

A REVIEW OF CONDITIONAL RARE EVENT SIMULATION FOR TAIL PROBABILITIES OF HEAVY TAILED RANDOM VARIABLES

LEONARDO ROJAS-NANDAYAPA

ABSTRACT. Approximating the tail probability of a sum of heavy-tailed random variables is a difficult problem. In this review we exhibit the challenges of approximating such probabilities and concentrate on a rare event simulation methodology capable of delivering the most reliable results: Conditional Monte Carlo. To provide a better flavor of this topic we further specialize on two algorithms which were specifically designed for tackling this problem: the Asmussen-Binswanger estimator and the Asmussen-Kroese estimator. We extend the applicability of these estimators to the non-independent case and prove their efficiencies.

1. Introduction

The term *rare event* is used to designate all those events whose probabilities are small, yet non-negligible and characterized by the difficulty of its calculation. Often, these rare events are extremely important in applications; for instance, consider the consequences of a natural disaster for an insurance company, or an economic crisis for a financial institution or the sudden arrival of huge number of jobs to a server as it often occurs in a web server. Many of the probability models employed for dealing with these problems contain multiple random variables (not necessarily independent) and the quantities of interest are given in terms of transformations such as sums, products or extremes. In consequence, the explicit calculation of a distribution of interest is often non-trivial and one must rely on approximation methods. Among these, the Monte Carlo method is considered to be one the most reliable, specially in cases where analytical approximations are not available.

In this review we mainly focus on the Monte Carlo method for approximating rare event probabilities, but we also discuss asymptotic approximations; the reason for this is that the implementation of efficient Monte Carlo estimators often requires to draw elements from asymptotic theory. In particular, we specialize on tail probabilities of a sum of random variables

$$P(S_n > x), \quad x \rightarrow \infty.$$

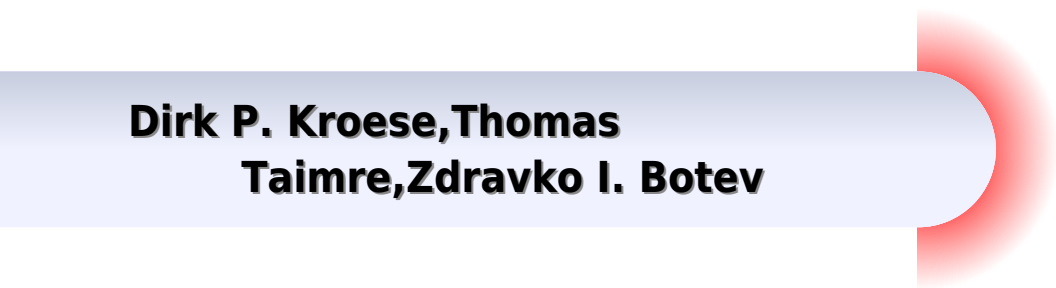
When the involved random variables are light tailed, the approximation of such probabilities is dealt via Large Deviations theory. Notwithstanding, certain phenomena are better modeled with heavy-tailed distributions. However, the approximation of rare event probabilities in the presence of heavy tails is often more involved and it has been considered a challenging problem among the applied

2010 *Mathematics Subject Classification*: 60E05, 90-04.

Keywords and phrases: rare-event simulation, conditional Monte Carlo, heavy-tails, efficiency, non-independent.

Rare Event Simulation In Models With Heavytailed Random Variables

**Dirk P. Kroese, Thomas
Taimre, Zdravko I. Botev**



Rare Event Simulation In Models With Heavytailed Random Variables:

Social Benefits and the Flow Approach to the Labor Market Nam Kyoo Boots, Udo Kock, 2002 **Rare Event Simulation using Monte Carlo Methods** Gerardo Rubino, Bruno Tuffin, 2009-03-18 In a probabilistic model a rare event is an event with a very small probability of occurrence The forecasting of rare events is a formidable task but is important in many areas For instance a catastrophic failure in a transport system or in a nuclear power plant the failure of an information processing system in a bank or in the communication network of a group of banks leading to financial losses Being able to evaluate the probability of rare events is therefore a critical issue Monte Carlo Methods the simulation of corresponding models are used to analyze rare events This book sets out to present the mathematical tools available for the efficient simulation of rare events Importance sampling and splitting are presented along with an exposition of how to apply these tools to a variety of fields ranging from performance and dependability evaluation of complex systems typically in computer science or in telecommunications to chemical reaction analysis in biology or particle transport in physics Graduate students researchers and practitioners who wish to learn and apply rare event simulation techniques will find this book beneficial **Computing Rare-event Probabilities for Affine Models and General State Space Markov Processes** Xiaowei Zhang, 2011 Rare event simulation concerns computing small probabilities i e rare event probabilities This dissertation investigates efficient simulation algorithms based on importance sampling for computing rare event probabilities for different models and establishes their efficiency via asymptotic analysis The first part discusses asymptotic behavior of affine models Stochastic stability of affine jump diffusions are carefully studied In particular positive recurrence ergodicity and exponential ergodicity are established for such processes under various conditions via a Foster Lyapunov type approach The stationary distribution is characterized in terms of its characteristic function Furthermore the large deviations behavior of affine point processes are explicitly computed based on which a logarithmically efficient importance sampling algorithm is proposed for computing rare event probabilities for affine point processes The second part is devoted to a much more general setting i e general state space Markov processes The current state of the art algorithm for computing rare event probabilities in this context heavily relies on the solution of a certain eigenvalue problem which is often unavailable in closed form unless certain special structure is present e g affine structure for affine models To circumvent this difficulty assuming the existence of a regenerative structure we propose a bootstrap based algorithm that conducts the importance sampling on the regenerative cycle path space instead of the original one step transition kernel The efficiency of this algorithm is also discussed

Advances in Heavy Tailed Risk Modeling Gareth W. Peters, Pavel V. Shevchenko, 2015-05-21 ADVANCES IN HEAVY TAILED RISK MODELING A cutting edge guide for the theories applications and statistical methodologies essential to heavy tailed risk modeling Focusing on the quantitative aspects of heavy tailed loss processes in operational risk and relevant insurance analytics Advances in Heavy Tailed Risk Modeling A Handbook of Operational Risk presents comprehensive

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Handbook of Monte Carlo Methods Dirk P. Kroese, Thomas Taimre, Zdravko I. Botev, 2013-06-06 A comprehensive overview of Monte Carlo simulation that explores the latest topics techniques and real world applications More and more of today's numerical problems found in engineering and finance are solved through Monte Carlo methods The heightened popularity of these methods and their continuing development makes it important for researchers to have a comprehensive understanding of the Monte Carlo approach Handbook of Monte Carlo Methods provides the theory algorithms and applications that helps provide a thorough understanding of the emerging dynamics of this rapidly growing field The authors begin with a discussion of fundamentals such as how to generate random numbers on a computer Subsequent chapters discuss key Monte Carlo topics and methods including Random variable and stochastic process generation Markov chain Monte Carlo featuring key algorithms such as the Metropolis Hastings method the Gibbs sampler and hit and run Discrete event simulation Techniques for the statistical analysis of simulation data including the delta method steady state estimation and kernel density estimation Variance reduction including importance sampling latin hypercube sampling and conditional Monte Carlo Estimation of derivatives and sensitivity analysis Advanced topics including cross entropy rare events kernel density estimation quasi Monte Carlo particle systems and randomized optimization The presented theoretical concepts are illustrated with worked examples that use MATLAB a related Web site houses the MATLAB code allowing readers to work hands on with the material and also features the author's own lecture notes on Monte Carlo methods Detailed appendices provide background material on probability theory stochastic processes and mathematical statistics as well as the key optimization concepts and techniques that are relevant to Monte Carlo simulation

Handbook of Monte Carlo Methods is an excellent reference for applied statisticians and practitioners working in the fields of engineering and finance who use or would like to learn how to use Monte Carlo in their research. It is also a suitable supplement for courses on Monte Carlo methods and computational statistics at the upper undergraduate and graduate levels.

Monte Carlo Methods and Models in Finance and Insurance Ralf Korn, Elke Korn, Gerald Kroisandt, 2010-02-26 Offering a unique balance between applications and calculations Monte Carlo Methods and Models in Finance and Insurance incorporates the application background of finance and insurance with the theory and applications of Monte Carlo methods. It presents recent methods and algorithms including the multilevel Monte Carlo method, the statistical Rom, Projects for shareholder value. A capital budgeting perspective Mehari Mekonnen Akalu, 2003 Handbooks in Operations Research and Management Science: Simulation Shane G. Henderson, Barry L. Nelson, 2006-09-02 This Handbook is a collection of chapters on key issues in the design and analysis of computer simulation experiments on models of stochastic systems. The chapters are tightly focused and written by experts in each area. For the purpose of this volume, simulation refers to the analysis of stochastic processes through the generation of sample paths, realization of the processes. Attention focuses on design and analysis issues, and the goal of this volume is to survey the concepts, principles, tools, and techniques that underlie the theory and practice of stochastic simulation. Design and analysis: Emphasis is placed on the ideas and methods that are likely to remain an intrinsic part of the foundation of the field for the foreseeable future. The chapters provide up-to-date references for both the simulation researcher and the advanced simulation user, but they do not constitute an introductory level. How to guide: Computer scientists, financial analysts, industrial engineers, management scientists, operations researchers, and many other professionals use stochastic simulation to design, understand, and improve communications, financial, manufacturing, logistics, and service systems. A theme that runs throughout these diverse applications is the need to evaluate system performance in the face of uncertainty, including uncertainty in user load, interest rates, demand for product availability of goods, cost of transportation, and equipment failures. Tightly focused chapters written by experts: Surveys concepts, principles, tools, and techniques that underlie the theory and practice of stochastic simulation design and analysis. Provides an up-to-date reference for both simulation researchers and advanced simulation users.

Stochastic Biomathematical Models Mostafa Bachar, Jerry J. Batzel, Susanne Ditlevsen, 2012-10-19 Stochastic biomathematical models are becoming increasingly important as new light is shed on the role of noise in living systems. In certain biological systems, stochastic effects may even enhance a signal, thus providing a biological motivation for the noise observed in living systems. Recent advances in stochastic analysis and increasing computing power facilitate the analysis of more biophysically realistic models, and this book provides researchers in computational neuroscience and stochastic systems with an overview of recent developments. Key concepts are developed in chapters written by experts in their respective fields. Topics include one-dimensional homogeneous diffusions and their boundary behavior, large deviation theory, and its

application in stochastic neurobiological models a review of mathematical methods for stochastic neuronal integrate and fire models stochastic partial differential equation models in neurobiology and stochastic modeling of spreading cortical depression **Real estate securitization and corporate strategy. From bricks to bucks** Dirk Brounen, 2003

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