Numerical Methods for Structured Markov Chains

DARIO A. BINI,
GUY LATOUCHE, and
BEATRICE MEINI

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

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

Numerical Methods For Structured Markov Chains

Annelies Wilder-Smith

Numerical Methods For Structured Markov Chains:

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** 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   **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

Numerical Methods for Structured Markov Chains ,2008   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 queuing systems   **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   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   Applied Modeling Techniques and Data Analysis 1 Yiannis Dimotikalis,Alex Karagrigoriou,Christina Parpoula,Christos H. Skiadas,2021-03-31 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   **The Princeton Companion to Applied Mathematics** Nicholas J. Higham,Mark R. Dennis,Paul Glendinning,Paul A. Martin,Fadil Santosa,Jared Tanner,2015-09-15 The must have compendium on applied mathematics This is the most authoritative and accessible single volume reference book on applied mathematics Featuring numerous entries by leading experts and organized thematically it introduces

readers to applied mathematics and its uses explains key concepts describes important equations laws and functions looks at exciting areas of research covers modeling and simulation explores areas of application and more Modeled on the popular Princeton Companion to Mathematics this volume is an indispensable resource for undergraduate and graduate students researchers and practitioners in other disciplines seeking a user friendly reference book on applied mathematics Features nearly 200 entries organized thematically and written by an international team of distinguished contributors Presents the major ideas and branches of applied mathematics in a clear and accessible way Explains important mathematical concepts methods equations and applications Introduces the language of applied mathematics and the goals of applied mathematical research Gives a wide range of examples of mathematical modeling Covers continuum mechanics dynamical systems numerical analysis discrete and combinatorial mathematics mathematical physics and much more Explores the connections between applied mathematics and other disciplines Includes suggestions for further reading cross references and a comprehensive index   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   **Linear Algebra, Markov Chains, and Queueing Models** Carl D. Meyer,Robert J. Plemmons,2012-12-06 This IMA Volume in Mathematics and its Applications LINEAR ALGEBRA MARKOV CHAINS AND QUEUEING MODELS is based on the proceedings of a workshop which was an integral part of the 1991 92 IMA program on Applied Linear Algebra We thank Carl Meyer and R J Plemmons for editing the proceedings We also take this opportunity to thank the National Science Founda tion whose financial support made the workshop possible A vner Friedman Willard Miller Jr xi PREFACE This volume contains some of the lectures given at the workshop Lin ear Algebra Markov Chains and Queueing Models held January 13 17 1992 as part of the Year of Applied Linear Algebra at the Institute for Mathematics and its Applications Markov chains and queueing models play an increasingly important role in the understanding of complex systems such as computer communi cation and transportation systems Linear algebra is an indispensable tool in such research and this volume collects a selection of important papers in this area The articles contained herein are representative of the underlying purpose of the workshop which was to bring together practitioners and re searchers from the areas of linear algebra numerical analysis and queueing theory who share a common interest of analyzing and solving finite state Markov chains The papers in this volume are grouped into three major categories perturbation theory and error analysis iterative methods and applications regarding queueing models   **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   Quantitative Evaluation of Systems David Parker,Verena Wolf,2019-09-04 This book constitutes the proceedings of the 16th International Conference on Quantitative Evaluation Systems QEST 2019 held in Glasgow UK in September 2019 The 17 full papers presented together with 2 short papers were carefully reviewed and selected from 40 submissions The papers cover topics in the field of Probabilistic Verification Learning and Verification Hybrid Systems Security Probabilistic Modelling and Abstraction and Applications and Tools   **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   **Fundamentals of Matrix-Analytic Methods** Qi-Ming He,2013-08-13 Fundamentals of Matrix Analytic Methods targets advanced level students in mathematics engineering and computer science It focuses on the fundamental parts of Matrix Analytic Methods Phase Type Distributions Markovian arrival processes and Structured Markov chains and matrix geometric solutions New materials and techniques are presented for the first time in research and engineering design This book emphasizes stochastic modeling by offering probabilistic interpretation and constructive proofs for Matrix Analytic Methods Such an approach is especially useful for engineering analysis and design Exercises and examples are provided throughout the book   Milestones in Matrix Computation Raymond Chan,Chen Greif,Dianne O'Leary,2007-02-22 The text presents and discusses some of the most influential papers in Matrix Computation authored by Gene H Golub one of the founding fathers of the field The collection of 21 papers is divided into five main areas iterative methods for linear systems solution of least squares problems matrix factorizations and applications orthogonal polynomials and quadrature and eigenvalue problems Commentaries for each area are provided by leading experts Anne Greenbaum Ake Bjorck Nicholas Higham Walter Gautschi and G W Pete Stewart Comments on each paper are also included

by the original authors providing the reader with historical information on how the paper came to be written and under what circumstances the collaboration was undertaken Including a brief biography and facsimiles of the original papers this text will be of great interest to students and researchers in numerical analysis and scientific computation **Implementation and Applications of Automata** Oscar H. Ibarra,2008-07-10 This book constitutes the thoroughly refereed post proceedings of the 13th International Conference on Implementation and Application of Automata CIAA 2008 held in San Francisco USA in July 2008 The 26 revised full papers togehter with 4 invited papers were carefully reviewed and selected from 40 submissions and have gone through two rounds of reviewing and improvement The papers cover various topics in the theory implementation and applications of automata and related structures **Numerical Methods for Solving Discrete Event Systems** Winfried Grassmann,Javad Tavakoli,2022-11-05 This graduate textbook provides an alternative to discrete event simulation It describes how to formulate discrete event systems how to convert them into Markov chains and how to calculate their transient and equilibrium probabilities The most appropriate methods for finding these probabilities are described in some detail and templates for efficient algorithms are provided These algorithms can be executed on any laptop even in cases where the Markov chain has hundreds of thousands of states This book features the probabilistic interpretation of Gaussian elimination a concept that unifies many of the topics covered such as embedded Markov chains and matrix analytic methods The material provided should aid practitioners significantly to solve their problems This book also provides an interesting approach to teaching courses of stochastic processes

This book delves into Numerical Methods For Structured Markov Chains. Numerical Methods For Structured Markov Chains is an essential topic that must be grasped by everyone, ranging from students and scholars to the general public. The book will furnish comprehensive and in-depth insights into Numerical Methods For Structured Markov Chains, encompassing both the fundamentals and more intricate discussions.

1. The book is structured into several chapters, namely:

    - Chapter 1: Introduction to Numerical Methods For Structured Markov Chains
    - Chapter 2: Essential Elements of Numerical Methods For Structured Markov Chains
    - Chapter 3: Numerical Methods For Structured Markov Chains in Everyday Life
    - Chapter 4: Numerical Methods For Structured Markov Chains in Specific Contexts
    - Chapter 5: Conclusion

2. In chapter 1, the author will provide an overview of Numerical Methods For Structured Markov Chains. This chapter will explore what Numerical Methods For Structured Markov Chains is, why Numerical Methods For Structured Markov Chains is vital, and how to effectively learn about Numerical Methods For Structured Markov Chains.
3. In chapter 2, this book will delve into the foundational concepts of Numerical Methods For Structured Markov Chains. This chapter will elucidate the essential principles that must be understood to grasp Numerical Methods For Structured Markov Chains in its entirety.
4. In chapter 3, this book will examine the practical applications of Numerical Methods For Structured Markov Chains in daily life. The third chapter will showcase real-world examples of how Numerical Methods For Structured Markov Chains can be effectively utilized in everyday scenarios.
5. In chapter 4, this book will scrutinize the relevance of Numerical Methods For Structured Markov Chains in specific contexts. This chapter will explore how Numerical Methods For Structured Markov Chains is applied in specialized fields, such as education, business, and technology.
6. In chapter 5, the author will draw a conclusion about Numerical Methods For Structured Markov Chains. The final chapter will summarize the key points that have been discussed throughout the book.
The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. This book is highly recommended for anyone seeking to gain a comprehensive understanding of Numerical Methods For Structured Markov Chains.

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