

Continuous Time Stochastic Control And Optimization With Financial Applications Stochastic Modelling And Applied Probability

"This volume is a textbook on linear control systems with an emphasis on stochastic optimal control with solution methods using spectral factorization in line with the original approach of N. Wiener. Continuous-time and discrete-time versions are presented in parallel.... Two appendices introduce functional analytic concepts and probability theory, and there are 77 references and an index. The chapters (except for the last two) end with problems.... [T]he book presents in a clear way important concepts of control theory and can be used for teaching." —Zentralblatt Math "This is a textbook intended for use in courses on linear control and filtering and estimation on (advanced) levels. Its major purpose is an introduction to both deterministic and stochastic control and estimation. Topics are treated in both continuous time and discrete time versions.... Each chapter involves problems and exercises, and the book is supplemented by appendices, where fundamentals on Hilbert and Banach spaces, operator theory, and measure theoretic probability may be found. The book will be very useful for students, but also for a variety of specialists interested in deterministic and stochastic control and filtering." —Applications of Mathematics "The strength of the book under review lies in the choice of specialized topics it contains, which may not be found in this form elsewhere. Also, the first half would make a good standard course in linear control." —Journal of the Indian Institute of Science

This volume collects papers, based on invited talks given at the IMA workshop in Modeling, Stochastic Control, Optimization, and Related Applications, held at the Institute for Mathematics and Its Applications, University of Minnesota, during May and June, 2018. There were four week-long workshops during the conference. They are (1) stochastic control, computation methods, and applications, (2) queueing theory and networked systems, (3) ecological and biological applications, and (4) finance and economics applications. For broader impacts, researchers from different fields covering both theoretically oriented and application intensive areas were invited to participate in the conference. It brought together researchers from multi-disciplinary communities in applied mathematics, applied probability, engineering, biology, ecology, and networked science, to review, and substantially update most recent progress. As an archive, this volume presents some of the highlights of the workshops, and collect papers covering a broad range of topics.

The problem of stochastic control of partially observable systems plays an important role in many applications. All real problems are in fact of this type, and deterministic control as well as stochastic control with full observation can only be approximations to the real world. This justifies the importance of having a theory as complete as possible, which can be used for numerical implementation. This book first presents those problems under the linear theory that may be dealt with algebraically. Later chapters discuss the nonlinear filtering theory, in which the statistics are infinite dimensional and thus, approximations and perturbation methods are developed.

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.

Yet again, here is a Springer volume that offers readers something completely new. Until now, solved examples of the application of stochastic control to actuarial problems could only be found in journals. Not any more: this is the first book to systematically present these methods in one volume. The author starts with a short introduction to stochastic control techniques, then applies the principles to several problems. These examples show how verification theorems and existence theorems may be proved, and that the non-diffusion case is simpler than the diffusion case. Schmidli's brilliant text also includes a number of appendices, a vital resource for those in both academic and professional settings.

A path-breaking account of Markov decision processes-theory and computation This book's clear presentation of theory, numerous chapter-end problems, and development of a unified method for the computation of optimal policies in both discrete and continuous time make it an excellent course text for graduate students and advanced undergraduates. Its comprehensive coverage of important recent advances in stochastic dynamic programming makes it a valuable working resource for operations research professionals, management scientists, engineers, and others. Stochastic Dynamic Programming and the Control of Queueing Systems presents the theory of optimization under the finite horizon, infinite horizon discounted, and average cost criteria. It then shows how optimal rules of operation (policies) for each criterion may be numerically determined. A great wealth of examples from the application area of the control of queueing systems is presented. Nine numerical programs for the computation of optimal policies are fully explicated. The Pascal source code for the programs is available for viewing and downloading on the Wiley Web site at www.wiley.com/products/subject/mathematics. The site contains a link to the author's own Web site and is also a place where readers may discuss developments on the programs or other aspects of the material. The source files are also available via ftp at ftp://ftp.wiley.com/public/sci_tech_med/stochastic Stochastic Dynamic Programming and the Control of Queueing Systems features: * Path-breaking advances in Markov decision process techniques, brought together for the first time in book form * A theorem/proof format (proofs may be omitted without loss of continuity) * Development of a unified method for the computation of optimal rules of system operation * Numerous examples drawn mainly from the control of queueing systems * Detailed discussions of nine numerical programs * Helpful chapter-end problems * Appendices with complete treatment of background material

Since its origins in the 1940s, the subject of decision making under uncertainty has grown into a diversified area with application in several branches of engineering and in those areas of the social sciences concerned with policy analysis and prescription. These approaches required a computing capacity too expensive for the time, until the ability to collect and process huge quantities of data engendered an explosion of work in the area. This book provides succinct and rigorous treatment of the foundations of stochastic control; a unified approach to filtering, estimation, prediction, and stochastic and adaptive control; and the conceptual

framework necessary to understand current trends in stochastic control, data mining, machine learning, and robotics.

The focus of the present volume is stochastic optimization of dynamical systems in discrete time where - by concentrating on the role of information regarding optimization problems - it discusses the related discretization issues. There is a growing need to tackle uncertainty in applications of optimization. For example the massive introduction of renewable energies in power systems challenges traditional ways to manage them. This book lays out basic and advanced tools to handle and numerically solve such problems and thereby is building a bridge between Stochastic Programming and Stochastic Control. It is intended for graduates readers and scholars in optimization or stochastic control, as well as engineers with a background in applied mathematics.

This accessible introduction to the mathematical underpinnings of finance concentrates on the probabilistic theory of continuous arbitrage pricing of financial derivatives. It includes a solved example for every new technique presented, numerous exercises, and a Further Reading list in each chapter.

This book is an introduction to optimal stochastic control for continuous time Markov processes and the theory of viscosity solutions. It covers dynamic programming for deterministic optimal control problems, as well as to the corresponding theory of viscosity solutions. New chapters in this second edition introduce the role of stochastic optimal control in portfolio optimization and in pricing derivatives in incomplete markets and two-controller, zero-sum differential games.

Exploration of stochastic control theory in terms of analysis, parametric optimization, and optimal stochastic control. Limited to linear systems with quadratic criteria; covers discrete time and continuous time systems. 1970 edition.

This monograph applies the relative optimization approach to time nonhomogeneous continuous-time and continuous-state dynamic systems. The approach is intuitively clear and does not require deep knowledge of the mathematics of partial differential equations. The topics covered have the following distinguishing features: long-run average with no under-selectivity, non-smooth value functions with no viscosity solutions, diffusion processes with degenerate points, multi-class optimization with state classification, and optimization with no dynamic programming. The book begins with an introduction to relative optimization, including a comparison with the traditional approach of dynamic programming. The text then studies the Markov process, focusing on infinite-horizon optimization problems, and moves on to discuss optimal control of diffusion processes with semi-smooth value functions and degenerate points, and optimization of multi-dimensional diffusion processes. The book concludes with a brief overview of performance derivative-based optimization. Among the more important novel considerations presented are: the extension of the Hamilton–Jacobi–Bellman optimality condition from smooth to semi-smooth value functions by derivation of explicit optimality conditions at semi-smooth points and application of this result to degenerate and reflected processes; proof of semi-smoothness of the value function at degenerate points; attention to the under-selectivity issue for the long-run average and bias optimality; discussion of state classification for time nonhomogeneous continuous processes and multi-class optimization; and development of the multi-dimensional Tanaka formula for semi-smooth functions and application of this formula to stochastic control of multi-dimensional systems with degenerate points. The book will be of interest to researchers and students in the field of stochastic control and performance optimization alike.

More than a decade ago, world-renowned control systems authority Frank L. Lewis introduced what would become a standard textbook on estimation, under the title *Optimal Estimation*, used in top universities throughout the world. The time has come for a new edition of this classic text, and Lewis enlisted the aid of two accomplished experts to bring the book completely up to date with the estimation methods driving today's high-performance systems. *A Classic Revisited Optimal and Robust Estimation: With an Introduction to Stochastic Control Theory, Second Edition* reflects new developments in estimation theory and design techniques. As the title suggests, the major feature of this edition is the inclusion of robust methods. Three new chapters cover the robust Kalman filter, H-infinity filtering, and H-infinity filtering of discrete-time systems. *Modern Tools for Tomorrow's Engineers* This text overflows with examples that highlight practical applications of the theory and concepts. Design algorithms appear conveniently in tables, allowing students quick reference, easy implementation into software, and intuitive comparisons for selecting the best algorithm for a given application. In addition, downloadable MATLAB® code allows students to gain hands-on experience with industry-standard software tools for a wide variety of applications. This cutting-edge and highly interactive text makes teaching, and learning, estimation methods easier and more modern than ever.

World leading experts give their accounts of the modern mathematical models in the field: Markov Decision Processes, controlled diffusions, piece-wise deterministic processes etc, with a wide range of performance functionals. One of the aims is to give a general view on the state-of-the-art. The authors use Dynamic Programming, Convex Analytic Approach, several numerical methods, index-based approach and so on. Most chapters either contain well developed examples, or are entirely devoted to the application of the mathematical control theory to real life problems from such fields as Insurance, Portfolio Optimization and Information Transmission. The book will enable researchers, academics and research students to get a sense of novel results, concepts, models, methods, and applications of controlled stochastic processes.

In recent years there has been a significant increase of interest in continuous-time Principal-Agent models, or contract theory, and their applications. Continuous-time models provide a powerful and elegant framework for solving stochastic optimization problems of finding the optimal contracts between two parties, under various assumptions on the information they have access to, and the effect they have on the underlying "profit/loss" values. This monograph surveys recent results of the theory in a systematic way, using the approach of the so-called Stochastic Maximum Principle, in models driven by Brownian Motion. Optimal contracts are characterized via a system of Forward-Backward Stochastic Differential Equations. In a number of interesting special cases these can be solved explicitly, enabling derivation of many qualitative economic conclusions.

Stochastic optimization problems arise in decision-making problems under uncertainty, and find various applications in economics and finance. On the other hand, problems in finance have recently led to new developments in the theory of stochastic control. This volume provides a systematic treatment of stochastic optimization problems applied to finance by presenting the different existing methods: dynamic programming, viscosity solutions, backward stochastic differential equations, and martingale duality methods. The theory is discussed in the context of recent developments in this field, with complete and detailed proofs, and is illustrated by means of concrete examples from the world of finance: portfolio allocation, option hedging, real options, optimal investment, etc. This book is directed towards graduate students and researchers in mathematical finance, and will also benefit applied mathematicians interested in financial applications and practitioners wishing to know more about the use of stochastic optimization methods in finance.

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.

Stochastic control theory is a relatively young branch of mathematics. The beginning of its intensive development falls in the late 1950s and early 1960s. ~urin~ that period an extensive literature appeared on optimal stochastic control using the quadratic performance criterion (see references in Wonham [76]). At the same time, Girsanov [25] and Howard [26] made the first steps in constructing a general theory, based on Bellman's technique of dynamic programming, developed by him somewhat earlier [4]. Two types of engineering problems engendered two different parts of stochastic control theory. Problems of the first type are associated with multistep decision making in discrete time, and are treated in the theory of discrete stochastic dynamic programming. For more on this theory, we note in addition to the work of Howard and Bellman, mentioned above, the books by Derman [8], Mine and Osaki [55], and Dynkin and Yushkevich [12]. Another class of engineering problems which encouraged the development of the theory of stochastic control involves time continuous control of a dynamic system in the presence of random noise. The case where the system is described by a differential equation and the noise is modeled as a time continuous random process is the core of the optimal control theory of diffusion processes. This book deals with this latter theory.

This book offers a systematic introduction to the optimal stochastic control theory via the dynamic programming principle, which is a powerful tool to analyze control problems. First we consider completely observable control problems with finite horizons. Using a time discretization we construct a nonlinear semigroup related to the dynamic programming principle (DPP), whose generator provides the Hamilton–Jacobi–Bellman (HJB) equation, and we characterize the value function via the nonlinear semigroup, besides the viscosity solution theory. When we control not only the dynamics of a system but also the terminal time of its evolution, control-stopping problems arise. This problem is treated in the same frameworks, via the nonlinear semigroup. Its results are applicable to the American option price problem. Zero-sum two-player time-homogeneous stochastic differential games and viscosity solutions of the Isaacs equations arising from such games are studied via a nonlinear semigroup related to DPP (the min-max principle, to be precise). Using semi-discretization arguments, we construct the nonlinear semigroups whose generators provide lower and upper Isaacs equations. Concerning partially observable control problems, we refer to stochastic parabolic equations driven by colored Wiener noises, in particular, the Zakai equation. The existence and uniqueness of solutions and regularities as well as Itô's formula are stated. A control problem for the Zakai equations has a nonlinear semigroup whose generator provides the HJB equation on a Banach space. The value function turns out to be a unique viscosity solution for the HJB equation under mild conditions. This edition provides a more generalized treatment of the topic than does the earlier book *Lectures on Stochastic Control Theory* (ISI Lecture Notes 9), where time-homogeneous cases are dealt with. Here, for finite time-horizon control problems, DPP was formulated as a one-parameter nonlinear semigroup, whose generator provides the HJB equation, by using a time-discretization method. The semigroup corresponds to the value function and is characterized as the envelope of Markovian transition semigroups of responses for constant control processes. Besides finite time-horizon controls, the book discusses control-stopping problems in the same frameworks.

Providing an introduction to stochastic optimal control in infinite dimension, this book gives a complete account of the theory of second-order HJB equations in infinite-dimensional Hilbert spaces, focusing on its applicability to associated stochastic optimal control problems. It features a general introduction to optimal stochastic control, including basic results (e.g. the dynamic programming principle) with proofs, and provides examples of applications. A complete and up-to-date exposition of the existing theory of viscosity solutions and regular solutions of second-order HJB equations in Hilbert spaces is given, together with an extensive survey of other methods, with a full bibliography. In particular, Chapter 6, written by M. Fuhrman and G. Tessitore, surveys the theory of regular solutions of HJB equations arising in infinite-dimensional stochastic control, via BSDEs. The book is of interest to both pure and applied researchers working in the control theory of stochastic PDEs, and in PDEs in infinite dimension. Readers from other fields who want to learn the basic theory will also find it useful. The prerequisites are: standard functional analysis, the theory of semigroups of operators and its use in the study of PDEs, some knowledge of the dynamic programming approach to stochastic optimal control problems in finite dimension, and the basics of stochastic analysis and stochastic equations in infinite-dimensional spaces.

Linear Stochastic Control Systems presents a thorough description of the mathematical theory and fundamental principles of linear stochastic control systems. Both continuous-time and discrete-time systems are thoroughly covered. Reviews of the modern probability and random processes theories and the Itô stochastic differential equations are provided. Discrete-time stochastic systems theory, optimal estimation and Kalman filtering, and optimal stochastic control theory are studied in detail. A modern treatment of these same topics for continuous-time stochastic control systems is included. The text is written in an easy-to-understand style, and the reader needs only to have a background of elementary real analysis and linear deterministic systems theory to comprehend the subject matter. This graduate textbook is also suitable for self-study, professional training, and as a handy research reference. *Linear Stochastic Control Systems* is self-contained and provides a step-by-step development of the theory, with many illustrative

examples, exercises, and engineering applications.

This book contains an introduction to three topics in stochastic control: discrete time stochastic control, i. e. , stochastic dynamic programming (Chapter 1), piecewise - deterministic control problems (Chapter 3), and control of Ito diffusions (Chapter 4). The chapters include treatments of optimal stopping problems. An Appendix - calls material from elementary probability theory and gives heuristic explanations of certain more advanced tools in probability theory. The book will hopefully be of interest to students in several fields: economics, engineering, operations research, finance, business, mathematics. In economics and business administration, graduate students should readily be able to read it, and the mathematical level can be suitable for advanced undergraduates in mathematics and science. The prerequisites for reading the book are only a calculus course and a course in elementary probability. (Certain technical comments may demand a slightly better background.) As this book perhaps (and hopefully) will be read by readers with widely differing backgrounds, some general advice may be useful: Don't be put off if paragraphs, comments, or remarks contain material of a seemingly more technical nature that you don't understand. Just skip such material and continue reading, it will surely not be needed in order to understand the main ideas and results. The presentation avoids the use of measure theory.

The goal of this textbook is to introduce students to the stochastic analysis tools that play an increasing role in the probabilistic approach to optimization problems, including stochastic control and stochastic differential games. While optimal control is taught in many graduate programs in applied mathematics and operations research, the author was intrigued by the lack of coverage of the theory of stochastic differential games. This is the first title in SIAM's Financial Mathematics book series and is based on the author's lecture notes. It will be helpful to students who are interested in stochastic differential equations (forward, backward, forward-backward); the probabilistic approach to stochastic control (dynamic programming and the stochastic maximum principle); and mean field games and control of McKean-Vlasov dynamics. The theory is illustrated by applications to models of systemic risk, macroeconomic growth, flocking/schooling, crowd behavior, and predatory trading, among others.

Continuous-time Stochastic Control and Optimization with Financial Applications Springer Science & Business Media
The book presents a comprehensive development of effective numerical methods for stochastic control problems in continuous time. The process models are diffusions, jump-diffusions or reflected diffusions of the type that occur in the majority of current applications. All the usual problem formulations are included, as well as those of more recent interest such as ergodic control, singular control and the types of reflected diffusions used as models of queuing networks. Convergence of the numerical approximations is proved via the efficient probabilistic methods of weak convergence theory. The methods also apply to the calculation of functionals of uncontrolled processes and for the appropriate to optimal nonlinear filters as well. Applications to complex deterministic problems are illustrated via application to a large class of problems from the calculus of variations. The general approach is known as the Markov Chain Approximation Method. Essentially all that is required of the approximations are some natural local consistency conditions. The approximations are consistent with standard methods of numerical analysis. The required background in stochastic processes is surveyed, there is an extensive development of methods of approximation, and a chapter is devoted to computational techniques. The book is written on two levels, that of practice (algorithms and applications), and that of the mathematical development. Thus the methods and use should be broadly accessible.

Praise for Previous Volumes "This book will be a useful reference to control engineers and researchers. The papers contained cover well the recent advances in the field of modern control theory." -IEEE GROUP CORRESPONDANCE
"This book will help all those researchers who valiantly try to keep abreast of what is new in the theory and practice of optimal control." -CONTROL

The focus of the book is the construction of optimal investment strategies in a security market model where the prices follow diffusion processes. It begins by presenting the complete Black-Scholes type model and then moves on to incomplete models and models including constraints and transaction costs. The models and methods presented will include the stochastic control method of Merton, the martingale method of Cox-Huang and Karatzas et al., the log optimal method of Cover and Jamshidian, the value-preserving model of Hellwig etc. Stress is laid on rigorous mathematical presentation and clear economic interpretations while technicalities are kept to the minimum. The underlying mathematical concepts will be provided. No a priori knowledge of stochastic calculus, stochastic control or partial differential equations is necessary (however some knowledge in stochastics and calculus is needed).

Contents: Introduction and Discrete-Time Models The Continuous-Time Market Model The Continuous-Time Portfolio Problem Constrained Continuous-Time Problems Portfolio Optimisation in the Presence of Transaction Costs Non-Utility Based Portfolio Selection Models Appendix Readership: Professionals in the financial industry, economists, mathematicians, physicians and students in stochastic processes. keywords: "This book provides not only a survey of the continuous-time portfolio selection theory, but also can be recommended to those who want to obtain a quick overview about methods of portfolio theory. Because of its friendly and inviting style, parts of this book are also suitable as a first introduction to this theory for those not familiar with stochastic analysis." Metrika

Advanced Topics in Control and Estimation of State-Multiplicative Noisy Systems begins with an introduction and extensive literature survey. The text proceeds to cover the field of H_2 time-delay linear systems where the issues of stability and L_2 -gain are presented and solved for nominal and uncertain stochastic systems, via the input-output approach. It presents solutions to the problems of state-feedback, filtering, and measurement-feedback control for these systems, for both the continuous- and the discrete-time settings. In the continuous-time domain, the problems of reduced-order and preview tracking control are also presented and solved. The second part of the monograph concerns non-linear stochastic state- multiplicative systems and covers the issues of stability, control and estimation of the systems in

the H^2 sense, for both continuous-time and discrete-time cases. The book also describes special topics such as stochastic switched systems with dwell time and peak-to-peak filtering of nonlinear stochastic systems. The reader is introduced to six practical engineering-oriented examples of noisy state-multiplicative control and filtering problems for linear and nonlinear systems. The book is rounded out by a three-part appendix containing stochastic tools necessary for a proper appreciation of the text: a basic introduction to stochastic control processes, aspects of linear matrix inequality optimization, and MATLAB codes for solving the L_2 -gain and state-feedback control problems of stochastic switched systems with dwell-time. *Advanced Topics in Control and Estimation of State-Multiplicative Noisy Systems* will be of interest to engineers engaged in control systems research and development, to graduate students specializing in stochastic control theory, and to applied mathematicians interested in control problems. The reader is expected to have some acquaintance with stochastic control theory and state-space-based optimal control theory and methods for linear and nonlinear systems.

This book collects some recent developments in stochastic control theory with applications to financial mathematics. We first address standard stochastic control problems from the viewpoint of the recently developed weak dynamic programming principle. A special emphasis is put on the regularity issues and, in particular, on the behavior of the value function near the boundary. We then provide a quick review of the main tools from viscosity solutions which allow to overcome all regularity problems. We next address the class of stochastic target problems which extends in a nontrivial way the standard stochastic control problems. Here the theory of viscosity solutions plays a crucial role in the derivation of the dynamic programming equation as the infinitesimal counterpart of the corresponding geometric dynamic programming equation. The various developments of this theory have been stimulated by applications in finance and by relevant connections with geometric flows. Namely, the second order extension was motivated by illiquidity modeling, and the controlled loss version was introduced following the problem of quantile hedging. The third part specializes to an overview of Backward stochastic differential equations, and their extensions to the quadratic case.?

The authors provide a comprehensive treatment of stochastic systems from the foundations of probability to stochastic optimal control. The book covers discrete- and continuous-time stochastic dynamic systems leading to the derivation of the Kalman filter, its properties, and its relation to the frequency domain Wiener filter as well as the dynamic programming derivation of the linear quadratic Gaussian (LQG) and the linear exponential Gaussian (LEG) controllers and their relation to H_2 and H_∞ controllers and system robustness. This book is suitable for first-year graduate students in electrical, mechanical, chemical, and aerospace engineering specializing in systems and control. Students in computer science, economics, and possibly business will also find it useful.

As is well known, Pontryagin's maximum principle and Bellman's dynamic programming are the two principal and most commonly used approaches in solving stochastic optimal control problems. * An interesting phenomenon one can observe from the literature is that these two approaches have been developed separately and independently. Since both methods are used to investigate the same problems, a natural question one will ask is the following: (Q) What is the relationship between the maximum principle and dynamic programming in stochastic optimal controls? There did exist some researches (prior to the 1980s) on the relationship between these two. Nevertheless, the results usually were stated in heuristic terms and proved under rather restrictive assumptions, which were not satisfied in most cases. In the statement of a Pontryagin-type maximum principle there is an adjoint equation, which is an ordinary differential equation (ODE) in the (finite-dimensional) deterministic case and a stochastic differential equation (SDE) in the stochastic case. The system consisting of the adjoint equation, the original state equation, and the maximum condition is referred to as an (extended) Hamiltonian system. On the other hand, in Bellman's dynamic programming, there is a partial differential equation (PDE), of first order in the (finite-dimensional) deterministic case and of second order in the stochastic case. This is known as a Hamilton-Jacobi-Bellman (HJB) equation.

This book presents the texts of seminars presented during the years 1995 and 1996 at the Université Paris VI and is the first attempt to present a survey on this subject. Starting from the classical conditions for existence and unicity of a solution in the most simple case-which requires more than basic stochastic calculus-several refinements on the hypotheses are introduced to obtain more general results.

This unified treatment of linear and nonlinear filtering theory presents material previously available only in journals, and in terms accessible to engineering students. Its sole prerequisites are advanced calculus, the theory of ordinary differential equations, and matrix analysis. Although theory is emphasized, the text discusses numerous practical applications as well. Taking the state-space approach to filtering, this text models dynamical systems by finite-dimensional Markov processes, outputs of stochastic difference, and differential equations. Starting with background material on probability theory and stochastic processes, the author introduces and defines the problems of filtering, prediction, and smoothing. He presents the mathematical solutions to nonlinear filtering problems, and he specializes the nonlinear theory to linear problems. The final chapters deal with applications, addressing the development of approximate nonlinear filters, and presenting a critical analysis of their performance.

Stochastic control is a very active area of research. This monograph, written by two leading authorities in the field, has been updated to reflect the latest developments. It covers effective numerical methods for stochastic control problems in continuous time on two levels, that of practice and that of mathematical development. It is broadly accessible for graduate students and researchers.

This book may be regarded as consisting of two parts. In Chapters I-IV we present what we regard as essential topics in an introduction to deterministic optimal control theory. This material has been used by the authors for one semester graduate-level courses at Brown University and the University of Kentucky. The simplest problem in calculus of variations is taken as the point of departure, in Chapter I. Chapters II, III, and IV deal with necessary conditions for an optimum, existence and regularity theorems for optimal controls, and the method of dynamic programming. The beginning reader may find it useful first to learn the main results, corollaries, and examples. These tend to be found in the earlier parts of each chapter. We have deliberately postponed some difficult technical proofs to later parts of these chapters. In the second part of the book we give an introduction to stochastic optimal control for Markov diffusion processes. Our treatment follows the dynamic programming method, and depends on the intimate relationship between second order partial differential equations of parabolic type and stochastic differential equations. This relationship is reviewed in Chapter V, which may be read independently of Chapters I-IV. Chapter VI is

based to a considerable extent on the authors' work in stochastic control since 1961. It also includes two other topics important for applications, namely, the solution to the stochastic linear regulator and the separation principle.

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.

This book is concerned with numerical methods for stochastic control and optimal stochastic control problems. The random process models of the controlled or uncontrolled stochastic systems are either diffusions or jump diffusions. Stochastic control is a very active area of research and new problem formulations and sometimes surprising applications appear regularly. We have chosen forms of the models which cover the great bulk of the formulations of the continuous time stochastic control problems which have appeared to date. The standard formats are covered, but much emphasis is given to the newer and less well known formulations. The controlled process might be either stopped or absorbed on leaving a constraint set or upon first hitting a target set, or it might be reflected or "projected" from the boundary of a constraining set. In some of the more recent applications of the reflecting boundary problem, for example the so-called heavy traffic approximation problems, the directions of reflection are actually discontinuous. In general, the control might be representable as a bounded function or it might be of the so-called impulsive or singular control types. Both the "drift" and the "variance" might be controlled. The cost functions might be any of the standard types: Discounted, stopped on first exit from a set, finite time, optimal stopping, average cost per unit time over the infinite time interval, and so forth.

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