

Preface

This book introduces the Monte Carlo simulation method for application to system reliability and risk analysis. Monte Carlo simulation is a modeling tool widely used in several scientific domains. The continuous improvements in computational power and software solutions allow its application to complex systems and problems.

The purpose of the book is to present basic and advanced techniques of Monte Carlo sampling and simulation for realistic system reliability and risk modeling. In the past, restrictive assumptions had to be introduced to the models in order to fit them to the analytical or numerical methods available for their solution, at the cost of drifting away from the actual system operation and at the risk of obtaining sometimes dangerously misleading results. Thanks to the inherent flexibility of Monte Carlo simulation, most of these assumptions can be relaxed so that realistic operating rules, including for example maintenance policies and component aging processes, can be accounted for in the model. This is of fundamental importance for systems and plants, such as those employed in the nuclear, aerospace, and chemical industry, which are safety-critical and must be designed and operated within a risk-informed approach. Yet, the efficient use of Monte Carlo simulation techniques is not trivial in large-scale applications, and the computational efforts involved may require appropriate “intelligent” techniques to obtain the results of interest in acceptable computing times.

This book collects, in a structured way, the material from a series of lectures held to senior undergraduate and graduate students at various Universities (e.g., Ecole Centrale Paris, Politecnico di Milano, Supélec, Universidad Politecnica de Valencia, Universidad Federico Santa Maria de Valparaiso, and others) and from research work carried out in the last 20 years by the author and his collaborators.

The material is organized as follows. In [Chap. 1](#), a general introduction is offered on the types of problems that can be addressed by Monte Carlo simulation. [Chapter 2](#) gives some basic concepts and definitions related to system reliability and risk analysis; some additional basic knowledge is given through Appendixes at the end of the book. In [Chap. 3](#), basic procedures are given for sampling random numbers from some probability distributions commonly used in system reliability

and risk analysis, for solving definite integrals and linear integral equations, and for sensitivity analysis. [Chapter 4](#) illustrates the use of Monte Carlo simulation for the problem of evaluating the reliability and availability of a system (formulated as a transport problem of the system states) and provides an operative procedure for its solution. The material in this chapter is completed by the presentation of a number of practical applications in the following [Chap. 5](#). In [Chap. 6](#), a number of advanced Monte Carlo simulation techniques are introduced to solve the problem of estimating the probability of system failure when this event is rare. These techniques include the classical Latin Hypercube Sampling and Importance Sampling, and also more recent techniques such as Cross-Entropy, Subset Sampling, Line Sampling. Examples of applications of some of these techniques are provided in [Chap. 7](#), where sample space is given to comparisons with standard Monte Carlo simulation to appreciate the benefits offered by these techniques.

In preparing the book, efforts have been made to maintain a balance between the required theoretical and mathematical rigor in the exposition of the methods and the clarity in the illustration of the numerical examples and practical applications. For this reason, this book can serve well as a reference to both reliability and risk analysis researchers and engineers, and it would also prove useful for a university course on the subject at junior/senior undergraduate or graduate levels. Although the book is self-explanatory, a standard background in probability theory, mathematical statistics, and integral calculus is recommended.

Finally, it is with sincere appreciation that I thank all those who have contributed to prepare this book. In particular, I am grateful to Drs. Piero Baraldi, Edoardo Patelli, Nicola Pedroni, Luca Podofillini, and Professor Marzio Marseguerra for contributing the research that has provided the material for many parts of the book, and to Dr. Michele Compare, Samuele Baronchelli and Fabio Frassini for their careful editing work.

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