

NUMERICAL MATHEMATICS
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Numerical Methods for Structured Markov Chains

DARIO A. BINI,
GUY LATOUCHE, and
BEATRICE MEINI

$$P = \begin{bmatrix} B_0 & B_1 & B_2 & B_3 & \dots \\ A_{-1} & A_0 & A_1 & A_2 & \dots \\ & A_{-1} & A_0 & A_1 & \ddots \\ & & A_{-1} & A_0 & \ddots \\ 0 & & & \ddots & \ddots \end{bmatrix}$$

$$G = A_{-1} + A_0 G + A_1 G^2 + A_2 G^3 + \dots$$

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Numerical Methods For Structured Markov Chains

**Dario A. Bini, Guy Latouche, Beatrice
Meini**



Numerical Methods For Structured Markov Chains:

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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 to engineers 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 and analysis 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 book ends 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

Numerical Methods for Structured Markov Chains, 2008 **Numerical Methods for Structured Markov Chains**, 2008 **Markov Chains: Models, Algorithms and Applications** Wai-Ki Ching, Michael K. Ng, 2006-06-05 Markov chains are a particularly powerful and widely used tool for analyzing a variety of stochastic probabilistic systems over time This monograph will present a series of Markov models starting from the basic models and then building up to higher order models Included in the higher order discussions are multivariate models higher order multivariate models and higher order hidden models In each case the focus is on the important kinds of applications that can be made with the class of models being considered in the current chapter Special attention is given to numerical algorithms that can efficiently solve the models Therefore Markov Chains Models Algorithms and Applications outlines recent developments of Markov chain models for modeling queueing sequences Internet re manufacturing systems reverse logistics inventory systems bio informatics DNA sequences genetic networks data mining and many other practical systems

Analyzing Markov Chains using Kronecker Products Tugrul Dayar, 2012-07-25 Kronecker products are used to define the underlying Markov chain MC in various modeling formalisms including compositional Markovian models hierarchical Markovian models and stochastic process algebras The motivation behind using a Kronecker structured representation rather than a flat one is to alleviate the storage requirements associated with the MC With this approach systems that are an order of magnitude larger can be analyzed on the same platform The developments in the solution of such MCs are reviewed from an algebraic point of view and possible areas for further research are indicated with an emphasis on preprocessing using reordering grouping and lumping and numerical analysis using block iterative preconditioned projection multilevel decompositional and matrix analytic methods Case studies from closed queueing networks and stochastic chemical kinetics are provided to motivate decompositional and matrix analytic methods respectively

Markov Chains Bruno Sericola, 2013-08-05 Markov Chains Theory and Applications Markov chains are a fundamental class of stochastic processes They are widely used to solve problems in a large number of domains such as operational research computer science communication networks and manufacturing systems The success of Markov chains is mainly due to their simplicity of use the large number of available theoretical results and the quality of algorithms developed for the numerical evaluation of many metrics of interest The author presents the theory of both discrete time and continuous time homogeneous Markov chains He carefully examines the explosion phenomenon the Kolmogorov equations the convergence to equilibrium and the passage time distributions to a state and to a subset of states These results are applied to birth and death processes He then proposes a detailed study of the uniformization technique by means of Banach algebra This technique is used for the transient analysis of several queueing systems

Algorithms for Quadratic Matrix and Vector Equations Federico Poloni, 2012-03-13 This book is devoted to studying algorithms for the solution of a class of quadratic matrix and vector equations These equations appear in different forms in several practical applications especially

in applied probability and control theory The equations are first presented using a novel unifying approach then specific numerical methods are presented for the cases most relevant for applications and new algorithms and theoretical results developed by the author are presented The book focuses on matrix multiplication rich iterations such as cyclic reduction and the structured doubling algorithm SDA and contains a variety of new research results which as of today are only available in articles or preprints

Matrix Methods: Theory, Algorithms And Applications - Dedicated To The Memory Of Gene Golub Vadim Olshevsky, Eugene E Tyrtyshnikov, 2010-04-05 Compared to other books devoted to matrices this volume is unique in covering the whole of a triptych consisting of algebraic theory algorithmic problems and numerical applications all united by the essential use and urge for development of matrix methods This was the spirit of the 2nd International Conference on Matrix Methods and Operator Equations from 23-27 July 2007 in Moscow that was organized by Dario Bini Gene Golub Alexander Guterman Vadim Olshevsky Stefano Serra Capizzano Gilbert Strang and Eugene Tyrtyshnikov Matrix methods provide the key to many problems in pure and applied mathematics However linear algebra theory numerical algorithms and matrices in FEM BEM applications usually live as if in three separate worlds In this volume maybe for the first time ever they are compiled together as one entity as it was at the Moscow meeting where the algebraic part was impersonated by Hans Schneider algorithms by Gene Golub and applications by Guri Marchuk All topics intervened in plenary sessions are specially categorized into three sections of this volume The soul of the meeting was Gene Golub who rendered a charming Golub's dimension to the three main axes of the conference topics This volume is dedicated in gratitude to his memory

Applied Modeling Techniques and Data Analysis 1 Yiannis Dimotikalis, Alex Karagrigoriou, Christina Parpoula, Christos H. Skiadas, 2021-05-11 BIG DATA ARTIFICIAL INTELLIGENCE AND DATA ANALYSIS SET Coordinated by Jacques Janssen Data analysis is a scientific field that continues to grow enormously most notably over the last few decades following rapid growth within the tech industry as well as the wide applicability of computational techniques alongside new advances in analytic tools Modeling enables data analysts to identify relationships make predictions and to understand interpret and visualize the extracted information more strategically This book includes the most recent advances on this topic meeting increasing demand from wide circles of the scientific community Applied Modeling Techniques and Data Analysis 1 is a collective work by a number of leading scientists analysts engineers mathematicians and statisticians working on the front end of data analysis and modeling applications The chapters cover a cross section of current concerns and research interests in the above scientific areas The collected material is divided into appropriate sections to provide the reader with both theoretical and applied information on data analysis methods models and techniques along with appropriate applications

Introduction to Matrix Analytic Methods in Queues 1 Srinivas R. Chakravathy, 2022-09-21 Matrix analytic methods MAM were introduced by Professor Marcel Neuts and have been applied to a variety of stochastic models since In order to provide a clear and deep understanding of MAM while showing their power this book presents MAM concepts and explains the

results using a number of worked out examples This book's approach will inform and kindle the interest of researchers attracted to this fertile field To allow readers to practice and gain experience in the algorithmic and computational procedures of MAM Introduction to Matrix Analytic Methods in Queues 1 provides a number of computational exercises It also incorporates simulation as another tool for studying complex stochastic models especially when the state space of the underlying stochastic models under analytic study grows exponentially The book's detailed approach will make it more accessible for readers interested in learning about MAM in stochastic models Handbook of Linear Algebra Leslie Hogben, 2013-11-26 With a substantial amount of new material the Handbook of Linear Algebra Second Edition provides comprehensive coverage of linear algebra concepts applications and computational software packages in an easy to use format It guides you from the very elementary aspects of the subject to the frontiers of current research Along with revisions and **Matrix-Analytic Methods in Stochastic Models** Guy Latouche, Vaidyanathan Ramaswami, Jay Sethuraman, Karl Sigman, Mark S. Squillante, David Yao, 2012-12-04 Matrix analytic and related methods have become recognized as an important and fundamental approach for the mathematical analysis of general classes of complex stochastic models Research in the area of matrix analytic and related methods seeks to discover underlying probabilistic structures intrinsic in such stochastic models develop numerical algorithms for computing functionals e.g performance measures of the underlying stochastic processes and apply these probabilistic structures and/or computational algorithms within a wide variety of fields This volume presents recent research results on the theory algorithms and methodologies concerning matrix analytic and related methods in stochastic models and the application of matrix analytic and related methods in various fields which includes but is not limited to computer science and engineering communication networks and telephony electrical and industrial engineering operations research management science financial and risk analysis and bio statistics These research studies provide deep insights and understanding of the stochastic models of interest from a mathematics and/or applications perspective as well as identify directions for future research *Numerical Methods for Delay Differential Equations* Alfredo Bellen, Marino Zennaro, 2013-01-10 This unique book describes analyses and improves various approaches and techniques for the numerical solution of delay differential equations It includes a list of available codes and also aids the reader in writing his or her own **Numerical Methods for Nonlinear Elliptic Differential Equations** Klaus Boehmer, 2010-10-07 Nonlinear elliptic problems play an increasingly important role in mathematics science and engineering creating an exciting interplay between the subjects This is the first and only book to prove in a systematic and unifying way stability convergence and computing results for the different numerical methods for nonlinear elliptic problems The proofs use linearization compact perturbation of the coercive principal parts or monotone operator techniques and approximation theory Examples are given for linear to fully nonlinear problems highest derivatives occur nonlinearly and for the most important space discretization methods conforming and nonconforming finite element discontinuous Galerkin finite difference wavelet and in

a volume to follow spectral and meshfree methods A number of specific long open problems are solved here numerical methods for fully nonlinear elliptic problems wavelet and meshfree methods for nonlinear problems and more general nonlinear boundary conditions We apply it to all these problems and methods in particular to eigenvalues monotone operators quadrature approximations and Newton methods Adaptivity is discussed for finite element and wavelet methods The book has been written for graduate students and scientists who want to study and to numerically analyze nonlinear elliptic differential equations in Mathematics Science and Engineering It can be used as material for graduate courses or advanced seminars

Trends in Ambient Intelligent Systems Kiran Kumar Ravulakollu, Mohammad Ayoub Khan, Ajith Abraham, 2016-03-18 This book demonstrates the success of Ambient Intelligence in providing possible solutions for the daily needs of humans The book addresses implications of ambient intelligence in areas of domestic living elderly care robotics communication philosophy and others The objective of this edited volume is to show that Ambient Intelligence is a boon to humanity with conceptual philosophical methodical and applicative understanding The book also aims to schematically demonstrate developments in the direction of augmented sensors embedded systems and behavioral intelligence towards Ambient Intelligent Networks or Smart Living Technology It contains chapters in the field of Ambient Intelligent Networks which received highly positive feedback during the review process The book contains research work with in depth state of the art from augmented sensors embedded technology and artificial intelligence along with cutting edge research and development of technologies and applications of Ambient Intelligent Networks This book is intended to introduce ideas methods technologies of the future development of humanity Science and Technology

Introduction to Matrix-Analytic Methods in Queues 2 Srinivas R. Chakravathy, 2022-10-18 Matrix analytic methods MAM were introduced by Professor Marcel Neuts and have been applied to a variety of stochastic models since In order to provide a clear and deep understanding of MAM while showing their power this book presents MAM concepts and explains the results using a number of worked out examples This book s approach will inform and kindle the interest of researchers attracted to this fertile field To allow readers to practice and gain experience in the algorithmic and computational procedures of MAM *Introduction to Matrix Analytic Methods in Queues 2* provides a number of computational exercises It also incorporates simulation as another tool for studying complex stochastic models especially when the state space of the underlying stochastic models under analytic study grows exponentially This book s detailed approach will make it more accessible for readers interested in learning about MAM in stochastic models

Constructive Computation in Stochastic Models with Applications Quan-Lin Li, 2011-02-02 *Constructive Computation in Stochastic Models with Applications* The RG Factorizations provides a unified constructive and algorithmic framework for numerical computation of many practical stochastic systems It summarizes recent important advances in computational study of stochastic models from several crucial directions such as stationary computation transient solution asymptotic analysis reward processes decision processes sensitivity analysis as well

as game theory Graduate students researchers and practicing engineers in the field of operations research management sciences applied probability computer networks manufacturing systems transportation systems insurance and finance risk management and biological sciences will find this book valuable Dr Quan Lin Li is an Associate Professor at the Department of Industrial Engineering of Tsinghua University China

Measurement, Modeling, and Evaluation of Computing Systems and Dependability and Fault Tolerance Jens B. Schmitt, 2012-03-08 This book constitutes the refereed proceedings of the 16th International GI ITG Conference on Measurement Modeling and Evaluation of Computing Systems and Dependability and Fault Tolerance MMB DFT 2012 held in Kaiserslautern Germany in March 2012 The 16 revised full papers presented together with 5 tool papers and 5 selected workshop papers were carefully reviewed and selected from 54 submissions MMB DFT 2012 covers diverse aspects of performance and dependability evaluation of systems including networks computer architectures distributed systems software fault tolerant and secure systems

Markov Chains Wai-Ki Ching, Ximin Huang, Michael K. Ng, Tak-Kuen Siu, 2013-03-27 This new edition of Markov Chains Models Algorithms and Applications has been completely reformatted as a text complete with end of chapter exercises a new focus on management science new applications of the models and new examples with applications in financial risk management and modeling of financial data This book consists of eight chapters Chapter 1 gives a brief introduction to the classical theory on both discrete and continuous time Markov chains The relationship between Markov chains of finite states and matrix theory will also be highlighted Some classical iterative methods for solving linear systems will be introduced for finding the stationary distribution of a Markov chain The chapter then covers the basic theories and algorithms for hidden Markov models HMMs and Markov decision processes MDPs Chapter 2 discusses the applications of continuous time Markov chains to model queueing systems and discrete time Markov chain for computing the PageRank the ranking of websites on the Internet Chapter 3 studies Markovian models for manufacturing and re manufacturing systems and presents closed form solutions and fast numerical algorithms for solving the captured systems In Chapter 4 the authors present a simple hidden Markov model HMM with fast numerical algorithms for estimating the model parameters An application of the HMM for customer classification is also presented Chapter 5 discusses Markov decision processes for customer lifetime values Customer Lifetime Values CLV is an important concept and quantity in marketing management The authors present an approach based on Markov decision processes for the calculation of CLV using real data Chapter 6 considers higher order Markov chain models particularly a class of parsimonious higher order Markov chain models Efficient estimation methods for model parameters based on linear programming are presented Contemporary research results on applications to demand predictions inventory control and financial risk measurement are also presented In Chapter 7 a class of parsimonious multivariate Markov models is introduced Again efficient estimation methods based on linear programming are presented Applications to demand predictions inventory control policy and modeling credit ratings data are discussed Finally Chapter 8

re visits hidden Markov models and the authors present a new class of hidden Markov models with efficient algorithms for estimating the model parameters Applications to modeling interest rates credit ratings and default data are discussed This book is aimed at senior undergraduate students postgraduate students professionals practitioners and researchers in applied mathematics computational science operational research management science and finance who are interested in the formulation and computation of queueing networks Markov chain models and related topics Readers are expected to have some basic knowledge of probability theory Markov processes and matrix theory

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