An Introduction To Markov Chains Mit Mathematics

In this 2002 book, the author develops the necessary background in probability theory and Markov chains then discusses important computing applications. Clear, rigorous, and intuitive, Markov Processes provides a bridge from an undergraduate probability course to a course in stochastic processes and also as a reference for those that want to see detailed proofs of the theorems of Markov processes. It contains copious computational examples that motivate and illustrate the theorems. The text is desi

Scientific knowledge grows at a phenomenal pace--but few books have had as lasting an impact or played as important a role in our modern world as The Mathematical Theory of Communication, published originally as a paper on communication theory more than fifty years ago. Republished in book form shortly thereafter, it has since gone through four hardcover and sixteen paperback printings. It is a revolutionary work, astounding in its foresight and contemporaneity. The University of Illinois Press is pleased and honored to issue this commemorative reprinting of a classic.

A cornerstone of applied probability, Markov chains can be used to help model how plants grow, chemicals react, and atoms diffuse--and applications are increasingly being found in such areas as engineering, computer science, economics, and education. To apply the techniques to real problems, however, it is necessary to understand how Markov chains can be solved numerically. In this book, the first to offer a systematic and detailed treatment of the numerical solution of Markov chains, William Stewart provides scientists on many levels with the power to put this theory to use in the actual world, where it has applications in areas as diverse as engineering, economics, and education. His efforts make for essential reading in a rapidly growing field. Here Stewart explores all aspects of numerically computing solutions of Markov chains, especially when the state is huge. He provides extensive background to both discrete-time and continuous-time Markov chains and examines many different numerical computing methods--direct, single-and multi-vector iterative, and projection methods. More specifically, he considers recursive methods often used when the structure of the Markov chain is upper Hessenberg, iterative aggregation/disaggregation methods that are particularly appropriate when it is NCD (nearly completely decomposable), and reduced schemes for cases in which the chain is periodic. There are chapters on methods for computing transient solutions, on stochastic automata networks, and, finally, on currently available software. Throughout Stewart draws on numerous examples and comparisons among the methods he so thoroughly explains.

This clear presentation of themost fundamental models ofrandom phenomena employsmethods that recognize computerrelatedaspects of theory. Topicsinclude probability spaces andrandom variables, expectationsand independence, Bernoulliprocesses and sums of independentrandom variables, Poisson

processes, Markov chainsand processes, and renewal theory. Assuming only a backgroundin calculus, this outstanding text includes an introductionto basic stochastic processes.Reprint of the Prentice-Hall Publishers, Englewood Cliffs,New Jersey, 1975 edition.

Markov process theory provides a mathematical framework for analyzing the elements of randomness that are involved in most real-world dynamical processes. This introductory text, which requires an understanding of ordinary calculus, develops the concepts and results of random variable theory.

Hidden Markov Models for Time Series: An Introduction Using R, Second Edition illustrates the great flexibility of hidden Markov models (HMMs) as general-purpose models for time series data. The book provides a broad understanding of the models and their uses. After presenting the basic model formulation, the book covers estimation, forecasting, decoding, prediction, model selection, and Bayesian inference for HMMs. Through examples and applications, the authors describe how to extend and generalize the basic model so that it can be applied in a rich variety of situations. The book demonstrates how HMMs can be applied to a wide range of types of time series: continuous-valued, circular, multivariate, binary, bounded and unbounded counts, and categorical observations. It also discusses how to employ the freely available computing environment R to carry out the computations. Features Presents an accessible overview of HMMs Explores a variety of applications in ecology, finance, epidemiology, climatology, and sociology Includes numerous theoretical and programming exercises Provides most of the analysed data sets online New to the second edition A total of five chapters on extensions, including HMMs for longitudinal data, hidden semi-Markov models and models with continuous-valued state process New case studies on animal movement, rainfall occurrence and capture-recapture data From observation to simulation -- Building the stochastic matrix -- Predictions by using 2-state Markov chains -- Predictions by using N-state Markov chains -- Absorbing Markov chains -- The average time spent in each state -- Discussions on different configurations of chains -- The simulation of an N-state Markov chain This book is an introduction to Markov chain modeling with applications to communication networks. It begins with a general introduction to performance modeling in Chapter 1 where we introduce different performance models. We then introduce basic ideas of Markov chain modeling: Markov property, discrete time Markov chain (DTMC) and continuous time Markov chain (CTMC). We also discuss how to find the steady state distributions from these Markov chains and how they can be used to compute the system performance metric. The solution methodologies include a balance equation technique, limiting probability technique, and the uniformization. We try to minimize the theoretical aspects of the Markov chain so that the book is easily accessible to readers without deep mathematical backgrounds. We then introduce how to develop a Markov chain model with simple applications: a forwarding system, a cellular system blocking, slotted ALOHA, Wi-Fi model, and multichannel based LAN model. The examples

cover CTMC, DTMC, birth-death process and non birth-death process. We then introduce more difficult examples in Chapter 4, which are related to wireless LAN networks: the Bianchi model and Multi-Channel MAC model with fixed duration. These models are more advanced than those introduced in Chapter 3 because they require more advanced concepts such as renewal-reward theorem and the queueing network model. We introduce these concepts in the appendix as needed so that readers can follow them without difficulty. We hope that this textbook will be helpful to students, researchers, and network practitioners who want to understand and use mathematical modeling techniques. Table of Contents: Performance Modeling / Markov Chain Modeling / Developing Markov Chain Performance Models / Advanced Markov Chain Models

This book concerns continuous-time controlled Markov chains, also known as continuous-time Markov decision processes. They form a class of stochastic control problems in which a single decision-maker wishes to optimize a given objective function. This book is also concerned with Markov games, where two decision-makers (or players) try to optimize their own objective function. Both decision-making processes appear in a large number of applications in economics, operations research, engineering, and computer science, among other areas. An extensive, self-contained, up-to-date analysis of basic optimality criteria (such as discounted and average reward), and advanced optimality criteria (e.g., bias, overtaking, sensitive discount, and Blackwell optimality) is presented. A particular emphasis is made on the application of the results herein: algorithmic and computational issues are discussed, and applications to population models and epidemic processes are shown. This book is addressed to students and researchers in the fields of stochastic control and stochastic games. Moreover, it could be of interest also to undergraduate and beginning graduate students because the reader is not supposed to have a high mathematical background: a working knowledge of calculus, linear algebra, probability, and continuous-time Markov chains should suffice to understand the contents of the book. Contents:IntroductionControlled Markov ChainsBasic Optimality CriteriaPolicy Iteration and Approximation TheoremsOvertaking, Bias, and Variance OptimalitySensitive Discount OptimalityBlackwell OptimalityConstrained Controlled Markov ChainsApplicationsZero-Sum Markov GamesBias and Overtaking Equilibria for Markov Games Readership: Graduate students and researchers in the fields of stochastic control and stochastic analysis. Keywords:Markov Decision Processes;Continuous-Time Controlled Markov Chains;Stochastic Dynamic Programming;Stochastic GamesKey Features:This book presents a reader-friendly, extensive, self-contained, and up-to-date analysis of advanced optimality criteria for continuous-time controlled Markov chains and Markov games. Most of the material herein is quite recent (it has been published in high-impact journals during the last five years) and it appears in book form for the first timeThis book introduces approximation theorems which, in particular, allow the reader to obtain numerical approximations of the solution

to several control problems of practical interest. To the best of our knowledge, this is the first time that such computational issues are studied for denumerable state continuous-time controlled Markov chains. Hence, the book has an adequate balance between, on the one hand, theoretical results and, on the other hand, applications and computational issuesThe books that analyze continuous-time controlled Markov chains usually restrict themselves to the case of bounded transition and reward rates, which can be reduced to discrete-time models by using the uniformization technique. In our case, however, the transition and the reward rates might be unbounded, and so the uniformization technique cannot be used. By the way, let us mention that in models of practical interest the transition and the reward rates are, typically, unboundedReviews:"The book contains a large number of recent research results on CMCs and Markov games and puts them in perspective. It is written in a very conscious manner, contains detailed proofs of all main results, as well as extensive bibliographic remarks. The book is a very valuable piece of work for researchers on continuous-time CMCs and Markov games."Zentralblatt MATH

This book is an introduction to quantum Markov chains and explains how this concept is connected to the question of how well a lost quantum mechanical system can be recovered from a correlated subsystem. To achieve this goal, we strengthen the data-processing inequality such that it reveals a statement about the reconstruction of lost information. The main difficulty in order to understand the behavior of quantum Markov chains arises from the fact that quantum mechanical operators do not commute in general. As a result we start by explaining two techniques of how to deal with non-commuting matrices: the spectral pinching method and complex interpolation theory. Once the reader is familiar with these techniques a novel inequality is presented that extends the celebrated Golden-Thompson inequality to arbitrarily many matrices. This inequality is the key ingredient in understanding approximate quantum Markov chains and it answers a question from matrix analysis that was open since 1973, i.e., if Lieb's triple matrix inequality can be extended to more than three matrices. Finally, we carefully discuss the properties of approximate quantum Markov chains and their implications. The book is aimed to graduate students who want to learn about approximate quantum Markov chains as well as more experienced scientists who want to enter this field. Mathematical majority is necessary, but no prior knowledge of quantum mechanics is required.

Provides a more accessible introduction than other books on Markov processes by emphasizing the structure of the subject and avoiding sophisticated measure theory Leads the reader to a rigorous understanding of basic theory

These notes are based on a course which I gave during the academic year 1983-84 at the University of Colorado. My intention was to provide both my audience as well as myself with an introduction to the theory of 1arie deviations • The organization of sections 1) through 3) owes something to chance and a great deal to the excellent set of notes written by R. Azencott for the course which he

gave in 1978 at Saint-Flour (cf. Springer Lecture Notes in Mathematics 774). To be more precise: it is chance that I was around N. Y. U. at the time'when M. Schilder wrote his thesis. and so it may be considered chance that I chose to use his result as a jumping off point; with only minor variations. everything else in these sections is taken from Azencott. In particular. section 3) is little more than a rewrite of his exoposition of the Cramer theory via the ideas of Bahadur and Zabel. Furthermore. the brief treatment which I have given to the Ventsel-Freidlin theory in section 4) is again based on Azencott's ideas. All in all. the biggest difference between his and my exposition of these topics is the language in which we have written. However. another major difference must be mentioned: his bibliography is extensive and constitutes a fine introduction to the available literature. mine shares neither of these attributes. Starting with section 5). Developed from celebrated Harvard statistics lectures, Introduction to Probability provides essential language and tools for understanding statistics, randomness, and uncertainty. The book explores a wide variety of applications and examples, ranging from coincidences and paradoxes to Google PageRank and Markov chain Monte Carlo (MCMC). Additional

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.

This book is an introduction to the modern approach to the theory of Markov chains. The main goal of this approach is to determine the rate of convergence of a Markov chain to the stationary distribution as a function of the size and geometry of the state space. The authors develop the key tools for estimating convergence times, including coupling, strong stationary times, and spectral methods. Whenever possible, probabilistic methods are emphasized. The book includes many examples and provides brief introductions to some central models of statistical mechanics. Also provided are accounts of random walks on networks, including hitting and cover times, and analyses of several methods of shuffling cards. As a prerequisite, the authors assume a modest understanding of probability theory and linear algebra at an undergraduate level. Markov Chains and Mixing Times is meant to bring the excitement of this active area of research to a wide audience.

Besides the investigation of general chains the book contains chapters which are concerned with eigenvalue techniques, conductance, stopping times, the strong Markov property, couplings, strong uniform times, Markov chains on arbitrary finite groups (including a crash-course in harmonic analysis), random generation and counting, Markov random fields, Gibbs fields, the Metropolis sampler, and simulated annealing. With 170 exercises.

Provides methods of analysing Markov chains based on Lyapunov functions. Markov processes are processes that have limited memory. In particular, their dependence on the past is only through the previous state. They are used to model the behavior of many systems including communications systems, transportation networks, image segmentation and analysis, biological systems and DNA sequence analysis, random atomic motion and diffusion in physics, social mobility, population studies, epidemiology, animal and insect migration, queueing systems, resource management, dams, financial engineering, actuarial science, and decision systems. Covering a wide range of areas of application of Markov processes, this second edition is revised to highlight the most important

aspects as well as the most recent trends and applications of Markov processes. The author spent over 16 years in the industry before returning to academia, and he has applied many of the principles covered in this book in multiple research projects. Therefore, this is an applications-oriented book that also includes enough theory to provide a solid ground in the subject for the reader. Presents both the theory and applications of the different aspects of Markov processes Includes numerous solved examples as well as detailed diagrams that make it easier to understand the principle being presented Discusses different applications of hidden Markov models, such as DNA sequence analysis and speech analysis.

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 queues 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

Speech and language technologies continue to grow in importance as they are used to create natural and efficient interfaces between people and machines, and to automatically transcribe, extract, analyze, and route information from high-volume streams of spoken and written information. The workshops on Mathematical Foundations of Speech Processing and Natural Language Modeling were held in the Fall of 2000 at the University of Minnesota's NSF-sponsored Institute for Mathematics and Its Applications, as part of a

"Mathematics in Multimedia" year-long program. Each workshop brought together researchers in the respective technologies on the one hand, and mathematicians and statisticians on the other hand, for an intensive week of cross-fertilization. There is a long history of benefit from introducing mathematical techniques and ideas to speech and language technologies. Examples include the source-channel paradigm, hidden Markov models, decision trees, exponential models and formal languages theory. It is likely that new mathematical techniques, or novel applications of existing techniques, will once again prove pivotal for moving the field forward. This volume consists of original contributions presented by participants during the two workshops. Topics include language modeling, prosody, acoustic-phonetic modeling, and statistical methodology.

This book is about discrete-time, time-homogeneous, Markov chains (Mes) and their ergodic behavior. To this end, most of the material is in fact about stable Mes, by which we mean Mes that admit an invariant probability measure. To state this more precisely and give an overview of the questions we shall be dealing with, we will first introduce some notation and terminology. Let (X,B) be a measurable space, and consider a X-valued Markov chain ~. = {~k' k = 0, 1, ... } with transition probability function (t.pJ.) P(x, B), i.e., P(x, B) := Prob (~k+1 E B I ~k = x) for each x E X, B E B, and k = 0,1, ... The Me ~. is said to be stable if there exists a probability measure (p.m.) /.l on B such that (*) VB EB. /.l(B) = Ix /.l(dx) P(x, B) If (*) holds then /.l is called an invariant p.m. for the Me ~. (or the t.p.f. P).

Primarily an introduction to the theory of 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 find this book of interest.

Papers presented at a workshop held January 1990 (location unspecified) cover just about all aspects of solving Markov models numerically. There are papers on matrix generation techniques and generalized stochastic Petri nets; the computation of stationary distributions, including aggregation/disagg

Provides an introduction to basic structures of probabilitywith a view towards applications in information technology A First Course in Probability and Markov Chains presentsan introduction to the basic elements in probability and focuses ontwo main areas. The first part explores notions and structures inprobability, including combinatorics, probability measures,probability distributions, conditional probability,inclusion-exclusion formulas, random variables, dispersion indexes,independent random variables as well as weak and strong laws oflarge numbers and central limit theorem. In the second part of thebook, focus is given to Discrete Time Discrete Markov Chains whichis addressed together with an introduction to Poisson processes andContinuous Time Discrete Markov Chains. This book also looks atmaking use of measure theory notations that unify all thepresentation, in particular avoiding

the separate treatment ofcontinuous and discrete distributions. A First Course in Probability and Markov Chains: Presents the basic elements of probability. Explores elementary probability with combinatorics, uniformprobability, the inclusion-exclusion principle, independence andconvergence of random variables. Features applications of Law of Large Numbers. Introduces Bernoulli and Poisson processes as well as discreteand continuous time Markov Chains with discrete states. Includes illustrations and examples throughout, along withsolutions to problems featured in this book. The authors present a unified and comprehensive overview ofprobability and Markov Chains aimed at educating engineers workingwith probability and statistics as well as advanced undergraduatestudents in sciences and engineering with a basic background inmathematical analysis and linear algebra. Presents a number of new and potentially useful self-learning (adaptive) control algorithms and theoretical as well as practical results for both unconstrained and constrained finite Markov chains-efficiently processing new information by adjusting the control strategies directly or indirectly.

For students in pure and applied probability; lots of applications, fairly self-contained.

The emergence of huge amounts of data which require analysis and in some cases real-time processing has forced exploration into fast algorithms for handling very large data sizes. Analysis of x-ray images in medical applications, cyber security data, crime data, telecommunications and stock market data, health records and business analytics data are but a few areas of interest. Applications and platforms including R, RapidMiner and Weka provide the basis for analysis, often used by practitioners who pay little to no attention to the underlying mathematics and processes impacting the data. This often leads to an inability to explain results or correct mistakes, or to spot errors. Applied Data Analytics - Principles and Applications seeks to bridge this missing gap by providing some of the most sought after techniques in big data analytics. Establishing strong foundations in these topics provides practical ease when big data analyses are undertaken using the widely available open source and commercially orientated computation platforms, languages and visualization systems. The book, when combined with such platforms, provides a complete set of tools required to handle big data and can lead to fast implementations and applications. The book contains a mixture of machine learning foundations, deep learning, artificial intelligence, statistics and evolutionary learning mathematics written from the usage point of view with rich explanations on what the concepts mean. The author has thus avoided the complexities often associated with these concepts when found in research papers. The tutorial nature of the book and the applications provided are some of the reasons why the book is suitable for undergraduate, postgraduate and big data analytics enthusiasts. This text should ease the fear of mathematics often associated with practical data analytics and support rapid applications in artificial intelligence, environmental sensor data modelling and analysis, health informatics, business data analytics, data from Internet of Things and deep learning applications.

Markov processes are among the most important stochastic processes for both theory and applications. This book develops the general theory of these processes, and applies this theory to various special examples. The initial chapter is devoted to the most important classical example - one dimensional Brownian motion. This, together with a chapter on continuous time Markov chains, provides the motivation for the general setup based on semigroups and generators. Chapters on stochastic calculus and probabilistic potential theory give an introduction to some of the key areas of application of Brownian motion and its relatives. A chapter on interacting particle systems treats a more recently developed class of Markov processes that have as their origin problems in physics and biology. This is a textbook for a graduate course that can follow one that covers basic probabilistic limit theorems and discrete time processes.

This is the revised and augmented edition of a now classic book which is an introduction to sub-

Markovian kernels on general measurable spaces and their associated homogeneous Markov chains. The first part, an expository text on the foundations of the subject, is intended for post-graduate students. A study of potential theory, the basic classification of chains according to their asymptotic behaviour and the celebrated Chacon-Ornstein theorem are examined in detail. The second part of the book is at a more advanced level and includes a treatment of random walks on general locally compact abelian groups. Further chapters develop renewal theory, an introduction to Martin boundary and the study of chains recurrent in the Harris sense. Finally, the last chapter deals with the construction of chains starting from a kernel satisfying some kind of maximum principle.

An Introduction to Stochastic Modeling provides information pertinent to the standard concepts and methods of stochastic modeling. This book presents the rich diversity of applications of stochastic processes in the sciences. Organized into nine chapters, this book begins with an overview of diverse types of stochastic models, which predicts a set of possible outcomes weighed by their likelihoods or probabilities. This text then provides exercises in the applications of simple stochastic analysis to appropriate problems. Other chapters consider the study of general functions of independent, identically distributed, nonnegative random variables representing the successive intervals between renewals. This book discusses as well the numerous examples of Markov branching processes that arise naturally in various scientific disciplines. The final chapter deals with queueing models, which aid the design process by predicting system performance. This book is a valuable resource for students of engineering and management science. Engineers will also find this book useful.

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.

This book provides an undergraduate-level introduction to discrete and continuous-time Markov chains and their applications, with a particular focus on the first step analysis technique and its applications to average hitting times and ruin probabilities. It also discusses classical topics such as recurrence and transience, stationary and limiting distributions, as well as branching processes. It first examines in detail two important examples (gambling processes and random walks) before presenting the general theory itself in the subsequent chapters. It also provides an introduction to discrete-time martingales and their relation to ruin probabilities and mean exit times, together with a chapter on spatial Poisson processes. The concepts presented are illustrated by examples, 138 exercises and 9 problems with their solutions.

Markov chains are central to the understanding of random processes. This is not only because they pervade the applications of random processes, but also because one can calculate explicitly many quantities of interest. This textbook, aimed at advanced undergraduate or MSc students with some background in basic probability theory, focuses on Markov chains and quickly develops a coherent and rigorous theory whilst showing also how actually to apply it. Both discrete-time and continuous-time chains are studied. A distinguishing feature is an introduction to more advanced topics such as

martingales and potentials in the established context of Markov chains. There are applications to simulation, economics, optimal control, genetics, queues and many other topics, and exercises and examples drawn both from theory and practice. It will therefore be an ideal text either for elementary courses on random processes or those that are more oriented towards applications.

This book provides a rigorous but elementary introduction to the theory of Markov Processes on a countable state space. It should be accessible to students with a solid undergraduate background in mathematics, including students from engineering, economics, physics, and biology. Topics covered are: Doeblin's theory, general ergodic properties, and continuous time processes. Applications are dispersed throughout the book. In addition, a whole chapter is devoted to reversible processes and the use of their associated Dirichlet forms to estimate the rate of convergence to equilibrium. These results are then applied to the analysis of the Metropolis (a.k.a simulated annealing) algorithm. The corrected and enlarged 2nd edition contains a new chapter in which the author develops computational methods for Markov chains on a finite state space. Most intriguing is the section with a new technique for computing stationary measures, which is applied to derivations of Wilson's algorithm and Kirchoff's formula for spanning trees in a connected graph.

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.

New up-to-date edition of this influential classic on Markov chains in general state spaces. Proofs are rigorous and concise, the range of applications is broad and knowledgeable, and key ideas are accessible to practitioners with limited mathematical background. New commentary by Sean Meyn, including updated references, reflects developments since 1996.

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