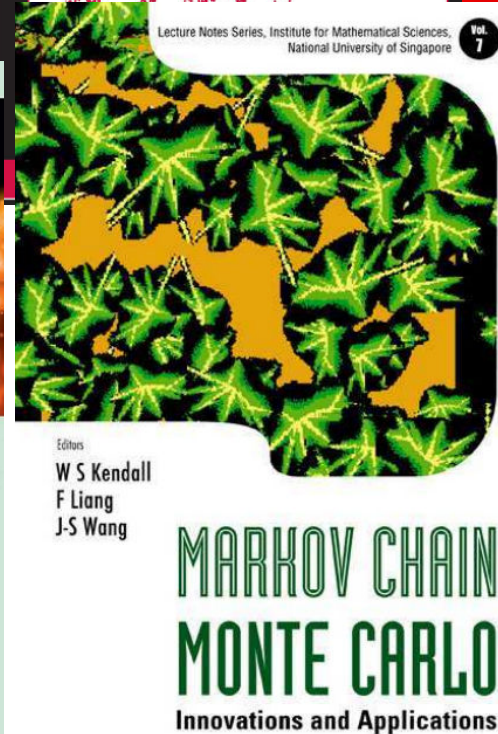
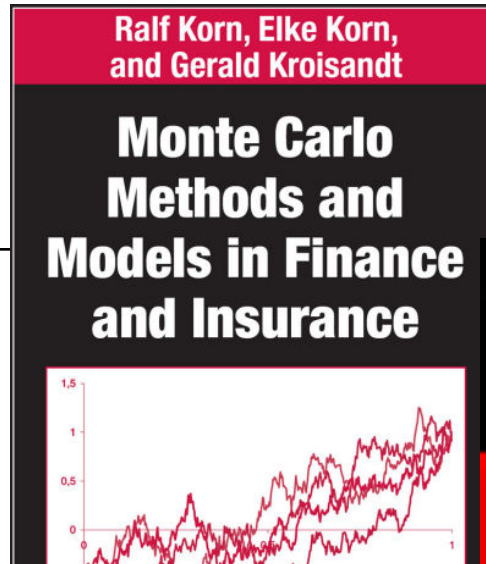
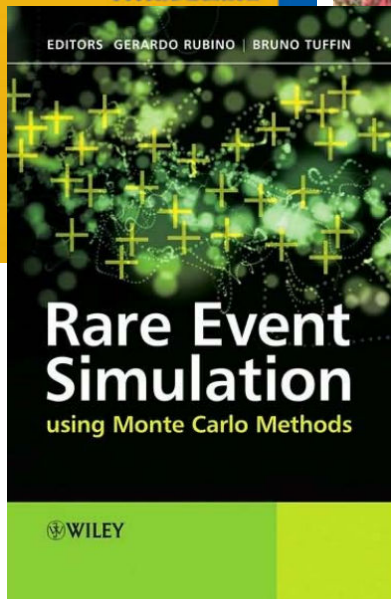
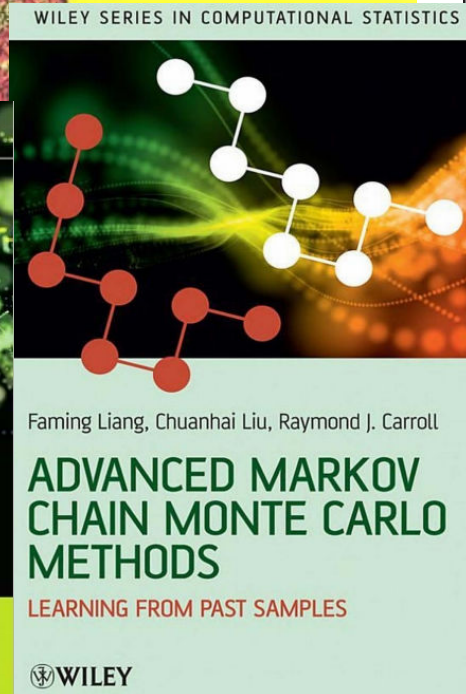
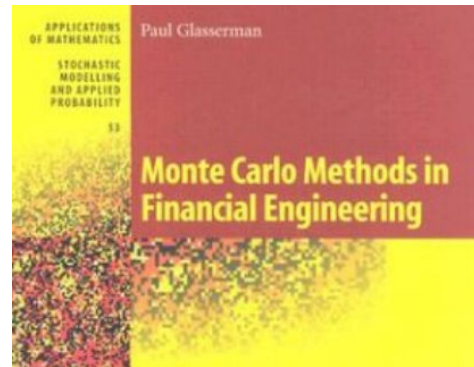
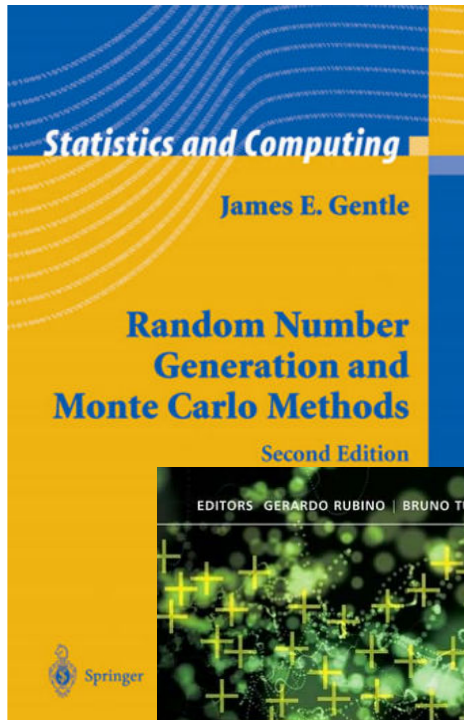
Metropolis-Hastings Algorithm

- In statistics and in statistical physics, the **Metropolis–Hastings algorithm** is a Markov chain Monte Carlo (MCMC) method for obtaining a sequence of random samples from a probability distribution for which direct sampling is difficult.
- This sequence can be used to approximate the distribution (i.e., to generate a histogram), or to compute an integral (such as an expected value).
- Metropolis–Hastings and other MCMC algorithms are generally used for sampling from multi-dimensional distributions, especially when the number of dimensions is high.
- For single-dimensional distributions, other methods are usually available (e.g. adaptive rejection sampling) that can directly return independent samples from the distribution, and are free from the problem of auto-correlated samples that is inherent in MCMC methods.

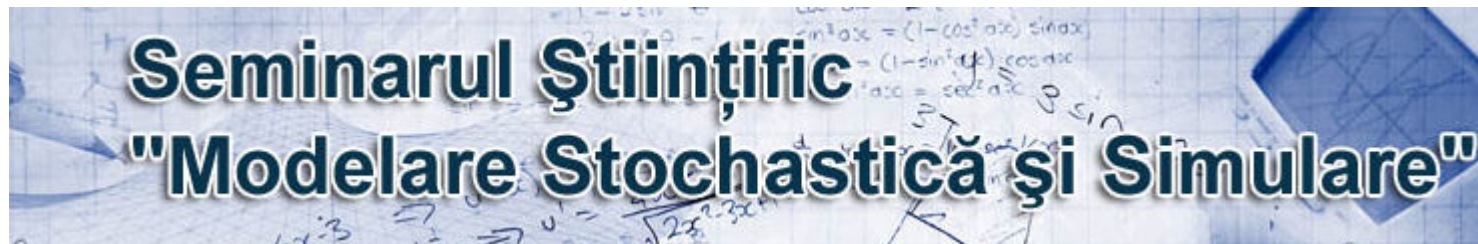
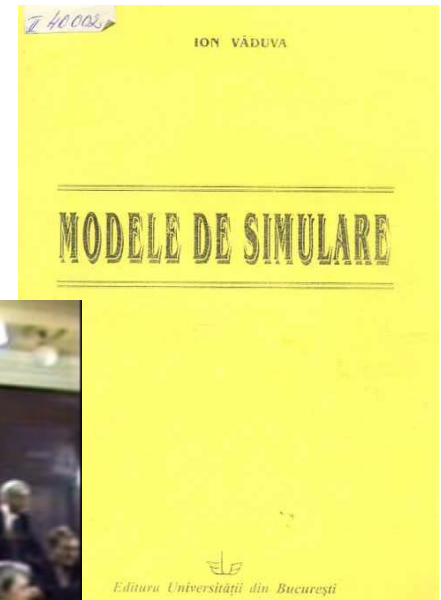
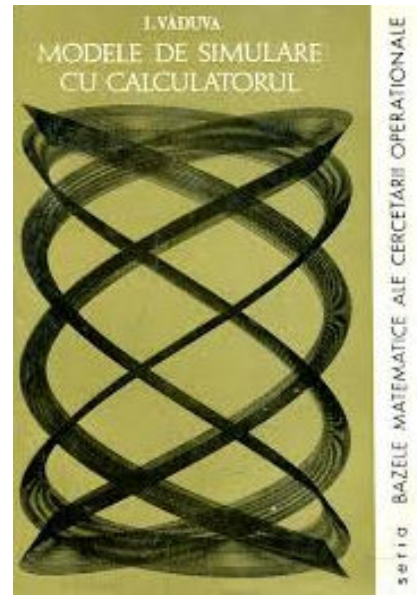
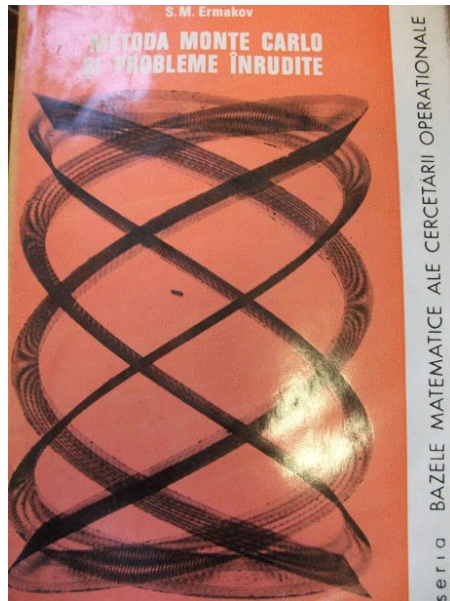
Applications ... many fields



Other Books



MC Methods In Romania(n)

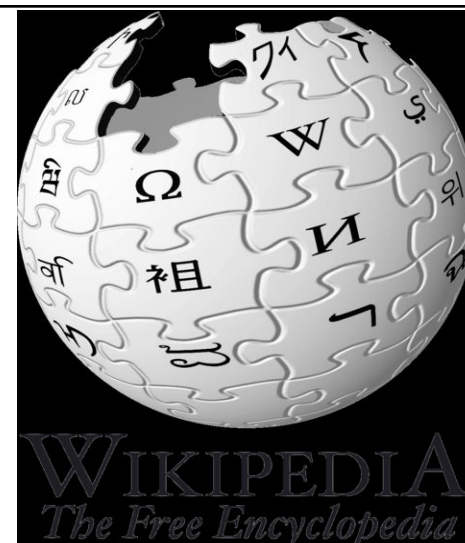


<http://www.ssmss.ro/despre/>

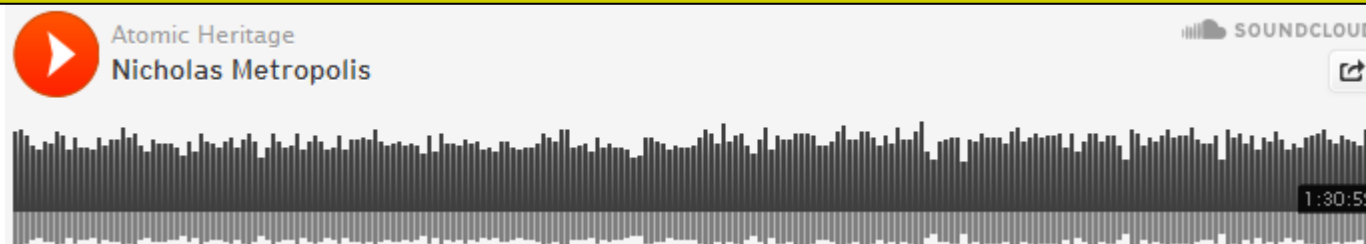
Credits



Google



<http://manhattanprojectvoices.org/oral-histories/nicholas-metropolis-interview>



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