Continuous-Time Markov Decision Processes: Theory And Applications

Fwu-Ranq Chang

Continuous-Time Markov Decision Processes Xianping Guo, Onésimo Hernández-Lerma, 2009-09-18

Continuous-time Markov decision processes (MDPs), also known as controlled Markov chains, are used for modeling decision-making problems that arise in operations research (for instance, inventory, manufacturing, and queueing systems), computer science, communications engineering, control of populations (such as fisheries and epidemics), and management science, among many other fields. This volume provides a unified, systematic, self-contained presentation of recent developments on the theory and applications of continuous-time MDPs. The MDPs in this volume include most of the cases that arise in applications, because they allow unbounded transition and reward/cost rates. Much of the material appears for the first time in book form.

Continuous-Time Markov Decision Processes Xianping Guo, Onesimo Hernandez-Lerma, 2010-04-29

Continuous-time Markov decision processes (MDPs), also known as controlled Markov chains, are used for modeling decision-making problems that arise in operations research (for instance, inventory, manufacturing, and queueing systems), computer science, communications engineering, control of populations (such as fisheries and epidemics), and management science, among many other fields. This volume provides a unified, systematic, self-contained presentation of recent developments on the theory and applications of continuous-time MDPs. The MDPs in this volume include most of the cases that arise in applications, because they allow unbounded transition and reward/cost rates. Much of the material appears for the first time in book form.

Continuous-Time Markov Decision Processes Alexey Piunovskiy, Yi Zhang, 2020-11-09

This book offers a systematic and rigorous treatment of continuous-time Markov decision processes, covering both theory and possible applications to queueing systems, epidemiology, finance, and other fields. Unlike most books on the subject, much attention is paid to problems with functional constraints and the realizability of strategies. Three major methods of investigations are presented, based on dynamic programming, linear programming, and reduction to discrete-time problems. Although the main focus is on models with total (discounted or undiscounted) cost criteria, models with average cost criteria and with impulsive controls
are also discussed in depth. The book is self-contained. A separate chapter is devoted to Markov pure jump processes and the appendices collect the requisite background on real analysis and applied probability. All the statements in the main text are proved in detail. Researchers and graduate students in applied probability, operational research, statistics and engineering will find this monograph interesting, useful and valuable.

*Continuous-Time Markov Chains and Applications* G. George Yin, Qing Zhang, 2012-11-14 This book gives a systematic treatment of singularly perturbed systems that naturally arise in control and optimization, queueing networks, manufacturing systems, and financial engineering. It presents results on asymptotic expansions of solutions of Komogorov forward and backward equations, properties of functional occupation measures, exponential upper bounds, and functional limit results for Markov chains with weak and strong interactions. To bridge the gap between theory and applications, a large portion of the book is devoted to applications in controlled dynamic systems, production planning, and numerical methods for controlled Markovian systems with large-scale and complex structures in the real-world problems. This second edition has been updated throughout and includes two new chapters on asymptotic expansions of solutions for backward equations and hybrid LQG problems. The chapters on analytic and probabilistic properties of two-time-scale Markov chains have been almost completely rewritten and the notation has been streamlined and simplified. This book is written for applied mathematicians, engineers, operations researchers, and applied scientists. Selected material from the book can also be used for a one semester advanced graduate-level course in applied probability and stochastic processes.

*Markov Decision Processes with Their Applications* Qiying Hu, Wuyi Yue, 2007-09-14 Put together by two top researchers in the Far East, this text examines Markov Decision Processes - also called stochastic dynamic programming - and their applications in the optimal control of discrete event systems, optimal replacement, and optimal allocations in sequential online auctions. This dynamic new book offers fresh applications of MDPs in areas such as the control of discrete event systems and the optimal allocations in sequential online auctions.

*Markov Decision Processes with Applications to Finance* Nicole Bäuerle, Ulrich Rieder, 2011-06-06 The theory of Markov decision processes focuses on controlled Markov chains in discrete time. The authors establish the theory for general state and action spaces and at the same time show its application by means of numerous examples, mostly taken from the fields of finance and operations research. By using a structural approach many technicalities (concerning measure theory) are avoided. They cover problems with finite and infinite horizons, as well as partially observable Markov decision processes, piecewise deterministic Markov decision processes and stopping problems. The book presents Markov decision processes in action and includes various state-of-the-art applications with a particular view towards finance. It is useful for upper-level undergraduates, Master's students and researchers in both applied probability and finance, and provides exercises (without solutions).
Discrete-Time Markov Chains George Yin, Qing Zhang, 2005

Focusing on discrete-time-scale Markov chains, the contents of this book are an outgrowth of some of the authors' recent research. The motivation stems from existing and emerging applications in optimization and control of complex hybrid Markovian systems in manufacturing, wireless communication, and financial engineering. Much effort in this book is devoted to designing system models arising from these applications, analyzing them via analytic and probabilistic techniques, and developing feasible computational algorithms so as to reduce the inherent complexity. This book presents results including asymptotic expansions of probability vectors, structural properties of occupation measures, exponential bounds, aggregation and decomposition and associated limit processes, and interface of discrete-time and continuous-time systems. One of the salient features is that it contains a diverse range of applications on filtering, estimation, control, optimization, and Markov decision processes, and financial engineering. This book will be an important reference for researchers in the areas of applied probability, control theory, operations research, as well as for practitioners who use optimization techniques. Part of the book can also be used in a graduate course of applied probability, stochastic processes, and applications.

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.

**Markov Decision Process** Fouad Sabry,2023-06-27 What Is Markov Decision Process A discrete-time stochastic control process is referred to as a Markov decision process (MDP) in the field of mathematics. It offers a mathematical framework for modeling decision making in scenarios in which the outcomes are partially controlled by a decision maker and partly determined by random chance. The study of optimization issues that can be handled by dynamic programming lends itself well to the use of MDPs. At the very least, MDPs were recognized to exist in the 1950s. Ronald Howard's book, published in 1960 and titled Dynamic Programming and Markov Processes, is credited for initiating a core body of study on Markov decision processes. They have applications in a wide variety of fields, including as robotics, automatic control, economics, and manufacturing, among others. Because Markov decision processes are an extension of Markov chains, the Russian mathematician Andrey Markov is where the term Markov decision processes (MDPs) originated. How You Will Benefit (I) Insights, and validations about the following topics: Chapter 1: Markov decision process Chapter 2: Markov chain Chapter 3: Reinforcement learning Chapter 4: Bellman equation Chapter 5: Admissible decision rule Chapter 6: Partially observable Markov decision process Chapter 7: Temporal difference learning Chapter 8: Multi-armed bandit Chapter 9: Optimal stopping Chapter 10: Metropolis-Hastings algorithm (II) Answering the public top questions about markov decision process. (III) Real world examples for the usage of markov decision process in many fields. (IV) 17 appendices to explain, briefly, 266 emerging technologies in each industry to have 360-degree full understanding of markov decision process' technologies. Who This Book Is For Professionals, undergraduate and graduate students, enthusiasts, hobbyists, and those who want to go beyond basic knowledge or information for any kind of markov decision process. What is Artificial Intelligence Series The artificial intelligence book series provides comprehensive coverage in over 200 topics. Each ebook covers a specific Artificial Intelligence topic in depth, written by experts in the field. The series aims to give readers a thorough understanding of the concepts, techniques, history and applications of artificial intelligence. Topics covered include machine learning, deep learning, neural networks, computer vision, natural language processing, robotics, ethics and more. The ebooks are written for professionals, students, and anyone interested in learning about the latest developments in this rapidly advancing field.
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**Selected Topics on Continuous-time Controlled Markov Chains and Markov Games** Tomás Prieto-Rumeau, Onésimo Hernández-Lerma, 2012

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.

**Examples in Markov Decision Processes** A. B. Piunovskiy, 2013

This invaluable book provides approximately eighty examples illustrating the theory of controlled discrete-time Markov processes. Except for applications of the theory to real-life problems like stock exchange, queues, gambling, optimal search etc., the main attention is paid to counter-intuitive, unexpected properties of optimization problems. Such examples illustrate the importance of conditions imposed in the theorems on Markov Decision Processes. Many of the examples are based upon examples published earlier in journal articles or textbooks while several other examples are new. The aim was to collect them together in one reference book which should be considered as a complement to existing monographs on Markov decision processes. The book is self-contained and unified in presentation. The main theoretical statements and constructions are provided, and particular examples can be read independently of others. Examples in Markov Decision Processes is an essential source of reference for mathematicians and all those who apply the optimal control theory to practical purposes. When studying or using mathematical methods, the researcher must understand what can happen if some of the conditions imposed in rigorous theorems are not satisfied. Many examples confirming the importance of such conditions were published in different journal articles which are often difficult
to find. This book brings together examples based upon such sources, along with several new ones. In addition, it indicates the areas where Markov decision processes can be used. Active researchers can refer to this book on applicability of mathematical methods and theorems. It is also suitable reading for graduate and research students where they will better understand the theory.

**Continuous Time Markov Processes** Thomas Milton Liggett, 2010 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.

**Semi-Markov Processes: Applications in System Reliability and Maintenance** Franciszek Grabski, 2014-09-25 Semi-Markov Processes: Applications in System Reliability and Maintenance is a modern view of discrete state space and continuous time semi-Markov processes and their applications in reliability and maintenance. The book explains how to construct semi-Markov models and discusses the different reliability parameters and characteristics that can be obtained from those models. The book is a useful resource for mathematicians, engineering practitioners, and PhD and MSc students who want to understand the basic concepts and results of semi-Markov process theory. Clearly defines the properties and theorems from discrete state Semi-Markov Process (SMP) theory. Describes the method behind constructing Semi-Markov (SM) models and SM decision models in the field of reliability and maintenance. Provides numerous individual versions of SM models, including the most recent and their impact on system reliability and maintenance.

**Handbook of Markov Decision Processes** Eugene A. Feinberg, Adam Shwartz, 2012-12-06 Eugene A. Feinberg Adam Shwartz This volume deals with the theory of Markov Decision Processes (MDPs) and their applications. Each chapter was written by a leading expert in the respective area. The papers cover major research areas and methodologies, and discuss open questions and future research directions. The papers can be read independently, with the basic notation and concepts of Section 1.2. Most chapters should be accessible by graduate or advanced undergraduate students in fields of operations research, electrical engineering, and computer science. 1.1 AN OVERVIEW OF MARKOV DECISION PROCESSES The theory of Markov Decision Processes-also known under several other names including sequential stochastic optimization, discrete-time stochastic control, and stochastic dynamic programming-studies sequential optimization of discrete time stochastic systems. The basic object is a discrete-time stochastic system whose transition mechanism can be controlled over time. Each control policy defines the stochastic process and values of objective functions associated with this process. The goal is to select a good control policy. In real life, decisions that humans and computers make on all levels usually have two types of impacts: (i) they cost or save time, money, or other resources, or they bring revenues, as well as (ii) they have an impact on the future, by influencing the dynamics. In many situations, decisions with the largest immediate profit may not be good in view of future events. MDPs model this paradigm and provide results on the structure and existence of good policies and on
methods for their calculation.

**Markov Decision Processes** Martin L. Puterman, 2014-08-28

The Wiley-Interscience Paperback Series consists of selected books that have been made more accessible to consumers in an effort to increase global appeal and general circulation. With these new unabridged softcover volumes, Wiley hopes to extend the lives of these works by making them available to future generations of statisticians, mathematicians, and scientists. This text is unique in bringing together so many results that have been found only in part in other texts and papers. . . . The text is fairly self-contained, inclusive of some basic mathematical results needed, and provides a rich diet of examples, applications, and exercises. The bibliographical material at the end of each chapter is excellent, not only from a historical perspective, but because it is valuable for researchers in acquiring a good perspective of the MDP research potential. —*Zentralblatt für Mathematik* . . . it is of great value to advanced-level students, researchers, and professional practitioners of this field to have now a complete volume (with more than 600 pages) devoted to this topic. . . . Markov Decision Processes: Discrete Stochastic Dynamic Programming represents an up-to-date, unified, and rigorous treatment of theoretical and computational aspects of discrete-time Markov decision processes. —*Journal of the American Statistical Association*

**Stochastic Optimization in Continuous Time** Fwu-Ranq Chang, 2004-04-26

First published in 2004, this is a rigorous but user-friendly book on the application of stochastic control theory to economics. A distinctive feature of the book is that mathematical concepts are introduced in a language and terminology familiar to graduate students of economics. The standard topics of many mathematics, economics, and finance books are illustrated with real examples documented in the economic literature. Moreover, the book emphasises the dos and don'ts of stochastic calculus, cautioning the reader that certain results and intuitions cherished by many economists do not extend to stochastic models. A special chapter (Chapter 5) is devoted to exploring various methods of finding a closed-form representation of the value function of a stochastic control problem, which is essential for ascertaining the optimal policy functions. The book also includes many practice exercises for the reader. Notes and suggested readings are provided at the end of each chapter for more references and possible extensions.

**Optimization, Control, and Applications of Stochastic Systems** Daniel Hernández-Hernández, J. Adolfo Minjárez-Sosa, 2012-08-15

This volume provides a general overview of discrete- and continuous-time Markov control processes and stochastic games, along with a look at the range of applications of stochastic control and some of its recent theoretical developments. These topics include various aspects of dynamic programming, approximation algorithms, and infinite-dimensional linear programming. In all, the work comprises 18 carefully selected papers written by experts in their respective fields. Optimization, Control, and Applications of Stochastic Systems will be a valuable resource for all practitioners, researchers, and professionals in applied mathematics and operations research who work in the areas of
stochastic control, mathematical finance, queueing theory, and inventory systems. It may also serve as a supplemental text for graduate courses in optimal control and dynamic games.

*Partially Observed Markov Decision Processes* Vikram Krishnamurthy, 2016-03-21 This book covers formulation, algorithms, and structural results of partially observed Markov decision processes, whilst linking theory to real-world applications in controlled sensing. Computations are kept to a minimum, enabling students and researchers in engineering, operations research, and economics to understand the methods and determine the structure of their optimal solution.

*Markov Decision Processes in Practice* Richard J. Boucherie, Nico M. van Dijk, 2017-03-10 This book presents classical Markov Decision Processes (MDP) for real-life applications and optimization. MDP allows users to develop and formally support approximate and simple decision rules, and this book showcases state-of-the-art applications in which MDP was key to the solution approach. The book is divided into six parts. Part 1 is devoted to the state-of-the-art theoretical foundation of MDP, including approximate methods such as policy improvement, successive approximation and infinite state spaces as well as an instructive chapter on Approximate Dynamic Programming. It then continues with five parts of specific and non-exhaustive application areas. Part 2 covers MDP healthcare applications, which includes different screening procedures, appointment scheduling, ambulance scheduling and blood management. Part 3 explores MDP modeling within transportation. This ranges from public to private transportation, from airports and traffic lights to car parking or charging your electric car. Part 4 contains three chapters that illustrates the structure of approximate policies for production or manufacturing structures. In Part 5, communications is highlighted as an important application area for MDP. It includes Gittins indices, down-to-earth call centers and wireless sensor networks. Finally Part 6 is dedicated to financial modeling, offering an instructive review to account for financial portfolios and derivatives under proportional transactional costs. The MDP applications in this book illustrate a variety of both standard and non-standard aspects of MDP modeling and its practical use. This book should appeal to readers for practitioners, academic research and educational purposes, with a background in, among others, operations research, mathematics, computer science, and industrial engineering.

*Further Topics on Discrete-Time Markov Control Processes* Onesimo Hernandez-Lerma, Jean B. Lasserre, 2012-12-06 Devoted to a systematic exposition of some recent developments in the theory of discrete-time Markov control processes, the text is mainly confined to MCPs with Borel state and control spaces. Although the book follows on from the author's earlier work, an important feature of this volume is that it is self-contained and can thus be read independently of the first. The control model studied is sufficiently general to include virtually all the usual discrete-time stochastic control models that appear in applications to engineering, economics, mathematical population processes, operations research, and management science.
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