

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

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Social Benefits and the Flow Approach to the Labor Market Nam Kyoo Boots,Udo Kock,2002 *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 coverage of the latest research on the theories and applications in risk measurement and modeling techniques Featuring a unique balance of mathematical and statistical perspectives the handbook begins by introducing the motivation for heavy tailed risk processes A companion with *Fundamental Aspects of Operational Risk and Insurance Analytics A Handbook of Operational Risk* the handbook provides a complete framework for all aspects of operational risk management and includes Clear coverage on advanced topics such as splice loss models extreme value theory heavy tailed closed form loss distribution approach models flexible heavy tailed risk models risk measures and higher order asymptotic approximations of risk measures for capital estimation An exploration of the characterization and estimation of risk and insurance modeling which includes sub exponential models alpha stable models and tempered alpha stable models An extended discussion of the core concepts of risk measurement and capital estimation as well as the details on numerical approaches to evaluation of heavy tailed loss process model capital estimates Numerous detailed examples of real world methods and practices of operational risk modeling used by both financial and non financial institutions *Advances in Heavy Tailed Risk Modeling A Handbook of Operational Risk* is an excellent reference for risk management practitioners quantitative analysts financial engineers and risk managers The handbook is also useful for graduate level courses on heavy tailed processes advanced risk management and actuarial science **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

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

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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

Monte Carlo and Quasi-Monte Carlo Methods 2000 Kai-Tai Fang, Fred J. Hickernell, Harald Niederreiter, 2011-06-28 This book represents the refereed proceedings of the Fourth International Conference on Monte Carlo and Quasi Monte Carlo Methods in Scientific Computing which was held at Hong Kong Baptist University in 2000 An important feature are invited surveys of the state of the art in key areas such as multidimensional numerical integration low discrepancy point sets random number generation and applications of Monte Carlo and quasi Monte Carlo methods These proceedings include also carefully selected contributed papers on all aspects of Monte Carlo and quasi Monte Carlo methods The reader will be informed about current research in this very active field

Mathematical Reviews, 2008 **Dissertation Abstracts International**, 2008 **Sequential Methods for Rare Event Simulations** Shaojie Deng, 2010 We consider rare events modeled as a Markov Chain hitting a certain rare set A sequential importance sampling with resampling SISR method is introduced to provide a versatile approach for computing such probabilities of rare events The method uses resampling to track the zero variance importance measure associated with the event of interest A general methodology for choosing the importance measure and resampling scheme to come up with an efficient estimator of the probability of occurrence of the rare event is developed and the distinction between light tailed and heavy tailed problems is highlighted Applications include classic tail probabilities for sums of independent light tailed or heavy tailed random variables Markovian extensions and simultaneous simulation are also given The heuristics and the methodology can also be applied to more complex Monte Carlo problems that arise in recent works on the dynamic portfolio credit risk model

INFORMS Annual Meeting Institute for Operations Research and the Management Sciences. National Meeting, 2008 **Applied Probability**, 2004 **AMSTAT News** American Statistical Association, 2004 Journal of the American Statistical Association, 2007 A scientific and educational journal not only for professional statisticians but

also for economists business executives research directors government officials university professors and others who are seriously interested in the application of statistical methods to practical problems in the development of more useful methods and in the improvement of basic statistical data *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 *Applied Probability Complete Author and Subject Index* ,2004 *Stochastic Networks* David D. Yao, 1996-07-30 Two of the most exciting topics of current research in stochastic networks are the complementary subjects of stability and rare events Both are classical topics that have experienced renewed interest motivated by new applications to emerging technologies For example new stability issues arise in the scheduling of multiple classes in semiconductor manufacturing the so called re entrant lines and a prominent need for studying rare events is associated with the design of telecommunication systems using the new ATM asynchronous transfer mode technology so as to guarantee quality of service The objective of this volume is to present a sample of recent research problems methodologies and results in these two exciting and burgeoning areas This volume originated from a workshop held at Columbia University in 1995 organized by Columbia s Center for Applied Probability **ACM Transactions on Modeling and Computer Simulation** ,2001 *Proceedings of the 8th International Conference on Radiation Shielding, Arlington, Texas, April 24-28, 1994* ,1994 **Annual International Phoenix Conference on Computers and Communications: Conference Proceedings** Edwin Sprott Towill, 1976

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