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Stochastic simulation: algorithms and analysis.

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In the authors' words, "this book is intended to provide a broad treatment of the basic ideas and algorithms associated with sampling-based methods, often also referred to as Monte Carlo algorithms or stochastic simulation. The reach of these ideas is illustrated here by discussing a wide range of different applications. Our goal is to provide coverage that reflects the richness of both the applications and the models that have found wide usage." The authors succeed admirably in their task, and the book will be very useful to students and researchers from a wide range of disciplines. The emphasis of the text is on breadth of coverage of topics, most combined with a small number of well-chosen illustrative examples. The one topic that is covered in only a cursory fashion is simulation of large-scale stochastic models of the kind often studied by students in operations research, e.g. networks of queues, manufacturing systems, or supply chains. The user desiring a deeper coverage of any topic covered can use this book for an introduction but will need to supplement it with other sources. Examples from a wide range of disciplines are covered, which adds to its utility as a reference text; however, since most courses on stochastic simulation are taught from the point of view of a single discipline, this range coupled with the relatively small number of exercises provided at the end of many of the chapters might make it less successful as a primary course textbook. Following an introductory chapter that gives a nice overview of stochastic simulation complete with many illustrative examples, the text is divided into two parts: (A) General Methods and Algorithms, and (B) Algorithms for Special Models.

Section A: General Methods and Algorithms.

Chapter 2: Generating Random Objects. The chapter provides a brief introduction to the generation of uniform random variables and statistical tests of uniformity. It presents general techniques for generating non-uniform variables, including the probability integral transform, the rejection algorithm and transform-based methods. Special algorithms such as the Box-Muller and aliasing algorithm are presented. The chapter also discusses the generation of multivariate random variables and presents copula-based methods. Finally it discusses the generation of simple stochastic processes, especially Markov processes, and it briefly overviews the generation of generalized semi-Markov processes.

Chapter 3: Output Analysis. This chapter deals with a broad survey of tools for the statistical analysis used to interpret simulation output. This ranges from standard normal theory to topics such as bootstrapping, variance/bias tradeoffs, and planning given a simulation budget.

Chapter 4: Steady-State Simulation. This chapter addresses the issue of simulating functionals from the stationary distribution of the underlying process, recognizing that this distribution is usually not known and that any simulation run must start from some initial condition which will influence the results. A variety of methods are discussed, including the regenerative method, the method of batch means, perfect sampling, and duality methods.

Chapter 5: Variance-Reduction Methods. Variance reduction methods exploit the specific problem structure to reduce the variance of simulation estimators and hence speed up the computation. The standard techniques, including antithetic variates, control variates, importance sampling, conditional Monte Carlo, stratification, common random numbers and splitting, are presented.

Chapter 6: Rare-Event Simulation. The estimation of rare-event probabilities is difficult. In standard Monte Carlo simulation the absolute error converges to zero as the event probability converges to zero; however, the relative error converges to infinity. This chapter provides a quite comprehensive overview of various methods to address this problem for both the light tail and heavy tail cases. The methods introduced include tail estimation, conditioned limit theorems, large deviations, and adaptive importance sampling schemes.

Chapter 7: Derivative Estimation. This chapter covers several methods for the estimation of derivatives, including finite differences, infinitesimal perturbation analysis, and the likelihood ratio method. Numerous examples are presented.

Chapter 8: Stochastic Optimization. A frequent goal of a simulation study is to find optimal parameter settings. The chapter introduces stochastic optimization algorithms such as the Kiefer-Wolfowitz and Robbins-Monro algorithms and addresses their convergence properties. Numerical illustrations using a PERT network and a GI/G/1 queue are presented along with a brief discussion of the stochastic EM algorithm.

Part B: Algorithms for Special Models.

Chapter 9: Numerical Integration. This chapter provides a very brief treatment of Monte Carlo and quasi-Monte Carlo (low discrepancy sequence) techniques for numerical integration.

Chapter 10: Stochastic Differential Equations. Stochastic differential equations and their solution are defined in continuous time; however, they must be simulated in discrete time. Except in the infrequent case in which the transition density is known, the discrete process is only approximate. Euler and Milstein discretization schemes are presented. The errors from linear interpolation for intermediate values derived from a discrete Brownian motion path are developed.

Chapter 11: Gaussian Processes. This chapter offers a brief introduction to the simulation of Gaussian processes. Some specific techniques such as Cholesky factorization, circulant embeddings, and spectral methods, including the FFT, are presented. Fractional Brownian motion is also discussed.

Chapter 12: Lvy Processes. This chapter provides a nice introduction to Lvy processes and their simulation, including the multivariate case.

Chapter 13: Markov Chain Monte Carlo Methods. This chapter provides a good overview of MCMC methods. Interesting examples ranging from Bayesian statistics to hidden Markov models are used to illustrate the importance of the methods. The Metropolis-Hastings algorithm, Gibbs sampler, and selected special samplers such as reversible-jump MCMC are covered.

Chapter 14: Selected Topics and Extended Examples. This chapter presents a wide range of special topics and examples. They include simulated annealing, resampling and particle filtering, Ising models, changes of measure, branching processes and examples from mathematical finance and queueing.

The book contains an appendix, 369 references and 24 Web links.