

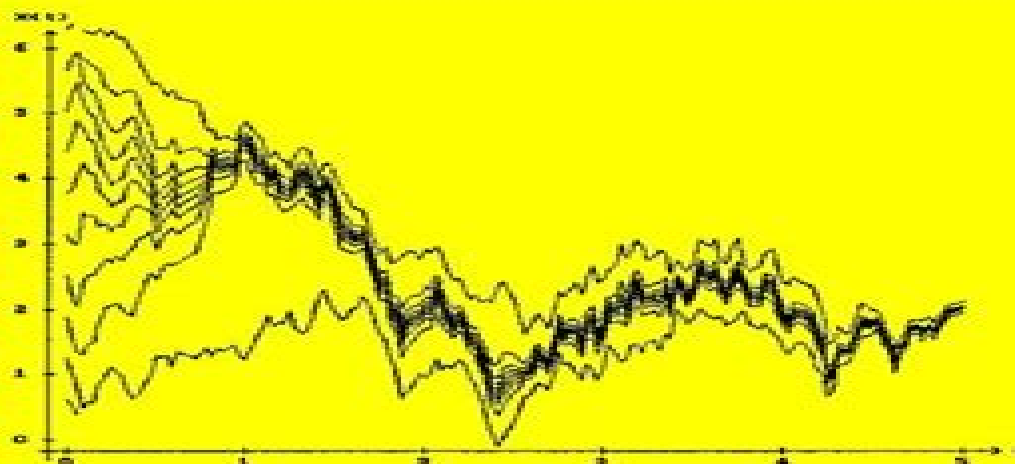
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Peter E. Kloeden  
Eckhard Platen

# Numerical Solution of Stochastic Differential Equations



Springer

# Numerical Solution Of Stochastic Differential Equations Applications Of Mathematics

**Peter E. Kloeden, Eckhard Platen**



## **Numerical Solution Of Stochastic Differential Equations Applications Of Mathematics:**

**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 differential 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 development 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 Solution of Stochastic Differential Equations** Peter E. Kloeden, Eckhard Platen, 2014-01-15

**Random Ordinary Differential Equations and Their Numerical Solution** Xiaoying Han, Peter E. Kloeden, 2017-10-25 This book is intended to make recent results on the derivation of higher order numerical schemes for random ordinary differential equations RODEs available to a broader readership and to familiarize readers with RODEs themselves as well as

the closely associated theory of random dynamical systems In addition it demonstrates how RODEs are being used in the biological sciences where non Gaussian and bounded noise are often more realistic than the Gaussian white noise in stochastic differential equations SODEs RODEs are used in many important applications and play a fundamental role in the theory of random dynamical systems They can be analyzed pathwise with deterministic calculus but require further treatment beyond that of classical ODE theory due to the lack of smoothness in their time variable Although classical numerical schemes for ODEs can be used pathwise for RODEs they rarely attain their traditional order since the solutions of RODEs do not have sufficient smoothness to have Taylor expansions in the usual sense However Taylor like expansions can be derived for RODEs using an iterated application of the appropriate chain rule in integral form and represent the starting point for the systematic derivation of consistent higher order numerical schemes for RODEs The book is directed at a wide range of readers in applied and computational mathematics and related areas as well as readers who are interested in the applications of mathematical models involving random effects in particular in the biological sciences The level of this book is suitable for graduate students in applied mathematics and related areas computational sciences and systems biology A basic knowledge of ordinary differential equations and numerical analysis is required

**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

**Numerical Solution of SDE Through Computer Experiments** Peter Eris Kloeden,Eckhard Platen,Henri Schurz,2012-12-06 The numerical solution of stochastic differential equations is becoming an indispensable worktool in a multitude of disciplines bridging a long standing gap between the well advanced theory of stochastic differential equations and its application to specific examples This has been made possible by the much greater accessibility to high powered computers at low cost combined with the availability of new effective higher order numerical schemes for stochastic differential equations Many hitherto intractable problems can now be tackled successfully and more realistic modelling with stochastic differential equations undertaken The aim of this book is to provide a computationally oriented introduction to the numerical solution of stochastic differential equations using computer experiments to develop in the readers an ability to undertake numerical studies of stochastic differential equations that arise in their own disciplines and an understanding intuitive at least of the necessary theoretical background It is related to but can also be used independently of the monograph P E Kloeden and E Platen Numerical Solution of Stochastic Differential Equations Applications of Mathematics Series Vol 23 Springer Verlag Heidelberg 1992 which is more theoretical presenting a systematic treatment of time discretized numerical schemes for stochastic differential equations along with background material on probability and stochastic calculus To facilitate the parallel use of both books the presentation of material in this book follows that in the monograph closely

**Stochastic Numerics for Mathematical Physics** Grigori Noah Milstein,Michael V. Tretyakov,2013-03-09 Stochastic differential equations have many applications in

the natural sciences Besides the employment of probabilistic representations together with the Monte Carlo technique allows us to reduce solution of multi dimensional problems for partial differential equations to integration of stochastic equations This approach leads to powerful computational mathematics that is presented in the treatise The authors propose many new special schemes some published here for the first time In the second part of the book they construct numerical methods for solving complicated problems for partial differential equations occurring in practical applications both linear and nonlinear All the methods are presented with proofs and hence founded on rigorous reasoning thus giving the book textbook potential An overwhelming majority of the methods are accompanied by the corresponding numerical algorithms which are ready for implementation in practice The book addresses researchers and graduate students in numerical analysis physics chemistry and engineering as well as mathematical biology and financial 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 Ordinary Differential Equations And Its Applications** Taketomo Mitsui,Y Shinohara,1995-10-12 The book collects original articles on numerical analysis of ordinary differential equations and its applications Some of the topics covered in this volume are discrete variable methods Runge Kutta methods linear multistep methods stability analysis parallel implementation self validating numerical methods analysis of nonlinear oscillation by numerical means differential algebraic and delay differential equations and stochastic initial value problems

*Numerical Integration of Stochastic Differential Equations* G.N. Milstein,2013-03-09 This book is devoted to mean square and weak approximations of solutions of stochastic differential equations SDE These approximations represent two fundamental aspects in the contemporary theory of SDE Firstly the construction of numerical methods for such systems is important as the solutions provided serve as characteristics for a number of mathematical physics problems Secondly the employment of probability representations together with a Monte Carlo method allows us to reduce the solution of complex multidimensional problems of mathematical physics to the integration of stochastic equations Along with a general theory of numerical integrations of such systems both in the mean square and the weak sense a number of concrete and sufficiently constructive numerical schemes are considered Various applications and particularly the approximate calculation of Wiener integrals are also dealt with This book is of interest to graduate students in the mathematical physical and engineering sciences and to specialists whose work involves differential equations mathematical physics numerical mathematics the theory of random processes estimation and control theory

**Exact Finite-Difference Schemes** Sergey Lemeshevsky,Piotr Matus,Dmitriy Poliakov,2016-09-26 Exact Finite Difference Schemes is a first overview of the topic also describing the state of the art in this field of numerical analysis Construction of exact difference schemes for various parabolic and elliptic partial differential equations are discussed including vibrations and transport problems After this applications are discussed such as the discretisation of ODEs and PDEs and numerical methods for stochastic differential equations Contents Basic notation Preliminary results Hyperbolic equations Parabolic equations Use of exact difference schemes to construct NSFD discretizations of differential equations Exact and truncated difference schemes for boundary value problem Exact difference schemes for stochastic differential equations Numerical blow up time Bibliography

**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

**Numerical Analysis of Ordinary Differential Equations and Its Applications** Taketomo Mitsui, Yoshitane Shinohara, 1995 The book collects original articles on numerical analysis of ordinary differential equations and its applications Some of the topics covered in this volume are discrete variable methods Runge Kutta methods linear multistep methods stability analysis parallel implementation self validating numerical methods analysis of nonlinear oscillation by numerical means differential algebraic and delay differential equations and stochastic initial value problems

*An Introduction to the Numerical Simulation of Stochastic Differential Equations* Desmond J. Higham, Peter E. Kloeden, 2020-12

*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

*Malliavin Calculus with Applications to Stochastic Partial Differential Equations* Marta Sanz-Sole, 2005-08-17 Developed in the 1970s to study the existence and smoothness of density

for the probability laws of random vectors Malliavin calculus a stochastic calculus of variation on the Wiener space has proven fruitful in many problems in probability theory particularly in probabilistic numerical methods in financial mathematics This book presents **Stochastic Differential Equations** K. Sobczyk, 2013-12-01 Et moi si lavait su CO llUJalt en revc nir One acMcc matbcmatica bu Jaldcred the human rac c It bu put COIDIDOD \_ beet je n y serais point aBe Jules Verne wbac it bdoup 0Jl be IbcII \_t to be dusty caualcr Iabc thc reforc we may be I ticT Bc Il able to do something with it O Hcavisidc Mathematics is a tool for thought A highly necessary tool in a world when both feedback and non linearities abound Similarly all kinds of parts of mathematics serve as tools for other parts and for other sciences Applying a simple rewriting rule to the quote on the right above one finds such statcmalts as One service topology has rendered mathematical physics One service logic has rendered c0m puter science One service category theory has rendered mathematics All arguably true And all statements obtainable this way form part of the raison d etre of this series This series Mathematics and Its Applications started in 19n Now that over one hundred volumes have appeared it seems opportune to reexamine its scope At the time I wrote Growing specialization and diversification have brought a host of monographs and textbooks on increasingly specialized topics However the tree of knowledge of mathematics and related fields does not grow only by putting forth new branc hes It also happens quite often in fact that branches which were thought to be completely

**Stochastic Numerics for Mathematical Physics** Grigori N. Milstein, Michael V. Tretyakov, 2021 This book is a substantially revised and expanded edition reflecting major developments in stochastic numerics since the first edition was published in 2004 The new topics in particular include mean square and weak approximations in the case of nonglobally Lipschitz coefficients of Stochastic Differential Equations SDEs including the concept of rejecting trajectories conditional probabilistic representations and their application to practical variance reduction using regression methods multi level Monte Carlo method computing ergodic limits and additional classes of geometric integrators used in molecular dynamics numerical methods for FBSDEs approximation of parabolic SPDEs and nonlinear filtering problem based on the method of characteristics SDEs have many applications in the natural sciences and in finance Besides the employment of probabilistic representations together with the Monte Carlo technique allows us to reduce the solution of multi dimensional problems for partial differential equations to the integration of stochastic equations This approach leads to powerful computational mathematics that is presented in the treatise Many special schemes for SDEs are presented In the second part of the book numerical methods for solving complicated problems for partial differential equations occurring in practical applications both linear and nonlinear are constructed All the methods are presented with proofs and hence founded on rigorous reasoning thus giving the book textbook potential An overwhelming majority of the methods are accompanied by the corresponding numerical algorithms which are ready for implementation in practice The book addresses researchers and graduate students in numerical analysis applied probability physics chemistry and engineering as well as mathematical biology and financial



mathematics      Numerical Solution of SDE Through Computer Experiments Peter Eris Kloeden, Eckhard Platen, Henri Schurz, 2002-12-12 This book provides an easily accessible computationally oriented introduction into the numerical solution of stochastic differential equations using computer experiments It develops in the reader an ability to apply numerical methods solving stochastic differential equations It also creates an intuitive understanding of the necessary theoretical background Software containing programs for over 100 problems is available online      Stochastic Differential Equations, Backward SDEs, Partial Differential Equations Etienne Pardoux, Aurel Răşcanu, 2014-06-24 This research monograph presents results to researchers in stochastic calculus forward and backward stochastic differential equations connections between diffusion processes and second order partial differential equations PDEs and financial mathematics It pays special attention to the relations between SDEs BSDEs and second order PDEs under minimal regularity assumptions and also extends those results to equations with multivalued coefficients The authors present in particular the theory of reflected SDEs in the above mentioned framework and include exercises at the end of each chapter Stochastic calculus and stochastic differential equations SDEs were first introduced by K It in the 1940s in order to construct the path of diffusion processes which are continuous time Markov processes with continuous trajectories taking their values in a finite dimensional vector space or manifold which had been studied from a more analytic point of view by Kolmogorov in the 1930s Since then this topic has become an important subject of Mathematics and Applied Mathematics because of its mathematical richness and its importance for applications in many areas of Physics Biology Economics and Finance where random processes play an increasingly important role One important aspect is the connection between diffusion processes and linear partial differential equations of second order which is in particular the basis for Monte Carlo numerical methods for linear PDEs Since the pioneering work of Peng and Pardoux in the early 1990s a new type of SDEs called backward stochastic differential equations BSDEs has emerged The two main reasons why this new class of equations is important are the connection between BSDEs and semilinear PDEs and the fact that BSDEs constitute a natural generalization of the famous Black and Scholes model from Mathematical Finance and thus offer a natural mathematical framework for the formulation of many new models in Finance

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