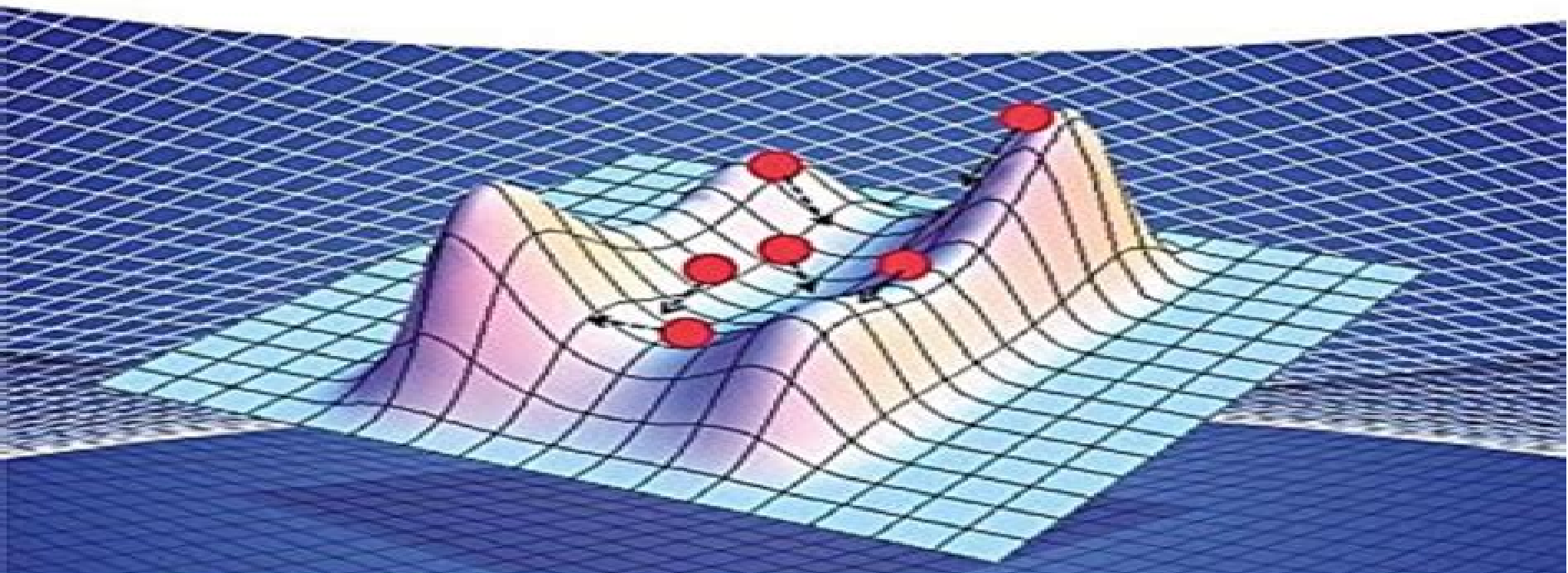Raúl Toral, Pere Colet

Stochastic Numerical Methods

An Introduction for Students and Scientists

Numerical Methods For Stochastic Processes

David Holcman

Numerical Methods For Stochastic Processes:

Numerical Methods for Stochastic Processes Nicolas Bouleau,Dominique Lépingle,1994-01-14 Gives greater rigor to numerical treatments of stochastic models Contains Monte Carlo and quasi Monte Carlo techniques simulation of major stochastic procedures deterministic methods adapted to Markovian problems and special problems related to stochastic integral and differential equations Simulation methods are given throughout the text as well as numerous exercises

Numerical Methods for Stochastic Control Problems in Continuous Time Harold Kushner,Paul G. Dupuis,2012-12-06 This book is concerned with numerical methods for stochastic control and optimal stochastic control problems The random process models of the controlled or uncontrolled stochastic systems are either diffusions or jump diffusions Stochastic control is a very active area of research and new prob lem formulations and sometimes surprising applications appear regularly We have chosen forms of the models which cover the great bulk of the for mulations of the continuous time stochastic control problems which have appeared to date The standard formats are covered but much emphasis is given to the newer and less well known formulations The controlled process might be either stopped or absorbed on leaving a constraint set or upon first hitting a target set or it might be reflected or projected from the boundary of a constraining set In some of the more recent applications of the reflecting boundary problem for example the so called heavy traffic approximation problems the directions of reflection are actually discontin uous In general the control might be representable as a bounded function or it might be of the so called impulsive or singular control types Both the drift and the variance might be controlled The cost functions might be any of the standard types Discounted stopped on first exit from a set finite time optimal stopping average cost per unit time over the infinite time interval and so forth   Numerical Solution of Stochastic Differential Equations Peter E. Kloeden,Eckhard Platen,2013-04-17 The aim of this book is to provide an accessible introduction to stochastic differ ential equations and their applications together with a systematic presentation of methods available for their numerical solution During the past decade there has been an accelerating interest in the de velopment of numerical methods for stochastic differential equations SDEs This activity has been as strong in the engineering and physical sciences as it has in mathematics resulting inevitably in some duplication of effort due to an unfamiliarity with the developments in other disciplines Much of the reported work has been motivated by the need to solve particular types of problems for which even more so than in the deterministic context specific methods are required The treatment has often been heuristic and ad hoc in character Nevertheless there are underlying principles present in many of the papers an understanding of which will enable one to develop or apply appropriate numerical schemes for particular problems or classes of problems   **Numerical Solution of Stochastic Differential Equations with Jumps in Finance** Eckhard Platen,Nicola Bruti-Liberati,2010-07-23 In financial and actuarial modeling and other areas of application stochastic differential equations with jumps have been employed to describe the dynamics of various state variables The numerical solution of such equations is more complex than that of those

only driven by Wiener processes described in Kloeden Platen Numerical Solution of Stochastic Differential Equations 1992 The present monograph builds on the above mentioned work and provides an introduction to stochastic differential equations with jumps in both theory and application emphasizing the numerical methods needed to solve such equations It presents many new results on higher order methods for scenario and Monte Carlo simulation including implicit predictor corrector extrapolation Markov chain and variance reduction methods stressing the importance of their numerical stability Furthermore it includes chapters on exact simulation estimation and filtering Besides serving as a basic text on quantitative methods it offers ready access to a large number of potential research problems in an area that is widely applicable and rapidly expanding Finance is chosen as the area of application because much of the recent research on stochastic numerical methods has been driven by challenges in quantitative finance Moreover the volume introduces readers to the modern benchmark approach that provides a general framework for modeling in finance and insurance beyond the standard risk neutral approach It requires undergraduate background in mathematical or quantitative methods is accessible to a broad readership including those who are only seeking numerical recipes and includes exercises that help the reader develop a deeper understanding of the underlying mathematics *Numerical Methods for Stochastic Partial Differential Equations with White Noise* Zhongqiang Zhang,George Em Karniadakis,2017-09-01 This book covers numerical methods for stochastic partial differential equations with white noise using the framework of Wong Zakai approximation The book begins with some motivational and background material in the introductory chapters and is divided into three parts Part I covers numerical stochastic ordinary differential equations Here the authors start with numerical methods for SDEs with delay using the Wong Zakai approximation and finite difference in time Part II covers temporal white noise Here the authors consider SPDEs as PDEs driven by white noise where discretization of white noise Brownian motion leads to PDEs with smooth noise which can then be treated by numerical methods for PDEs In this part recursive algorithms based on Wiener chaos expansion and stochastic collocation methods are presented for linear stochastic advection diffusion reaction equations In addition stochastic Euler equations are exploited as an application of stochastic collocation methods where a numerical comparison with other integration methods in random space is made Part III covers spatial white noise Here the authors discuss numerical methods for nonlinear elliptic equations as well as other equations with additive noise Numerical methods for SPDEs with multiplicative noise are also discussed using the Wiener chaos expansion method In addition some SPDEs driven by non Gaussian white noise are discussed and some model reduction methods based on Wick Malliavin calculus are presented for generalized polynomial chaos expansion methods Powerful techniques are provided for solving stochastic partial differential equations This book can be considered as self contained Necessary background knowledge is presented in the appendices Basic knowledge of probability theory and stochastic calculus is presented in Appendix A In Appendix B some semi analytical methods for SPDEs are presented In Appendix C an introduction to Gauss quadrature is provided In Appendix

D all the conclusions which are needed for proofs are presented and in Appendix E a method to compute the convergence rate empirically is included In addition the authors provide a thorough review of the topics both theoretical and computational exercises in the book with practical discussion of the effectiveness of the methods Supporting Matlab files are made available to help illustrate some of the concepts further Bibliographic notes are included at the end of each chapter This book serves as a reference for graduate students and researchers in the mathematical sciences who would like to understand state of the art numerical methods for stochastic partial differential equations with white noise   Numerical Analysis of Stochastic Processes Wolf-Jürgen Beyn,Raphael Kruse,2016-10-15 This textbook introduces into the art of analysing approximating and solving stochastic differential equations Random number generation and monte carlo methods as well as convergence theorems and discretisation effects are discussed Apart from mathematical problems these equations occur in physical engineering and economic models e g due to a lack of knowledge of the underlying complex systems
    Stochastic Simulation and Monte Carlo Methods Carl Graham,Denis Talay,2013-07-16 In various scientific and industrial fields stochastic simulations are taking on a new importance This is due to the increasing power of computers and practitioners aim to simulate more and more complex systems and thus use random parameters as well as random noises to model the parametric uncertainties and the lack of knowledge on the physics of these systems The error analysis of these computations is a highly complex mathematical undertaking Approaching these issues the authors present stochastic numerical methods and prove accurate convergence rate estimates in terms of their numerical parameters number of simulations time discretization steps As a result the book is a self contained and rigorous study of the numerical methods within a theoretical framework After briefly reviewing the basics the authors first introduce fundamental notions in stochastic calculus and continuous time martingale theory then develop the analysis of pure jump Markov processes Poisson processes and stochastic differential equations In particular they review the essential properties of It integrals and prove fundamental results on the probabilistic analysis of parabolic partial differential equations These results in turn provide the basis for developing stochastic numerical methods both from an algorithmic and theoretical point of view The book combines advanced mathematical tools theoretical analysis of stochastic numerical methods and practical issues at a high level so as to provide optimal results on the accuracy of Monte Carlo simulations of stochastic processes It is intended for master and Ph D students in the field of stochastic processes and their numerical applications as well as for physicists biologists economists and other professionals working with stochastic simulations who will benefit from the ability to reliably estimate and control the accuracy of their simulations   Stochastic Numerical Methods Raúl Toral,Pere Colet,2014-06-26 Stochastic Numerical Methods introduces at Master level the numerical methods that use probability or stochastic concepts to analyze random processes The book aims at being rather general and is addressed at students of natural sciences Physics Chemistry Mathematics Biology etc and Engineering but also social sciences Economy Sociology etc where some of the techniques have

been used recently to numerically simulate different agent based models Examples included in the book range from phase transitions and critical phenomena including details of data analysis extraction of critical exponents finite size effects etc to population dynamics interfacial growth chemical reactions etc Program listings are integrated in the discussion of numerical algorithms to facilitate their understanding From the contents Review of Probability Concepts Monte Carlo Integration Generation of Uniform and Non uniform Random Numbers Non correlated Values Dynamical Methods Applications to Statistical Mechanics Introduction to Stochastic Processes Numerical Simulation of Ordinary and Partial Stochastic Differential Equations Introduction to Master Equations Numerical Simulations of Master Equations Hybrid Monte Carlo Generation of n Dimensional Correlated Gaussian Variables Collective Algorithms for Spin Systems Histogram Extrapolation Multicanonical Simulations   Stochastic Processes: Modeling and Simulation D N Shanbhag,Calyampudi Radhakrishna Rao,2003-02-24 This sequel to volume 19 of Handbook on Statistics on Stochastic Processes Modelling and Simulation is concerned mainly with the theme of reviewing and in some cases unifying with new ideas the different lines of research and developments in stochastic processes of applied flavour This volume consists of 23 chapters addressing various topics in stochastic processes These include among others those on manufacturing systems random graphs reliability epidemic modelling self similar processes empirical processes time series models extreme value therapy applications of Markov chains modelling with Monte Carlo techniques and stochastic processes in subjects such as engineering telecommunications biology astronomy and chemistry particular with modelling simulation techniques and numerical methods concerned with stochastic processes The scope of the project involving this volume as well as volume 19 is already clarified in the preface of volume 19 The present volume completes the aim of the project and should serve as an aid to students teachers researchers and practitioners interested in applied stochastic processes   **Simulation and Numerical Methods for Stochastic Processes** Timothy Charles Stutz,2020 Stochastic processes and randomness are vital features of mathematical modeling in biology Unfortunately analytical results are rarely available for even moderately complex stochastic processes leaving simulation and numerical techniques the main avenues of attack We begin this work by exploring coupling bounds for birth death processes a fundamental type of stochastic process that describes how populations of individuals change over time By forming a coupling between a truncated version of the process and the original unbounded version we are able to compute both moments and transition probabilities for the true process within an acceptable error bound Second we present an algorithm design framework for Interacting Particle Systems IPSs These are complex stochastic processes with wide application to spatial phenomenon across many scientific disciplines Here we describe a method for efficiently sorting particles into classes based off of their type and spatial configuration in such a fashion that reduces the spatial simulation to that of a non spatial well mixed process albeit with a more complicated update step This also allows us to apply a large suite of well developed stochastic simulation algorithms to IPSs with little additional coding cost Third we return to numerical

methods this time for multi type branching processes applied to gene therapy We derive a series of ordinary differential equations that govern the evolution of the probability generating function and provide a straightforward numerical inversion approach to obtain marginalized probability distributions for probabilistic quantities of interest We provide examples of our techniques applied to lentiviral gene therapy and the associated risk of oncogenesis in transplanted hematopoietic stem cell lines Finally we conclude with a chapter on future directions both related to the previous three chapters as well as projects not previously addressed in this work   Numerical Analysis of Systems of Ordinary and Stochastic Differential Equations S. S. Artemiev,T. A. Averina,2011-02-11 No detailed description available for Numerical Analysis of Systems of Ordinary and Stochastic Differential Equations   **Stochastic Processes, Multiscale Modeling, and Numerical Methods for Computational Cellular Biology** David Holcman,2017-10-04 This book focuses on the modeling and mathematical analysis of stochastic dynamical systems along with their simulations The collected chapters will review fundamental and current topics and approaches to dynamical systems in cellular biology This text aims to develop improved mathematical and computational methods with which to study biological processes At the scale of a single cell stochasticity becomes important due to low copy numbers of biological molecules such as mRNA and proteins that take part in biochemical reactions driving cellular processes When trying to describe such biological processes the traditional deterministic models are often inadequate precisely because of these low copy numbers This book presents stochastic models which are necessary to account for small particle numbers and extrinsic noise sources The complexity of these models depend upon whether the biochemical reactions are diffusion limited or reaction limited In the former case one needs to adopt the framework of stochastic reaction diffusion models while in the latter one can describe the processes by adopting the framework of Markov jump processes and stochastic differential equations Stochastic Processes Multiscale Modeling and Numerical Methods for Computational Cellular Biology will appeal to graduate students and researchers in the fields of applied mathematics biophysics and cellular biology   **Stochastic Dynamical Systems** Josef Honerkamp,1996-12-17 Dieser einzigartige Band f hrt den Leser in die mathematische Begriffsbildung f r komplexe Systeme ein Er ist ideal f r Studenten der Mathematik Physik Chemie und Medizin die sich in ihrem Studium erstmals mit stochastischen dynamischen Systemen besch ftigen Das Buch stellt praktische Methoden zur Verf gung um mit solchen Systemen umgehen zu k nnen und stellt die zugundeliegenden Definitionen und theoretischen Annahmen wo erforderlich klar heraus Im Gegensatz zu anderen B chern ber dieses Gebiet die oft einen bestimmten Zugang bevorzugen deckt Stochastical Dynamical Systems eine Vielzahl von stochastischen und statistischen Methoden ab die f r die Untersuchung von komplexen Systemen wie Polymerschmelzen dem menschlichen K rper und der Atmosph re absolut notwendig sind Das Buch behandelt die Datenanalyse ebenso wie Simulationsmethoden f r gegebene Modelle Die ganze Vielfalt der klassischen und neuartigen Begriffe der mathematischen Stochastik wird in einem leicht verst ndlichen Stil erkl rt so da die Leser diese Konzepte leicht f r die Untersuchung ihrer Daten anwenden k nnen

Handbook of Stochastic Analysis and Applications D. Kannan,V. Lakshmikantham,2001-10-23 An introduction to general theories of stochastic processes and modern martingale theory The volume focuses on consistency stability and contractivity under geometric invariance in numerical analysis and discusses problems related to implementation simulation variable step size algorithms and random number generation *Stochastic Processes for Physicists* Kurt Jacobs,2010-02-18 Stochastic processes are an essential part of numerous branches of physics as well as in biology chemistry and finance This textbook provides a solid understanding of stochastic processes and stochastic calculus in physics without the need for measure theory In avoiding measure theory this textbook gives readers the tools necessary to use stochastic methods in research with a minimum of mathematical background Coverage of the more exotic Levy processes is included as is a concise account of numerical methods for simulating stochastic systems driven by Gaussian noise The book concludes with a non technical introduction to the concepts and jargon of measure theoretic probability theory With over 70 exercises this textbook is an easily accessible introduction to stochastic processes and their applications as well as methods for numerical simulation for graduate students and researchers in physics *Numerical Methods for Stochastic Processes with Applications in Chemical Kinetics and Biology* Basil Bayati,2011 **Numerical Methods for Structured Markov Chains** Dario A. Bini,Guy Latouche,Beatrice Meini,2005-02-03 Intersecting two large research areas numerical analysis and applied probability queuing theory this book is a self contained introduction to the numerical solution of structured Markov chains which have a wide applicability in queuing theory and stochastic modeling and include M G 1 and GI M 1 type Markov chain quasi birth death processes non skip free queues and tree like stochastic processes Written for applied probabilists and numerical analysts but accessible toengineers and scientists working on telecommunications and evaluation of computer systems performances it provides a systematic treatment of the theory and algorithms for important families of structured Markov chains and a thorough overview of the current literature The book consisting of nine Chapters is presented in three parts Part 1 covers a basic description of the fundamental concepts related to Markov chains a systematic treatment of the structure matrix tools including finite Toeplitz matrices displacement operators FFT and the infinite block Toeplitz matrices their relationship with matrix power series and the fundamental problems of solving matrix equations and computing canonical factorizations Part 2 deals with the description andanalysis of structure Markov chains and includes M G 1 quasi birth death processes non skip free queues and tree like processes Part 3 covers solution algorithms where new convergence and applicability results are proved Each chapter ends with bibliographic notes for further reading and the bookends with an appendix collecting the main general concepts and results used in the book a list of the main annotations and algorithms used in the book and an extensive index **Probability and Stochastic Processes** Ionut Florescu,2014-10-27 A comprehensive and accessible presentation of probability and stochastic processes with emphasis on key theoretical concepts and real world applications With a sophisticated approach Probability and Stochastic Processes successfully balances theory

and applications in a pedagogical and accessible format The book s primary focus is on key theoretical notions in probability to provide a foundation for understanding concepts and examples related to stochastic processes Organized into two main sections the book begins by developing probability theory with topical coverage on probability measure random variables integration theory product spaces conditional distribution and conditional expectations and limit theorems The second part explores stochastic processes and related concepts including the Poisson process renewal processes Markov chains semi Markov processes martingales and Brownian motion Featuring a logical combination of traditional and complex theories as well as practices Probability and Stochastic Processes also includes Multiple examples from disciplines such as business mathematical finance and engineering Chapter by chapter exercises and examples to allow readers to test their comprehension of the presented material A rigorous treatment of all probability and stochastic processes concepts An appropriate textbook for probability and stochastic processes courses at the upper undergraduate and graduate level in mathematics business and electrical engineering Probability and Stochastic Processes is also an ideal reference for researchers and practitioners in the fields of mathematics engineering and finance   **An Introduction to Computational Stochastic PDEs** Gabriel J. Lord,Catherine E. Powell,Tony Shardlow,2014 This book gives a comprehensive introduction to numerical methods and analysis of stochastic processes random fields and stochastic differential equations and offers graduate students and researchers powerful tools for understanding uncertainty quantification for risk analysis Coverage includes traditional stochastic ODEs with white noise forcing strong and weak approximation and the multi level Monte Carlo method Later chapters apply the theory of random fields to the numerical solution of elliptic PDEs with correlated random data discuss the Monte Carlo method and introduce stochastic Galerkin finite element methods Finally stochastic parabolic PDEs are developed Assuming little previous exposure to probability and statistics theory is developed in tandem with state of the art computational methods through worked examples exercises theorems and proofs The set of MATLAB codes included and downloadable allows readers to perform computations themselves and solve the test problems discussed Practical examples are drawn from finance mathematical biology neuroscience fluid flow modelling and materials science

Modeling with Itô Stochastic Differential Equations E. Allen,2007-03-08 Dynamical systems with random influences occur throughout the physical biological and social sciences By carefully studying a randomly varying system over a small time interval a discrete stochastic process model can be constructed Next letting the time interval shrink to zero an Ito stochastic differential equation model for the dynamical system is obtained This modeling procedure is thoroughly explained and illustrated for randomly varying systems in population biology chemistry physics engineering and finance Introductory chapters present the fundamental concepts of random variables stochastic processes stochastic integration and stochastic differential equations These concepts are explained in a Hilbert space setting which unifies and simplifies the presentation Computer programs given throughout the text are useful in solving representative stochastic problems Analytical and

computational exercises are provided in each chapter that complement the material in the text Modeling with It Stochastic Differential Equations is useful for researchers and graduate students As a textbook for a graduate course prerequisites include probability theory differential equations intermediate analysis and some knowledge of scientific programming

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