MONTE CARLO SIMULATION

SCIENCE AND ENGINEERING APPLICATIONS

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PREFACE

Knowledge about Monte Carlo simulation in science and engineering is an invaluable tool for analyzing and studying different phenomena around us. When other methodologies are too expensive to use, too hazardous, impossible or would use drastic approximations, the Monte Carlo method with its simple algorithmic structure can always be depended upon to provide a solution. In many cases its application would offer insight into developing analytical, experimental and numerical methods to solve a multitude of problems. Monte Carlo excels in situations of multidimensional, nonlinear and complex systems in general. An advantage of its application is that an estimate of the statistical error in the result can be computed simultaneously with the mean value. With the advent of more sophisticated computing platforms, it is being applied in new fields such as decision support and pervasive computing.

Monte Carlo simulations provide solutions to a variety of problems with inherent probabilistic structure, as well as problems that do not have a probabilistic content. The solutions are based on constructing on a computer platform a statistical experiment that possesses the same mean or expectation values as the original problem, then estimating the solution's parameters over a large number of repetitions of the experiment.

The Monte Carlo method is characterized by an absolute error that is inversely proportional to the square root of the number of sampled points whereas, absent any useful special structures, the absolute error in other numerical methods is inversely proportional to the n-th root of the number of points. The implication is that for multidimensional systems, the Monte Carlo method becomes more favorable than other numerical methods.

This work originated as lecture notes for a course taught about Monte Carlo simulation since 1981. These notes were written and updated, over several years, primarily for the benefit of the author himself in a modest attempt at understanding the topics covered. Numerous updates of these notes were requested and made available over time to those interested in using, learning and teaching Monte Carlo at different teaching and research institutions.

Based on the experience in teaching the class, this work uniqueness is that the material exposed includes tested procedures of the algorithms covered that are written in the Fortran programming language. These serve as templates that the students are capable of emulating on their own, sometimes rewriting them in their favorite languages such as Basic, C or Java or Matlab. Interspersed comments make that task possible. The problem sets also a challenge to the readers to modify the procedures and explore new tasks. This approach has been very successful in getting those wishing to learn the method to master it in their respective fields, since theory and lectures alone are not sufficient to learn the methodology. Actual hands-on usage is the key to master the Monte Carlo method. An approach that emphasizes the actual application of the methodology makes it suitable for scientists and engineers to get started in using it, and encourages them to acquire deeper theoretical knowledge in the formal mathematical treatment of the method in research papers, reports, and other publications.

In addition to covering the basic techniques used in analog and Direct Simulation Monte Carlo and Mathematical Simulation Monte Carlo, emphasis is placed on the use of variance reduction methods such as importance sampling, antithetic variates and correlated sampling. The use of these techniques is paramount in identifying solutions for problems that are otherwise unsolvable by Monte Carlo or other methods even on the most powerful of modern computing platforms.

The material is presented in the Portable Document Format (pdf), and requires a download of the freely accessible Adobe Acrobat Reader on any computer. The chapters can be read in the order that the reader wishes. The work is still in progress and is evolving and is frequently being updated, or in the parlance of the World Wide Web, it is continually "under construction." In fact, it is an ongoing experiment that started in 1981.

The hope is that this modest effort will contribute to the scientific literacy of the readers, as scientists, engineers, college students, and possibly high school students, so that they can teach themselves and others a wonderful technique that makes mathematics a fun activity on modern computers. It is hoped that the present work will spike their interest and launch them in the direction of deeper learning, discovery and enjoyment of their respective fields of interest.

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