# PROBABILITY, MARKOV CHAINS, QUEUES, AND SIMULATION

The Mathematical Basis of Performance Modeling

WILLIAM J. STEWART

Probability Markov Chains Queues And Simulation The Mathematical Basis Of Performance Modeling Author William J Stewart Jul 2009

Research Institute for Advanced Computer Science (U.S.), Bernard Philippe, Youcef Saad, William J. Stewart

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Probability, Markov Chains, Queues, and Simulation William J. Stewart, 2009-07-06 Probability Markov Chains Queues and Simulation provides a modern and authoritative treatment of the mathematical processes that underlie performance modeling The detailed explanations of mathematical derivations and numerous illustrative examples make this textbook readily accessible to graduate and advanced undergraduate students taking courses in which stochastic processes play a fundamental role The textbook is relevant to a wide variety of fields including computer science engineering operations research statistics and mathematics The textbook looks at the fundamentals of probability theory from the basic concepts of set based probability through probability distributions to bounds limit theorems and the laws of large numbers Discrete and continuous time Markov chains are analyzed from a theoretical and computational point of view Topics include the Chapman Kolmogorov equations irreducibility the potential fundamental and reachability matrices random walk problems reversibility renewal processes and the numerical computation of stationary and transient distributions The M M 1 queue and its extensions to more general birth death processes are analyzed in detail as are queues with phase type arrival and service processes The M G 1 and G M 1 gueues are solved using embedded Markov chains the busy period residual service time and priority scheduling are treated Open and closed queueing networks are analyzed The final part of the book addresses the mathematical basis of simulation Each chapter of the textbook concludes with an extensive set of exercises An instructor s solution manual in which all exercises are completely worked out is also available to professors only Numerous examples illuminate the mathematical theories Carefully detailed explanations of mathematical derivations guarantee a valuable pedagogical approach Each chapter concludes with an extensive set of exercises Introduction to the Numerical **Solution of Markov Chains** William J. Stewart,1994-12-04 Markov Chains Direct Methods Iterative Methods Projection Methods Block Hessenberg Matrices Decompositional Methods LI Cyclic Markov Chains Transient Solutions Stochastic **Computations with Markov Chains** William J. Stewart, 2012-12-06 Computations with Automata Networks Software Markov Chains presents the edited and reviewed proceedings of the Second International Workshop on the Numerical Solution of Markov Chains held January 16 18 1995 in Raleigh North Carolina New developments of particular interest include recent work on stability and conditioning Krylov subspace based methods for transient solutions quadratic convergent procedures for matrix geometric problems further analysis of the GTH algorithm the arrival of stochastic automata networks at the forefront of modelling stratagems and more An authoritative overview of the field for applied probabilists numerical analysts and systems modelers including computer scientists and engineers Queueing Networks and Markov Chains Gunter Bolch, Stefan Greiner, Hermann de Meer, Kishor S. Trivedi, 2006-04-14 Critically acclaimed text for computer performance analysis now in its second edition The Second Edition of this now classic text provides a current and

thorough treatment of queueing systems queueing networks continuous and discrete time Markov chains and simulation Thoroughly updated with new content as well as new problems and worked examples the text offers readers both the theory and practical guidance needed to conduct performance and reliability evaluations of computer communication and manufacturing systems Starting with basic probability theory the text sets the foundation for the more complicated topics of queueing networks and Markov chains using applications and examples to illustrate key points Designed to engage the reader and build practical performance analysis skills the text features a wealth of problems that mirror actual industry challenges New features of the Second Edition include Chapter examining simulation methods and applications Performance analysis applications for wireless Internet J2EE and Kanban systems Latest material on non Markovian and fluid stochastic Petri nets as well as solution techniques for Markov regenerative processes Updated discussions of new and popular performance analysis tools including ns 2 and OPNET New and current real world examples including DiffServ routers in the Internet and cellular mobile networks With the rapidly growing complexity of computer and communication systems the need for this text which expertly mixes theory and practice is tremendous Graduate and advanced undergraduate students in computer science will find the extensive use of examples and problems to be vital in mastering both the basics and the fine points of the field while industry professionals will find the text essential for developing systems that comply with industry Markov Chains Pierre Brémaud, 2020-05-23 Primarily an introduction to the theory of standards and regulations stochastic processes at the undergraduate or beginning graduate level the primary objective of this book is to initiate students in the art of stochastic modelling However it is motivated by significant applications and progressively brings the student to the borders of contemporary research Examples are from a wide range of domains including operations research and electrical engineering Researchers and students in these areas as well as in physics biology and the social sciences will **Markov Chains** Pierre Bremaud, 2013-03-09 In this book the author begins with the elementary find this book of interest theory of Markov chains and very progressively brings the reader to the more advanced topics He gives a useful review of probability that makes the book self contained and provides an appendix with detailed proofs of all the prerequisites from calculus algebra and number theory A number of carefully chosen problems of varying difficulty are proposed at the close of each chapter and the mathematics are slowly and carefully developed in order to make self study easier The author treats the classic topics of Markov chain theory both in discrete time and continuous time as well as the connected topics such as finite Gibbs fields nonhomogeneous Markov chains discrete time regenerative processes Monte Carlo simulation simulated annealing and queuing theory The result is an up to date textbook on stochastic processes Students and researchers in operations research and electrical engineering as well as in physics and biology will find it very accessible and relevant

<u>Computations with Markov Chains</u> William J Stewart,1995-02-28 **Markov Chains and Dependability Theory** Gerardo Rubino,Bruno Sericola,2014-06-12 Dependability metrics are omnipresent in every engineering field from simple

ones through to more complex measures combining performance and dependability aspects of systems This book presents the mathematical basis of the analysis of these metrics in the most used framework Markov models describing both basic results and specialised techniques. The authors first present both discrete and continuous time Markov chains before focusing on dependability measures which necessitate the study of Markov chains on a subset of states representing different user satisfaction levels for the modelled system Topics covered include Markovian state lumping analysis of sojourns on subset of states of Markov chains analysis of most dependability metrics fundamentals of performability analysis and bounding and simulation techniques designed to evaluate dependability measures The book is of interest to graduate students and researchers in all areas of engineering where the concepts of lifetime repair duration availability reliability and risk are Queueing Networks and Markov Chains ,2008 Eintrag f r die Universit tsbibliographie important Paul A. Gagniuc, 2017-07-05 A fascinating and instructive guide to Markov chains for experienced users and newcomers alike This unique quide to Markov chains approaches the subject along the four convergent lines of mathematics implementation simulation and experimentation It introduces readers to the art of stochastic modeling shows how to design computer implementations and provides extensive worked examples with case studies Markov Chains From Theory to Implementation and Experimentation begins with a general introduction to the history of probability theory in which the author uses quantifiable examples to illustrate how probability theory arrived at the concept of discrete time and the Markov model from experiments involving independent variables An introduction to simple stochastic matrices and transition probabilities is followed by a simulation of a two state Markov chain The notion of steady state is explored in connection with the long run distribution behavior of the Markov chain Predictions based on Markov chains with more than two states are examined followed by a discussion of the notion of absorbing Markov chains Also covered in detail are topics relating to the average time spent in a state various chain configurations and n state Markov chain simulations used for verifying experiments involving various diagram configurations Fascinating historical notes shed light on the key ideas that led to the development of the Markov model and its variants Various configurations of Markov Chains and their limitations are explored at length Numerous examples from basic to complex are presented in a comparative manner using a variety of color graphics All algorithms presented can be analyzed in either Visual Basic Java Script or PHP Designed to be useful to professional statisticians as well as readers without extensive knowledge of probability theory Covering both the theory underlying the Markov model and an array of Markov chain implementations within a common conceptual framework Markov Chains From Theory to Implementation and Experimentation is a stimulating introduction to and a valuable reference for those wishing to deepen their understanding of this extremely valuable statistical tool Paul A Gagniuc PhD is Associate Professor at Polytechnic University of Bucharest Romania He obtained his MS and his PhD in genetics at the University of Bucharest Dr Gagniuc s work has been published in numerous high profile scientific journals ranging from the Public Library of Science to

BioMed Central and Nature journals He is the recipient of several awards for exceptional scientific results and a highly active figure in the review process for different scientific areas Probability, Markov Chains, Queues William J. Stewart, 2009-09-01 Numerical Methods in Markov Chain Modeling Research Institute for Advanced Computer Science (U.S.), Bernard Philippe, Youcef Saad, William J. Stewart, 1989 Markov Chains Bruno Sericola, 2013-08-05 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 Contents 1 Discrete Time Markov Chains 2 Continuous Time Markov Chains 3 Birth and Death Processes 4 Uniformization 5 Queues About the Authors Bruno Sericola is a Senior Research Scientist at Inria Rennes Bretagne Atlantique in France His main research activity is in performance evaluation of computer and communication systems dependability analysis of fault tolerant systems and stochastic models

Continuous-Time Markov Chains William J. Anderson, 2012-12-06 Continuous time parameter Markov chains have been useful for modeling various random phenomena occurring in queueing theory genetics demography epidemiology and competing populations This is the first book about those aspects of the theory of continuous time Markov chains which are useful in applications to such areas It studies continuous time Markov chains through the transition function and corresponding g matrix rather than sample paths An extensive discussion of birth and death processes including the Stieltjes moment problem and the Karlin McGregor method of solution of the birth and death processes and multidimensional population processes is included and there is an extensive bibliography Virtually all of this material is appearing in book form for the first time An Introduction to Queueing Theory Brian D. Bunday, 1996 Developed from a successful course on queueing theory for students in operational research this textbook develops a wide variety of realistic queueing systems The models are developed carefully and linked to important examples The material assumes a background in calculus and probability Topics include birth death models Markov chains and transient solutions and the book includes numerous exercises with solutions Markov Models & Optimization M.H.A. Davis, 2018-02-19 This book presents a radically new approach to problems of evaluating and optimizing the performance of continuous time stochastic systems This approach is based on the use of a family of Markov processes called Piecewise Deterministic Processes PDPs as a general class of stochastic system models A PDP is a Markov process that follows deterministic trajectories between random jumps the latter

occurring either spontaneously in a Poisson like fashion or when the process hits the boundary of its state space This formulation includes an enormous variety of applied problems in engineering operations research management science and economics as special cases examples include queueing systems stochastic scheduling inventory control resource allocation problems optimal planning of production or exploitation of renewable or non renewable resources insurance analysis fault detection in process systems and tracking of maneuvering targets among many others. The first part of the book shows how these applications lead to the PDP as a system model and the main properties of PDPs are derived There is particular emphasis on the so called extended generator of the process which gives a general method for calculating expectations and distributions of system performance functions The second half of the book is devoted to control theory for PDPs with a view to controlling PDP models for optimal performance characterizations are obtained of optimal strategies both for continuously acting controllers and for control by intervention impulse control Throughout the book modern methods of stochastic analysis are used but all the necessary theory is developed from scratch and presented in a self contained way The book will be useful to engineers and scientists in the application areas as well as to mathematicians interested in applications of stochastic analysis 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 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 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

Markov Chains and Mixing Times David A. Levin, Yuval Peres, 2017-10-31 This book is an introduction to the modern theory of Markov chains whose goal is to determine the rate of convergence to the stationary distribution as a function of state space size and geometry This topic has important connections to combinatorics statistical physics and theoretical

computer science Many of the techniques presented originate in these disciplines The central tools for estimating convergence times including coupling strong stationary times and spectral methods are developed The authors discuss many examples including card shuffling and the Ising model from statistical mechanics and present the connection of random walks to electrical networks and apply it to estimate hitting and cover times The first edition has been used in courses in mathematics and computer science departments of numerous universities The second edition features three new chapters on monotone chains the exclusion process and stationary times and also includes smaller additions and corrections throughout Updated notes at the end of each chapter inform the reader of recent research developments **Numerical Methods in Markov Chains and Bulk Queues** T. P. Bagchi, J. G. C. Templeton, 1972-09-29 Mathematical formulation of the bulk queuing problem A numerical approach to waiting line problems Conclusions and directions for further research

Comparison Methods for Queues and Other Stochastic Models Dietrich Stoyan,1983 Studies stochastic models of queueing reliability inventory and sequencing in which random influences are considered One stochastic mode rl is approximated by another that is simpler in structure or about which simpler assumptions can be made After general results on comparison properties of random variables and stochastic processes are given the properties are illustrated by application to various queueing models and questions in experimental design renewal and reliability theory PERT networks and branching processes

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