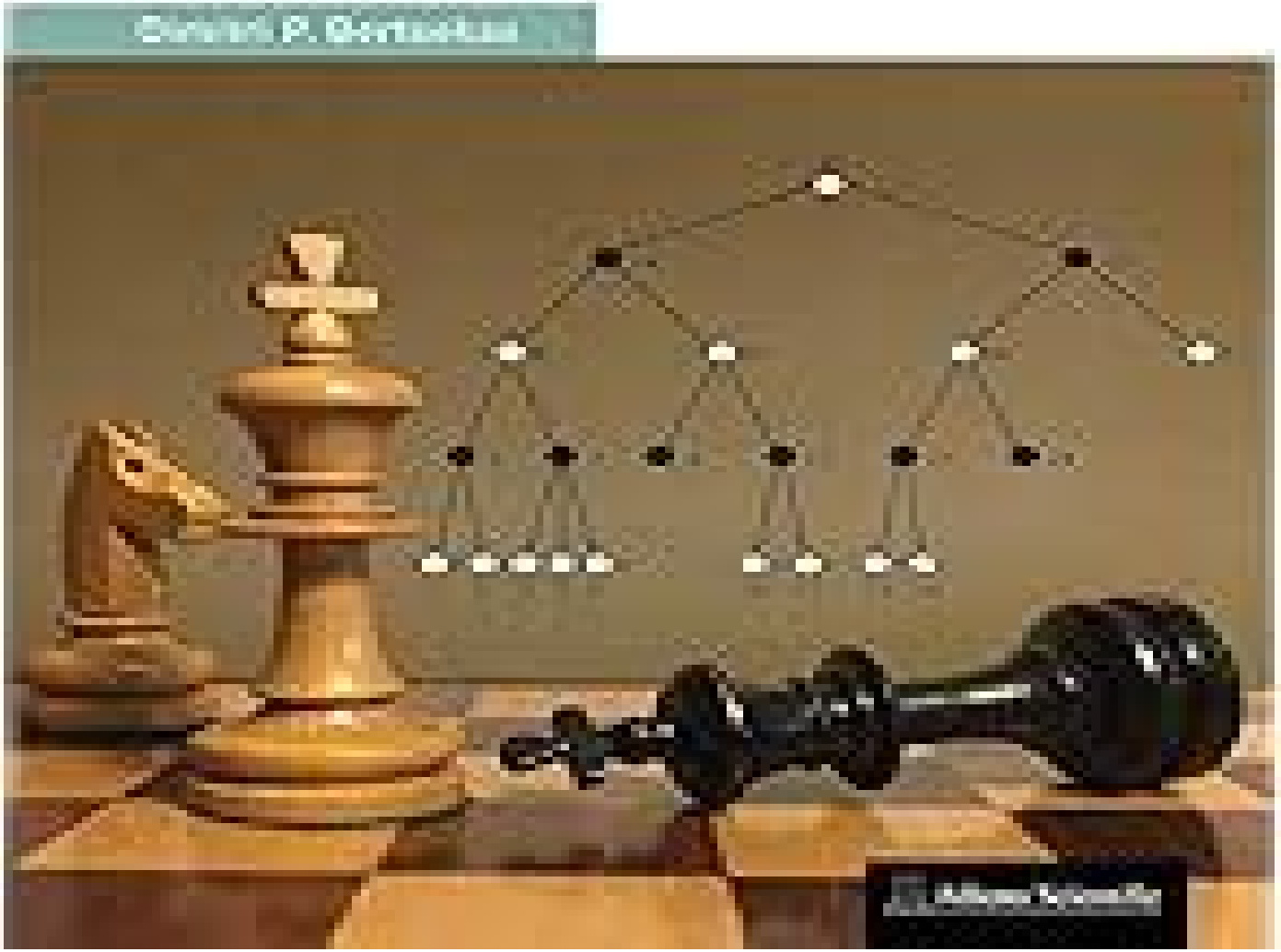
Dynamic Programming and Optimal Control



Dynamic Programming And Optimal Control Vol Ii 4th Edition Approximate Dynamic Programming

Ali H. Sayed

Dynamic Programming And Optimal Control Vol Ii 4th Edition Approximate Dynamic Programming:

Dynamic Programming and Optimal Control Dimitri Bertsekas,2012-10-23 This is the leading and most up to date textbook on the far ranging algorithmic methodology 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 **Abstract Dynamic Programming** Dimitri Bertsekas,2022-01-01 This is the 3rd edition of a research monograph providing a synthesis of old research on the foundations of dynamic programming DP with the modern theory of approximate DP and new research on semicontractive models It aims at a unified and economical development of the core theory and algorithms of total cost sequential decision problems based on the strong connections of the subject with fixed point theory The analysis focuses on the abstract mapping that underlies DP and defines the mathematical character of the associated problem The discussion centers on two fundamental properties that this mapping may have monotonicity and weighted sup norm contraction It turns out that the nature of the analytical and algorithmic DP theory is determined primarily by the presence or absence of these two properties and the rest of the problem s structure is largely inconsequential New research is focused on two areas 1 The ramifications of these properties in the context of algorithms for approximate DP and 2 The new class of semicontractive models exemplified by stochastic shortest path problems where some but not all policies are contractive The 3rd edition is very similar to the 2nd edition except for the addition of a new chapter Chapter 5 which deals with abstract DP models for sequential minimax problems and zero sum games The book is an excellent supplement to several of our books Neuro Dynamic Programming Athena Scientific 1996 Dynamic Programming and Optimal Control Athena Scientific 2017 Reinforcement Learning and Optimal Control Athena Scientific 2019 and Rollout Policy Iteration and Distributed Reinforcement Learning Athena Scientific 2020 **Reinforcement Learning and Optimal Control** Dimitri

Bertsekas,2019-07-01 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 A Course in Reinforcement Learning: 2nd Edition Dimitri Bertsekas,2024-12-20 This is the 2nd edition of the textbook used at the author s ASU research oriented course on Reinforcement Learning RL offered in each of the last six years Its purpose is to give an overview of the RL methodology particularly as it relates to problems of optimal and suboptimal decision and control as well as discrete optimization While in this book mathematical proofs are deemphasized there is considerable related analysis which supports the conclusions and can be found in the author s recent RL and DP books These books also contain additional material on off line training of neural networks on the use of policy gradient methods for approximation in policy space and on aggregation **Structural Econometric Models** Eugene Choo,Matthew Shum,2013-12-18 This volume focuses on recent developments in the use of structural econometric models in empirical economics The first part looks at recent developments in the estimation of dynamic discrete choice models The second part looks at recent advances in the area empirical matching models **Rollout, Policy Iteration, and Distributed Reinforcement Learning** Dimitri Bertsekas,2021-08-20 The purpose of this book is to develop in greater depth some of the methods from the author s Reinforcement Learning and Optimal Control recently published textbook Athena Scientific 2019 In particular we present new research relating to systems involving multiple agents partitioned architectures and distributed asynchronous computation We pay special attention to the contexts of dynamic programming policy iteration and control theory model predictive control We also discuss in some detail the application of the methodology to challenging discrete combinatorial optimization problems such as routing scheduling assignment and mixed integer programming including the use of neural network approximations within these contexts The book focuses on the fundamental idea of policy iteration i e start from some policy and successively generate one or more improved policies If just one improved policy is generated this is called rollout which based on broad and consistent computational experience appears to be one of the most versatile and reliable of all reinforcement learning methods In this book rollout algorithms are developed for both discrete deterministic and stochastic DP problems and the development of distributed implementations in both multiagent and multiprocessor settings aiming to take advantage of parallelism Approximate policy iteration is more ambitious than rollout but it is a strictly off line method and it is generally far more computationally intensive This motivates the use of parallel and distributed computation One of the purposes of the monograph is to discuss distributed possibly asynchronous methods that relate to rollout and policy iteration both in the context of an exact and an approximate implementation involving neural networks or other approximation architectures Much of the new research is inspired by the remarkable AlphaZero chess program where policy iteration value and policy networks approximate lookahead minimization and parallel computation all play an important role *Portfolio Construction and Analytics* Frank J. Fabozzi,Dessislava A. Pachamanova,2016-03-17 A detailed multi disciplinary approach to investment analytics Portfolio Construction and Analytics provides an up to date

understanding of the analytic investment process for students and professionals alike With complete and detailed coverage of portfolio analytics and modeling methods this book is unique in its multi disciplinary approach Investment analytics involves the input of a variety of areas and this guide provides the perspective of data management modeling software resources and investment strategy to give you a truly comprehensive understanding of how today s firms approach the process Real world examples provide insight into analytics performed with vendor software and references to analytics performed with open source software will prove useful to both students and practitioners Portfolio analytics refers to all of the methods used to screen model track and evaluate investments Big data regulatory change and increasing risk is forcing a need for a more coherent approach to all aspects of investment analytics and this book provides the strong foundation and critical skills you need Master the fundamental modeling concepts and widely used analytics Learn the latest trends in risk metrics modeling and investment strategies Get up to speed on the vendor and open source software most commonly used Gain a multi angle perspective on portfolio analytics at today s firms Identifying investment opportunities keeping portfolios aligned with investment objectives and monitoring risk and performance are all major functions of an investment firm that relies heavily on analytics output This reliance will only increase in the face of market changes and increased regulatory pressure and practitioners need a deep understanding of the latest methods and models used to build a robust investment strategy Portfolio Construction and Analytics is an invaluable resource for portfolio management in any capacity **Big Data and Electric Mobility** Haoran Zhang,Quan Zhou,2025-03-31 This book details how to assess electric mobility characteristics within electric vehicles discussing energy management methods automated systems and the enormous potential of data resources mined from software navigation systems and connectivity Big Data and Electric Mobility presents methods to mine data specifically for electric vehicles to comprehend their performance and to present opportunities to develop data driven technological advancements Including contributions from experts across the world the book will look at topics such as human mobile behavior battery charging and health powertrain simulation energy management and multiphysics constrained optimal charging The book will be key reading for researchers and engineers in the fields of automotive engineering electrical engineering and data mining **Mathematical Foundations of Reinforcement Learning** Shiyu Zhao,2025-01-21 This book provides a mathematical yet accessible introduction to the fundamental concepts core challenges and classic reinforcement learning algorithms It aims to help readers understand the theoretical foundations of algorithms providing insights into their design and functionality Numerous illustrative examples are included throughout The mathematical content is carefully structured to ensure readability and approachability The book is divided into two parts The first part is on the mathematical foundations of reinforcement learning covering topics such as the Bellman equation Bellman optimality equation and stochastic approximation The second part explicates reinforcement learning algorithms including value iteration and policy iteration Monte Carlo methods temporal difference methods value function methods policy gradient

methods and actor critic methods With its comprehensive scope the book will appeal to undergraduate and graduate students post doctoral researchers lecturers industrial researchers and anyone interested in reinforcement learning

Lessons from AlphaZero for Optimal, Model Predictive, and Adaptive Control Dimitri Bertsekas,2022-03-19 The purpose of this book is to propose and develop a new conceptual framework for approximate Dynamic Programming DP and Reinforcement Learning RL This framework centers around two algorithms which are designed largely independently of each other and operate in synergy through the powerful mechanism of Newton s method We call these the off line training and the on line play algorithms the names are borrowed from some of the major successes of RL involving games Primary examples are the recent 2017 AlphaZero program which plays chess and the similarly structured and earlier 1990s TD Gammon program which plays backgammon In these game contexts the off line training algorithm is the method used to teach the program how to evaluate positions and to generate good moves at any given position while the on line play algorithm is the method used to play in real time against human or computer opponents Both AlphaZero and TD Gammon were trained off line extensively using neural networks and an approximate version of the fundamental DP algorithm of policy iteration Yet the AlphaZero player that was obtained off line is not used directly during on line play it is too inaccurate due to approximation errors that are inherent in off line neural network training Instead a separate on line player is used to select moves based on multistep lookahead minimization and a terminal position evaluator that was trained using experience with the off line player The on line player performs a form of policy improvement which is not degraded by neural network approximations As a result it greatly improves the performance of the off line player Similarly TD Gammon performs on line a policy improvement step using one step or two step lookahead minimization which is not degraded by neural network approximations To this end it uses an off line neural network trained terminal position evaluator and importantly it also extends its on line lookahead by rollout simulation with the one step lookahead player that is based on the position evaluator Significantly the synergy between off line training and on line play also underlies Model Predictive Control MPC a major control system design methodology that has been extensively developed since the 1980s This synergy can be understood in terms of abstract models of infinite horizon DP and simple geometrical constructions and helps to explain the all important stability issues within the MPC context An additional benefit of policy improvement by approximation in value space not observed in the context of games which have stable rules and environment is that it works well with changing problem parameters and on line replanning similar to indirect adaptive control Here the Bellman equation is perturbed due to the parameter changes but approximation in value space still operates as a Newton step An essential requirement here is that a system model is estimated on line through some identification method and is used during the one step or multistep lookahead minimization process In this monograph we aim to provide insights often based on visualization which explain the beneficial effects of on line decision making on top of off line training In the process we will bring out the strong connections between

the artificial intelligence view of RL and the control theory views of MPC and adaptive control Moreover we will show that in addition to MPC and adaptive control our conceptual framework can be effectively integrated with other important methodologies such as multiagent systems and decentralized control discrete and Bayesian optimization and heuristic algorithms for discrete optimization One of our principal aims is to show through the algorithmic ideas of Newton s method and the unifying principles of abstract DP that the AlphaZero TD Gammon methodology of approximation in value space and rollout applies very broadly to deterministic and stochastic optimal control problems Newton s method here is used for the solution of Bellman s equation an operator equation that applies universally within DP with both discrete and continuous state and control spaces as well as finite and infinite horizon **Reinforcement Learning and Approximate Dynamic Programming for Feedback Control** Frank L. Lewis,Derong Liu,2013-01-28 Reinforcement learning RL and adaptive dynamic programming ADP has been one of the most critical research fields in science and engineering for modern complex systems This book describes the latest RL and ADP techniques for decision and control in human engineered systems covering both single player decision and control and multi player games Edited by the pioneers of RL and ADP research the book brings together ideas and methods from many fields and provides an important and timely guidance on controlling a wide variety of systems such as robots industrial processes and economic decision making Algorithmic Mathematics in Machine Learning Bastian Bohn,Jochen Garcke,Michael Griebel,2024-04-08 This unique book explores several well known machine learning and data analysis algorithms from a mathematical and programming perspective The authors present machine learning methods review the underlying mathematics and provide programming exercises to deepen the reader s understanding accompany application areas with exercises that explore the unique characteristics of real world data sets e g image data for pedestrian detection biological cell data and provide new terminology and background information on mathematical concepts as well as exercises in info boxes throughout the text Algorithmic Mathematics in Machine Learning is intended for mathematicians computer scientists and practitioners who have a basic mathematical background in analysis and linear algebra but little or no knowledge of machine learning and related algorithms Researchers in the natural sciences and engineers interested in acquiring the mathematics needed to apply the most popular machine learning algorithms will also find this book useful This book is appropriate for a practical lab or basic lecture course on machine learning within a mathematics curriculum **Symmetry in Complex Systems** J. A. Tenreiro Machado,António M. Lopes,2021-01-21 Complex systems with symmetry arise in many fields at various length scales including financial markets social transportation telecommunication and power grid networks world and country economies ecosystems molecular dynamics immunology living organisms computational systems and celestial and continuum mechanics The emergence of new orders and structures in complex systems means symmetry breaking and transitions from unstable to stable states Modeling complexity has attracted many researchers from different areas dealing both with theoretical concepts and practical applications This

Special Issue fills the gap between the theory of symmetry based dynamics and its application to model and analyze complex systems *Reinforcement Learning, second edition* Richard S. Sutton,Andrew G. Barto,2018-11-13 The significantly expanded and updated new edition of a widely used text on reinforcement learning one of the most active research areas in artificial intelligence Reinforcement learning one of the most active research areas in artificial intelligence is a computational approach to learning whereby an agent tries to maximize the total amount of reward it receives while interacting with a complex uncertain environment In Reinforcement Learning Richard Sutton and Andrew Barto provide a clear and simple account of the field s key ideas and algorithms This second edition has been significantly expanded and updated presenting new topics and updating coverage of other topics Like the first edition this second edition focuses on core online learning algorithms with the more mathematical material set off in shaded boxes Part I covers as much of reinforcement learning as possible without going beyond the tabular case for which exact solutions can be found Many algorithms presented in this part are new to the second edition including UCB Expected Sarsa and Double Learning Part II extends these ideas to function approximation with new sections on such topics as artificial neural networks and the Fourier basis and offers expanded treatment of off policy learning and policy gradient methods Part III has new chapters on reinforcement learning s relationships to psychology and neuroscience as well as an updated case studies chapter including AlphaGo and AlphaGo Zero Atari game playing and IBM Watson s wagering strategy The final chapter discusses the future societal impacts of reinforcement learning **Integration of Constraint Programming, Artificial Intelligence, and Operations Research** Pierre Schaus,2022-06-09 This book constitutes the proceedings of the 19th International Conference on the Integration of Constraint Programming Artificial Intelligence and Operations Research CPAIOR 2022 which was held in Los Angeles CA USA in June 2022 The 28 regular papers presented were carefully reviewed and selected from a total of 60 submissions The conference program included a Master Class on the topic Bridging the Gap between Machine Learning and Optimization

From Shortest Paths to Reinforcement Learning Paolo Brandimarte,2021-01-11 Dynamic programming DP has a relevant history as a powerful and flexible optimization principle but has a bad reputation as a computationally impractical tool This book fills a gap between the statement of DP principles and their actual software implementation Using MATLAB throughout this tutorial gently gets the reader acquainted with DP and its potential applications offering the possibility of actual experimentation and hands on experience The book assumes basic familiarity with probability and optimization and is suitable to both practitioners and graduate students in engineering applied mathematics management finance and economics

Inference and Learning from Data Ali H. Sayed,2022-12-22 Discover techniques for inferring unknown variables and quantities with the second volume of this extraordinary three volume set **An Introduction to Financial Markets** Paolo Brandimarte,2017-11-13 COVERS THE FUNDAMENTAL TOPICS IN MATHEMATICS STATISTICS AND FINANCIAL MANAGEMENT THAT ARE REQUIRED FOR A THOROUGH STUDY OF FINANCIAL MARKETS This comprehensive yet

accessible book introduces students to financial markets and delves into more advanced material at a steady pace while providing motivating examples poignant remarks counterexamples ideological clashes and intuitive traps throughout Tempered by real life cases and actual market structures An Introduction to Financial Markets A Quantitative Approach accentuates theory through quantitative modeling whenever and wherever necessary It focuses on the lessons learned from timely subject matter such as the impact of the recent subprime mortgage storm the collapse of LTCM and the harsh criticism on risk management and innovative finance The book also provides the necessary foundations in stochastic calculus and optimization alongside financial modeling concepts that are illustrated with relevant and hands on examples An Introduction to Financial Markets A Quantitative Approach starts with a complete overview of the subject matter It then moves on to sections covering fixed income assets equity portfolios derivatives and advanced optimization models This book s balanced and broad view of the state of the art in financial decision making helps provide readers with all the background and modeling tools needed to make honest money and in the process to become a sound professional Stresses that gut feelings are not always sufficient and that critical thinking and real world applications are appropriate when dealing with complex social systems involving multiple players with conflicting incentives Features a related website that contains a solution manual for end of chapter problems Written in a modular style for tailored classroom use Bridges a gap for business and engineering students who are familiar with the problems involved but are less familiar with the methodologies needed to make smart decisions An Introduction to Financial Markets A Quantitative Approach offers a balance between the need to illustrate mathematics in action and the need to understand the real life context It is an ideal text for a first course in financial markets or investments for business economic statistics engineering decision science and management science students Abstract Dynamic Programming Dimitri Bertsekas,2018-02-01 A research monograph providing a synthesis of old research on the foundations of dynamic programming with the modern theory of approximate dynamic programming and new research on semicontractive models It aims at a unified and economical development of the core theory and algorithms of total cost sequential decision problems based on the strong connections of the subject with fixed point theory The analysis focuses on the abstract mapping that underlies dynamic programming and defines the mathematical character of the associated problem The discussion centers on two fundamental properties that this mapping may have monotonicity and weighted sup norm contraction It turns out that the nature of the analytical and algorithmic DP theory is determined primarily by the presence or absence of these two properties and the rest of the problem s structure is largely inconsequential New research is focused on two areas 1 The ramifications of these properties in the context of algorithms for approximate dynamic programming and 2 The new class of semicontractive models exemplified by stochastic shortest path problems where some but not all policies are contractive The 2nd edition aims primarily to amplify the presentation of the semicontractive models of Chapter 3 and Chapter 4 of the first 2013 edition and to supplement it with a broad spectrum of

research results that I obtained and published in journals and reports since the first edition was written see below As a result the size of this material more than doubled and the size of the book increased by nearly 40% The book is an excellent supplement to several of our books Dynamic Programming and Optimal Control Athena Scientific 2017 and Neuro Dynamic Programming Athena Scientific 1996 *Decision Criteria and Optimal Inventory Processes* Baoding Liu,Augustine O. Esogbue,2012-12-06 Decision Criteria and Optimal Inventory Processes provides a theoretical and practical introduction to decision criteria and inventory processes Inventory theory is presented by focusing on the analysis and processes underlying decision criteria Included are many state of the art criterion models as background material These models are extended to the authors newly developed fuzzy criterion models which constitute a general framework for the study of stochastic inventory models with special focus on the real world inventory theoretic reservoir operations problems The applications of fuzzy criterion dynamic programming models are illustrated by reservoir operations including the integrated network of reservoir operation and the open inventory network problems An interesting feature of this book is the special attention it pays to the analysis of some theoretical and applied aspects of fuzzy criteria and dynamic fuzzy criterion models thus opening up a new way of injecting the much needed type of non cost intuitive and easy to use methods into multi stage inventory processes This is accomplished by constructing and optimizing the fuzzy criterion models developed for inventory processes Practitioners in operations research management science and engineering will find numerous new ideas and strategies for modeling real world multi stage inventory problems and researchers and applied mathematicians will find this work a stimulating and useful reference

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