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Optimal Control Via Nonsmooth Analysis Optimal Control by Mathematical Programming Optimal Control Optimal Control Theory Applied Optimal Control Dynamic Programming and Optimal Control Optimal Control Theory Practical Methods for Optimal Control Using Nonlinear Programming, Third Edition Optimal Control Robust Output LQ Optimal Control via Integral Sliding Modes Optimal Control of Dynamic Systems Driven by Vector Measures Optimal Control and Estimation Linear Systems and Optimal Control Optimal Control Optimal Control Optimal Control Systems Adaptive Optimal Control Via Reinforcement Learning Nonlinear and Optimal Control Systems Optimal Control Optimal Control Theory for Applications Adaptive Finite Element Methods Optimal Control Optimal Control Data-dependent System Optimal Control by Neural Networks Applied Optimal Control Data Dependent Systems Optimal Control Theory The Theory of Bounded Phase Optimal Control Via the Interior Penalty Method Adaptive Implementation of One-step-ahead Optimal Control Via Input Matching Introduction to Optimal Control Theory Reinforcement Learning and Optimal Control Stochastic Optimal Control Via Bellman's Principle Practical Methods for Optimal Control and Estimation Using Nonlinear Programming Optimal Control of Distributed Systems Approximate Methods of Optimal Control Via Dynamic Programming Models Optimal Control Stochastic Optimal Control in Infinite Dimension Applied and Computational Optimal Control Neural Approximations for Optimal Control and Decision

Designed for one-semester introductory senior-or graduate-level course, the authors provide the student with an introduction of analysis techniques used in the design of nonlinear and optimal feedback control systems. There is special emphasis on the fundamental topics of stability, controllability, and optimality, and on the corresponding geometry associated with these topics. Each chapter contains several examples and a variety of exercises. Geared toward advanced undergraduate and graduate engineering students, this text introduces the theory and applications of optimal control. It serves as a bridge to the technical literature, enabling students to evaluate the implications of theoretical control work, and to judge the merits of papers on the subject. Rather than presenting an exhaustive treatise, Optimal Control offers a detailed introduction that fosters careful thinking and disciplined intuition. It develops the basic mathematical background, with a coherent formulation of the control problem and discussions of the necessary conditions for optimality based on the maximum principle of Pontryagin. In-depth examinations cover applications of the theory to minimum time, minimum fuel, and to quadratic criteria problems. The structure, properties, and engineering realizations of several optimal feedback control systems also receive attention. Special features include numerous specific problems, carried through to engineering realization in block diagram form. The text treats almost all current examples of control problems that permit analytic solutions, and its unified approach makes frequent use of geometric ideas to encourage students' intuition. A focused presentation of how sparse optimization methods can be used to solve optimal control and estimation problems. This best-selling text focuses on the analysis and design of complicated dynamics systems. CHOICE called it “a high-level, concise book that could well be used as a reference by engineers, applied mathematicians, and undergraduates. The format is good, the presentation clear, the diagrams instructive, the examples and problems helpful...References and a multiple-choice examination are included.” Summary: "This book emphasizes the discussions of some unique issues from the adaptive finite element approximation of optimal control. The main idea used in the approximation error analysis (both a priori and a posteriori) is to first combine convex analysis and interpolation error estimations of suitable interpolators, which much depend on the structure of the control constraints, to derive the error estimates for the control via the variational inequalities in the optimality conditions, and then to apply the standard techniques to derive the error estimates for the state equations. The need, the framework and the techniques of using multi adaptive meshes in developing efficient numerical algorithms for optimal control have been emphasized throughout the book. The book starts from several typical examples of optimal control problems and then discusses existence and optimality conditions for some optimal control problems. It is believed that these discussions are especially useful for the researchers and students who first entered this area. Then the finite element approximation schemes for several typical optimal control problems are set up, their a priori and a posteriori error estimates are derived following the main idea mentioned, and their computational methods are studied."-- Publisher website, viewed 13th July, 2012. Neural Approximations for Optimal Control and Decision provides a comprehensive methodology for the approximate solution of functional optimization problems using neural networks and other nonlinear approximators where the use of traditional optimal control tools is prohibited by complicating factors like non-Gaussian noise, strong nonlinearities, large dimension of state and control vectors, etc. Features of the text include: • a general functional optimization framework; • thorough illustration of recent theoretical insights into the approximate solutions of complex functional optimization problems; • comparison of classical and neural-network based methods of approximate solution; • bounds to the errors of approximate solutions; • solution algorithms for optimal control and decision in deterministic or stochastic environments with perfect or imperfect state measurements over a finite or infinite time horizon and with one decision maker or several; • applications of current interest: routing in communications networks, traffic control, water resource management, etc.; and • numerous, numerically detailed examples. The authors’ diverse backgrounds in systems and control theory, approximation theory, machine learning, and operations research lend the book a range of expertise and subject matter appealing to academics and graduate students in any of those disciplines together with computer science and other areas of engineering. This paper presents a method for finding optimal controls of nonlinear systems subject to random excitations. The method is capable to generate global control solutions when state and control constraints are present. The solution is global in the sense that controls for all initial conditions in a region of the state space are obtained. The approach is based on Bellman's Principle of optimality, the Gaussian closure and the Short-time Gaussian approximation. Examples include a system with a state-dependent diffusion term, a system in which the infinite hierarchy of moment equations cannot be analytically closed, and an impact system with a elastic boundary. The uncontrolled and controlled dynamics are studied by creating a Markov chain with a control dependent transition probability matrix via the Generalized Cell Mapping method. In this fashion, both the transient and stationary controlled responses are evaluated. The results show excellent control performances.Crespo, Luis G. and Sun, Jian Q.Langley Research CenterOPTIMAL CONTROL; STOCHASTIC PROCESSES; NONLINEAR SYSTEMS; HAMILTON-JACOBI EQUATION; BELLMAN THEORY; NUMERICAL ANALYSIS; MARKOV CHAINS; TRANSITION PROBABILITIES; BOUNDARY CONDITIONS; NORMAL DENSITY FUNCTIONS; DIFFERENTIAL EQUATIONS Featuring original research from well-known experts in the field of sliding mode control, this book presents new design schemes for a useful and practical optimal control with very few impractical assumptions. The results presented allow optimal control theory to grow in its applicability to real-world systems. On the cutting-edge of optimal control research, this book is an excellent resource for both graduate students and researchers in engineering, mathematics, and optimal control. February 27 - March 1, 1997, the conference Optimal Control: The ory, Algorithms, and Applications took place at the University of Florida, hosted by the Center for Applied Optimization. The conference brought together researchers from universities, industry, and government laborato ries in the United States, Germany, Italy, France, Canada, and Sweden. There were forty-five invited talks, including seven talks by students. The conference was sponsored by the National Science Foundation and endorsed by the SIAM Activity Group on Control and Systems Theory, the Mathe matical Programming Society, the International Federation for Information Processing (IFIP), and the International Association for Mathematics and Computers in Simulation (IMACS). Since its inception in the 1940s and 1950s, Optimal Control has been closely connected to industrial applications, starting with aerospace. The program for the Gainesville conference, which reflected the rich cross-disci plinary flavor of the field, included aerospace applications as well as both novel and emerging applications to superconductors, diffractive optics, non linear optics, structural analysis, bioreactors, corrosion detection, acoustic flow, process design in chemical engineering, hydroelectric power plants, sterilization of canned foods, robotics, and thermoelastic plates and shells. The three days of the conference were organized around the three confer ence themes, theory, algorithms, and applications. This book is a collection of the papers presented at the Gainesville conference. We would like to take this opportunity to thank the sponsors and participants of the conference, the authors, the referees, and the publisher for making this volume possible. 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. This book provides a complete and unified treatment of deterministic problems of dynamic optimization, from the classical themes of the calculus of variations to the forefront of modern research in optimal control. At the heart of the presentation is nonsmooth analysis, a theory of local approximation developed over the last twenty years to provide useful first-order information about sets and functions lying beyond the reach of classical analysis. The book includes an intuitive and geometrically transparent approach to nonsmooth analysis, serving not only to introduce the basic ideas, but also to illuminate the calculations and derivations in the applied sections dealing with the calculus of variations and optimal control. Written in a lively, engaging style and stocked with numerous figures and practice problems, this book offers an ideal introduction to this vigorous field of current research. It is suitable as a graduate text for a one-semester course in optimal control or as a manual for self-study. Each chapter closes with a list of references to ease the reader's transition from active learner to contributing researcher. Numerous examples highlight this treatment of the use of linear quadratic Gaussian methods for control system design. It explores linear optimal control theory from an engineering viewpoint, with illustrations of practical applications. Key topics include loop-recovery techniques, frequency shaping, and controller reduction. Numerous examples and complete solutions. 1990 edition. Geared toward upper-level undergraduates, this text introduces three aspects of optimal control theory: dynamic programming, Pontryagin's minimum principle, and numerical techniques for trajectory optimization. Numerous problems, which introduce additional topics and illustrate basic concepts, appear throughout the text. Solution guide available upon request. 131 figures. 14 tables. 1970 edition. This book considers large and challenging multistage decision problems, which can be solved in principle by dynamic programming (DP), but their exact solution is computationally intractable. We discuss solution methods that rely on approximations to produce suboptimal policies with adequate performance. These methods are collectively known by several essentially equivalent names: reinforcement learning, approximate dynamic programming, neuro-dynamic programming. They have been at the forefront of research for the last 25 years, and they underlie, among others, the recent impressive successes of self-learning in the context of games such as chess and Go. Our subject has benefited greatly from the interplay of ideas from optimal control and from artificial intelligence, as it relates to reinforcement learning and simulation-based neural network methods. One of the aims of the book is to explore the common boundary between these two fields and to form a bridge that is accessible by workers with background in either field. Another aim is to organize coherently the broad mosaic of methods that have proved successful in practice while having a solid theoretical and/or logical foundation. This may help researchers and practitioners to find their way through the maze of competing ideas that constitute the current state of the art. This book relates to several of our other books: Neuro-Dynamic Programming (Athena Scientific, 1996), Dynamic Programming and Optimal Control (4th edition, Athena Scientific, 2017), Abstract Dynamic Programming (2nd edition, Athena Scientific, 2018), and Nonlinear Programming (Athena Scientific, 2016). However, the mathematical style of this book is somewhat different. While we provide a rigorous, albeit short, mathematical account of the theory of finite and infinite horizon dynamic programming, and some fundamental approximation methods, we rely more on intuitive explanations and less on proof-based insights. Moreover, our mathematical requirements are quite modest: calculus, a minimal use of matrix-vector algebra, and elementary probability (mathematically complicated arguments involving laws of large numbers and stochastic convergence are bypassed in favor of intuitive explanations). The book illustrates the methodology with many examples and illustrations, and uses a gradual expository approach, which proceeds along four directions: (a) From exact DP to approximate DP: We first discuss exact DP algorithms, explain why they may be difficult to implement, and then use them as the basis for approximations. (b) From finite horizon to infinite horizon problems: We first discuss finite horizon exact and approximate DP methodologies, which are intuitive and mathematically simple, and then progress to infinite horizon problems. (c) From deterministic to stochastic models: We often discuss separately deterministic and stochastic problems, since deterministic problems are simpler and offer special advantages for some of our methods. (d) From model-based to model-free implementations: We first discuss model-based implementations, and then we identify schemes that can be appropriately modified to work with a simulator. The book is related and supplemented by the companion research monograph Rollout, Policy Iteration, and Distributed Reinforcement Learning (Athena Scientific, 2020), which focuses more closely on several topics related to rollout, approximate policy iteration, multiagent problems, discrete and Bayesian optimization, and distributed computation, which are either discussed in less detail or not covered at all in the present book. The author's website contains class notes, and a series of videolectures and slides from a 2021 course at ASU, which address a selection of topics from both books. Upper-level undergraduate text introduces aspects of optimal control theory: dynamic programming, Pontryagin's minimum principle, and numerical techniques for trajectory optimization. Numerous figures, tables. Solution guide available upon request. 1970 edition. There is an ever-growing interest in control problems today, con nected with the urgent problems of the effective use of natural resources, manpower, materials, and technology. When referring to the most important achievements of science and technology in the 20th Century, one usually mentions the splitting of the atom, the exploration of space, and computer engineering. Achievements in control theory seem less spectacular when viewed against this background, but the applications of control theory are playing an important role in the development of modern civilization, and there is every reason to believe that this role will be even more signifi cant in the future. Wherever there is active human participation, the problem arises of finding the best, or optimal, means of control. The demands of economics and technology have given birth to optimization problems which, in turn, have created new branches of mathematics. In the Forties, the investigation of problems of economics gave rise to a new branch of mathematical analysis called linear and convex program ming. At that time, problems of controlling flying vehicles and technolog ical processes of complex structures became important. A mathematical theory was formulated in the mid-Fifties known as optimal control theory. Here the maximum principle of L. S. Pontryagin played a pivotal role. Op timal control theory synthesized the concepts and methods of investigation using the classical methods of the calculus of variations and the methods of contemporary mathematics, for which Soviet mathematicians made valuable contributions. This book focuses on how to implement optimal control problems via the variational method. It studies how to implement the extrema of functional by applying the variational method and covers the extrema of functional with different boundary conditions, involving multiple functions and with certain constraints etc. It gives the necessary and sufficient condition for the (continuous-time) optimal control solution via the variational method, solves the optimal control problems with different boundary conditions, analyzes the linear quadratic regulator & tracking problems respectively in detail, and provides the solution of optimal control problems with state constraints by applying the Pontryagin’s minimum principle which is developed based upon the calculus of variations. And the developed results are applied to implement several classes of popular optimal control problems and say minimum-time, minimum-fuel and minimum-energy problems and so on. As another key branch of optimal control methods, it also presents how to solve the optimal control problems via dynamic programming and discusses the relationship between the variational method and dynamic programming for comparison. Concerning the system involving individual agents, it is also worth to study how to implement the decentralized solution for the underlying optimal control problems in the framework of differential games. The equilibrium is implemented by applying both Pontryagin’s minimum principle and dynamic programming. The book also analyzes the discrete-time version for all the above materials as well since the discrete-time optimal control problems are very popular in many fields. The published material represents the outgrowth of teaching analytical optimization to aerospace engineering graduate students. To make the material available to the widest audience, the prerequisites are limited to calculus and differential equations. It is also a book about the mathematical aspects of optimal control theory. It was developed in an engineering environment from material learned by the author while applying it to the solution of engineering problems. One goal of the book is to help engineering graduate students learn the fundamentals which are needed to apply the methods to engineering problems. The examples are from geometry and elementary dynamical systems so that they can be understood by all engineering students. Another goal of this text is to unify optimization by using the differential of calculus to create the Taylor series expansions needed to derive the optimality conditions of optimal control theory. This book is devoted to the development of optimal control theory for finite dimensional systems governed by deterministic and stochastic differential equations driven by vector measures. The book deals with a broad class of controls, including regular controls (vector-valued measurable functions), relaxed controls (measure-valued functions) and controls determined by vector measures, where both fully and partially observed control problems are considered. In the past few decades, there have been remarkable advances in the field of systems and control theory thanks to the unprecedented interaction between mathematics and the physical and engineering sciences. Recently, optimal control theory for dynamic systems driven by vector measures has attracted increasing interest. This book presents this theory for dynamic systems governed by both ordinary and stochastic differential equations, including extensive results on the existence of optimal controls and necessary conditions for optimality. Computational algorithms are developed based on the optimality conditions, with numerical results presented to demonstrate the applicability of the theoretical results developed in the book. This book will be of interest to researchers in optimal control or applied functional analysis interested in applications of vector measures to control theory, stochastic systems driven by vector measures, and related topics. In particular, this self-contained account can be a starting point for further advances in the theory and applications of dynamic systems driven and controlled by vector measures. This best-selling text focuses on the analysis and design of complicated dynamics systems. CHOICE called it ""a high-level, concise book that could well be used as a reference by engineers, applied mathematicians, and undergraduates. The format is good, the presentation clear, the diagrams instructive, the examples and problems helpful...References and a multiple-choice examination are included. The theory of optimal control systems has grown and flourished since the 1960's. Many texts, written on varying levels of sophistication, have been published on the subject. Yet even those purportedly designed for beginners in the field are often riddled with complex theorems, and many treatments fail to include topics that are essential to a thorough grounding in the various aspects of and approaches to optimal control. Optimal Control Systems provides a comprehensive but accessible treatment of the subject with just the right degree of mathematical rigor to be complete but practical. It provides a solid bridge between "traditional" optimization using the calculus of variations and what is called "modern" optimal control. It also treats both continuous-time and discrete-time optimal control systems, giving students a firm grasp on both methods. Among this book's most outstanding features is a summary table that accompanies each topic or problem and includes a statement of the problem with a step-by-step solution. Students will also gain valuable experience in using industry-standard MATLAB and SIMULINK software, including the Control System and Symbolic Math Toolboxes. Diverse applications across fields from power engineering to medicine make a foundation in optimal control systems an essential part of an engineer's background. This clear, streamlined presentation is ideal for a graduate level course on control systems and as a quick reference for working engineers. This new, updated edition of Optimal Control reflects major changes that have occurred in the field in recent years and presents, in a clear and direct way, the fundamentals of optimal control theory. It covers the major topics involving measurement, principles of optimality, dynamic programming, variational methods, Kalman filtering, and other solution techniques. To give the reader a sense of the problems that can arise in a hands-on project, the authors have included new material on optimal output feedback control, a technique used in the aerospace industry. Also included are two new chapters on robust control to provide background in this rapidly growing area of interest. Relations to classical control theory are emphasized throughout the text, and a root-locus approach to steady-state controller design is included. A chapter on optimal control of polynomial systems is designed to give the reader sufficient background for further study in the field of adaptive control. The authors demonstrate through numerous examples that computer simulations of optimal controllers are easy to implement and help give the reader an intuitive feel for the equations. To help build the reader's confidence in understanding the theory and its practical applications, the authors have provided many opportunities throughout the book for writing simple programs. Optimal Control will also serve as an invaluable reference for control engineers in the industry. It offers numerous tables that make it easy to find the equations needed to implement optimal controllers for practical applications. All simulations have been performed using MATLAB and relevant Toolboxes. Optimal Control assumes a background in the state-variable representation of systems; because matrix manipulations are the basic mathematical vehicle of the book, a short review is included in the appendix. A lucid introductory text and an invaluable reference, Optimal Control will serve as a complete tool for the professional engineer and advanced student alike. As a superb introductory text and an indispensable reference, this new edition of Optimal Control will serve the needs of both the professional engineer and the advanced student in mechanical, electrical, and aerospace engineering. Its coverage encompasses all the fundamental topics as well as the major changes of recent years, including output-feedback design and robust design. An abundance of computer simulations using MATLAB and relevant Toolboxes is included to give the reader the actual experience of applying the theory to real-world situations. Major topics covered include: Static Optimization Optimal Control of Discrete-Time Systems Optimal Control of Continuous-Time Systems The Tracking Problem and Other LQR Extensions Final-Time-Free and Constrained Input Control Dynamic Programming Optimal Control for Polynomial Systems Output Feedback and Structured Control Robustness and Multivariable Frequency-Domain Techniques A knowledge of linear systems provides a firm foundation for the study of optimal control theory and many areas of system theory and signal processing. State-space techniques developed since the early sixties have been proved to be very effective. The main objective of this book is to present a brief and somewhat complete investigation on the theory of linear systems, with emphasis on these techniques, in both continuous-time and discrete-time settings, and to demonstrate an application to the study of elementary (linear and nonlinear) optimal control theory. An essential feature of the state-space approach is that both time-varying and time-invariant systems are treated systematically. When time-varying systems are considered, another important subject that depends very much on the state-space formulation is perhaps real-time filtering, prediction, and smoothing via the Kalman filter. This subject is treated in our monograph entitled "Kalman Filtering with Real-Time Applications" published in this Springer Series in Information Sciences (Volume 17). For time-invariant systems, the recent frequency domain approaches using the techniques of Adamjan, Arov, and Krein (also known as AAK), balanced realization, and oo H theory via Nevanlinna-Pick interpolation seem very promising, and this will be studied in our forthcoming monograph entitled "Mathematical Ap proach to Signal Processing and System Theory". The present elementary treatise on linear system theory should provide enough engineering and mathe of these two subjects. "An excellent introduction to optimal control and estimation theory and its relationship with LQG design. . . . invaluable as a reference for those already familiar with the subject." —Automatica. This highly regarded graduate-level text provides a comprehensive introduction to optimal control theory for stochastic systems, emphasizing application of its basic concepts to real problems. The first two chapters introduce optimal control and review the mathematics of control and estimation. Chapter 3 addresses optimal control of systems that may be nonlinear and time-varying, but whose inputs and parameters are known without error. Chapter 4 of the book presents methods for estimating the dynamic states of a system that is driven by uncertain forces and is observed with random measurement error. Chapter 5 discusses the general problem of stochastic optimal control, and the concluding chapter covers linear time-invariant systems. Robert F. Stengel is Professor of Mechanical and Aerospace Engineering at Princeton University, where he directs the Topical Program on Robotics and Intelligent Systems and the Laboratory for Control and Automation. He was a principal designer of the Project Apollo Lunar Module control system. "An excellent teaching book with many examples and worked problems which would be ideal for self-study or for use in the classroom. . . . The book also has a practical orientation and would be of considerable use to people applying these techniques in practice." — Short Book Reviews, Publication of the International Statistical Institute. "An excellent book which guides the reader through most of the important concepts and techniques. . . . A useful book for students (and their teachers) and for those practicing engineers who require a comprehensive reference to the subject." — Library Reviews, The Royal Aeronautical Society. From the reviews: "The style of the book reflects the author’s wish to assist in the effective learning of optimal control by suitable choice of topics, the mathematical level used, and by including numerous illustrated examples. . . .In my view the book suits its function and purpose, in that it gives a student a comprehensive coverage of optimal control in an easy-to-read fashion." —Measurement and Control This is the leading and most up-to-date textbook on the far-ranging algorithmic methododogy of Dynamic Programming, which can be used for optimal control, Markovian decision problems, planning and sequential decision making under uncertainty, and discrete/combinatorial optimization. The treatment focuses on basic unifying themes, and conceptual foundations. It illustrates the versatility, power, and generality of the method with many examples and applications from engineering, operations research, and other fields. It also addresses extensively the practical application of the methodology, possibly through the use of approximations, and provides an extensive treatment of the far-reaching methodology of Neuro-Dynamic Programming/Reinforcement Learning. Among its special features, the book 1) provides a unifying framework for sequential decision making, 2) treats simultaneously deterministic and stochastic control problems popular in modern control theory and Markovian decision popular in operations research, 3) develops the theory of deterministic optimal control problems including the Pontryagin Minimum Principle, 4) introduces recent suboptimal control and simulation-based approximation techniques (neuro-dynamic programming), which allow the practical application of dynamic programming to complex problems that involve the dual curse of large dimension and lack of an accurate mathematical model, 5) provides a comprehensive treatment of infinite horizon problems in the second volume, and an introductory treatment in the first volume The electronic version of the book includes 29 theoretical problems, with high-quality solutions, which enhance the range of coverage of the book. Systems that evolve with time occur frequently in nature and modelling the behavior of such systems provides an important application of mathematics. These systems can be completely deterministic, but it may be possible too to control their behavior by intervention through "controls". The theory of optimal control is concerned with determining such controls which, at minimum cost, either direct the system along a given trajectory or enable it to reach a given point in its state space. This textbook is a straightforward introduction to the theory of optimal control with an emphasis on presenting many different applications. Professor Hocking has taken pains to ensure that the theory is developed to display the main themes of the arguments but without using sophisticated mathematical tools. Problems in this setting can arise across a wide range of subjects and there are illustrative examples of systems from fields as diverse as dynamics, economics, population control, and medicine. Throughout there are many worked examples, and numerous exercises (with solutions) are provided. This monograph is an introduction to optimal control theory for systems governed by vector ordinary differential equations. It is not intended as a state-of-the-art handbook for researchers. We have tried to keep two types of reader in mind: (1) mathematicians, graduate students, and advanced undergraduates in mathematics who want a concise introduction to a field which contains nontrivial interesting applications of mathematics (for example, weak convergence, convexity, and the theory of ordinary differential equations); (2) economists, applied scientists, and engineers who want to understand some of the mathematical foundations. of optimal control theory. In general, we have emphasized motivation and explanation, avoiding the "definition-axiom-theorem-proof" approach. We make use of a large number of examples, especially one simple canonical example which we carry through the entire book. In proving theorems, we often just prove the simplest case, then state the more general results which can be proved. Many of the more difficult topics are discussed in the "Notes" sections at the end of chapters and several major proofs are in the Appendices. We feel that a solid understanding of basic facts is best attained by at first avoiding excessive generality. We have not tried to give an exhaustive list of references, preferring to refer the reader to existing books or papers with extensive bibliographies. References are given by author's name and the year of publication, e.g., Waltman [1974]. A NEW EDITION OF THE CLASSIC TEXT ON OPTIMAL CONTROL THEORY As a superb introductory text and an indispensable reference, this new edition of Optimal Control will serve the needs of both the professional engineer and the advanced student in mechanical, electrical, and aerospace engineering. Its coverage encompasses all the fundamental topics as well as the major changes that have occurred in recent years. An abundance of computer simulations using MATLAB and relevant Toolboxes is included to give the reader the actual experience of applying the theory to real-world situations. Major topics covered include: Static Optimization Optimal Control of Discrete-Time Systems Optimal Control of Continuous-Time Systems The Tracking Problem and Other LQR Extensions Final-Time-Free and Constrained Input Control Dynamic Programming Optimal Control for Polynomial Systems Output Feedback and Structured Control Robustness and Multivariable Frequency-Domain Techniques Differential Games Reinforcement Learning and Optimal Adaptive Control How do you fly an airplane from one point to another as fast as possible? What is the best way to administer a vaccine to fight the harmful effects of disease? What is the most efficient way to produce a chemical substance? This book presents practical methods for solving real optimal control problems such as these. Practical Methods for Optimal Control Using Nonlinear Programming, Third Edition focuses on the direct transcription method for optimal control. It features a summary of relevant material in constrained optimization, including nonlinear programming; discretization techniques appropriate for ordinary differential equations and differential-algebraic equations; and several examples and descriptions of computational algorithm formulations that implement this discretize-then-optimize strategy. The third edition has been thoroughly updated and includes new material on implicit Runge–Kutta discretization techniques, new chapters on partial differential equations and delay equations, and more than 70 test problems and open source FORTRAN code for all of the problems. This book will be valuable for academic and industrial research and development in optimal control theory and applications. It is appropriate as a primary or supplementary text for advanced undergraduate and graduate students. This volume presents the analysis of optimal control problems for systems described by partial differential equations. The book offers simple and clear exposition of main results in this area. The methods proposed by the author cover cases where the controlled system corresponds to well-posed or ill-posed boundary value problems, which can be linear or nonlinear. The uniqueness problem for the solution of nonlinear optimal control problems is analysed in various settings. Solutions of several previously unsolved problems are given. In addition, general methods are applied to the study of two problems connected with optimal control of fluid flows described by the Navier-Stokes equations. The aim of this book is to furnish the reader with a rigorous and detailed exposition of the concept of control parametrization and time scaling transformation. It presents computational solution techniques for a special class of constrained optimal control problems as well as applications to some practical examples. The book may be considered an extension of the 1991 monograph A Unified Computational Approach Optimal Control Problems, by K.L. Teo, C.J. Goh, and K.H. Wong. This publication discusses the development of new theory and computational methods for solving various optimal control problems numerically and in a unified fashion. To keep the book accessible and uniform, it includes those results developed by the authors, their students, and their past and present collaborators. A brief review of methods that are not covered in this exposition, is also included. Knowledge gained from this book may inspire advancement of new techniques to solve complex problems that arise in the future. This book is intended as reference for researchers in mathematics, engineering, and other sciences, graduate students and practitioners who apply optimal control methods in their work. It may be appropriate reading material for a graduate level seminar or as a text for a course in optimal control.