Dynamic Programming and Optimal Control

Dimitri P. Bertsekas

Dynamic Programming Optimal Control Vol

Konrad Schade

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Dynamic Programming and Optimal Control Dimitri Bertsekas,2012 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   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   **Dynamic programming and optimal control,vol. 2** Dimitri P. Bertsekas,2000   **Optimale Kontrolle ökonomischer Prozesse** Gustav Feichtinger,Richard F. Hartl,1986 Keine ausf hrliche Beschreibung f r Optimale Kontrolle konomischer Prozesse verf gbar   Stochastische Optimierung Konrad Schade,2012-01-10 Konrad Schade stellt Verfahren der stochastischen linearen ganzzahligen Optimierung vor mit deren Hilfe robuste Bestellpunkte f r ein mehrstufiges Lagernetzwerk bestimmt werden k nnen Der Autor zeigt wie dabei die erwarteten Gesamtkosten ber das gesamte Lagernetzwerk minimiert werden k nnen   **Optimierung und ökonomische Analyse** Peter Stahlecker,Nils Hauenschild,Markus Klintworth,2013-03-07 Gegenstand des Buches sind die Darstellung Herleitung und Erl uterung sowohl statischer als auch dynamischer Optimierungsmethoden die zur Behandlung konomischer Modelle ben tigt werden Dabei wird ein gro es Gewicht auf das Zusammenspiel zwischen konomischer Interpretation auf der einen und mathematischer Argumentation auf der anderen Seite gelegt Alle Optimierungsprobleme werden zun chst anhand konomischer Beispiele begr ndet Nach der mathematischen Herleitung verschiedener prinzipieller L sungsmethoden werden diese dann konkret auf die eingangs betrachteten konomischen Modelle angewandt Die verwendete Satz Beweis Struktur macht das Buch auch zu einem guten Nachschlagewerk   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

Quantitative Portfolio Optimization Miquel Noguer Alonso,Julian Antolin Camarena,Alberto Bueno Guerrero,2025-01-29 Expert guidance on implementing quantitative portfolio optimization techniques In Quantitative Portfolio Optimization Theory and Practice renowned financial practitioner Miquel Noguer alongside physicists Alberto Bueno Guerrero and Julian Antolin Camarena who possess excellent knowledge in finance delve into advanced mathematical techniques for portfolio optimization The book covers a range of topics including mean variance optimization the Black Litterman Model risk parity and hierarchical risk parity factor investing methods based on moments and robust optimization as well as machine learning and reinforcement technique These techniques enable readers to develop a systematic objective and repeatable approach to investment decision making particularly in complex financial markets Readers will gain insights into the associated mathematical models statistical analyses and computational algorithms for each method allowing them to put these techniques into practice and identify the best possible mix of assets to maximize returns while minimizing risk Topics explored in this book include Specific drivers of return across asset classes Personal risk tolerance and it s impact on ideal asses allocation The importance of weekly and monthly variance in the returns of specific securities Serving as a blueprint for solving portfolio optimization problems Quantitative Portfolio Optimization Theory and Practice is an essential resource for finance practitioners and individual investors It helps them stay on the cutting edge of modern portfolio theory and achieve the best returns on investments for themselves their clients and their organizations *Model-Based Reinforcement Learning* Milad Farsi,Jun Liu,2022-12-02 Model Based Reinforcement Learning Explore a comprehensive and practical approach to reinforcement learning Reinforcement learning is an essential paradigm of machine learning wherein an intelligent agent performs actions that ensure optimal behavior from devices While this paradigm of machine learning has gained tremendous success and popularity in recent years previous scholarship has focused either on theory optimal control and dynamic programming or on algorithms most of which are simulation based Model Based Reinforcement Learning

provides a model based framework to bridge these two aspects thereby creating a holistic treatment of the topic of model based online learning control In doing so the authors seek to develop a model based framework for data driven control that bridges the topics of systems identification from data model based reinforcement learning and optimal control as well as the applications of each This new technique for assessing classical results will allow for a more efficient reinforcement learning system At its heart this book is focused on providing an end to end framework from design to application of a more tractable model based reinforcement learning technique Model Based Reinforcement Learning readers will also find A useful textbook to use in graduate courses on data driven and learning based control that emphasizes modeling and control of dynamical systems from data Detailed comparisons of the impact of different techniques such as basic linear quadratic controller learning based model predictive control model free reinforcement learning and structured online learning Applications and case studies on ground vehicles with nonholonomic dynamics and another on quadrator helicopters An online Python based toolbox that accompanies the contents covered in the book as well as the necessary code and data Model Based Reinforcement Learning is a useful reference for senior undergraduate students graduate students research assistants professors process control engineers and roboticists   **Planning Algorithms** Steven M. LaValle,2006-05-29 Planning algorithms are impacting technical disciplines and industries around the world including robotics computer aided design manufacturing computer graphics aerospace applications drug design and protein folding This coherent and comprehensive book unifies material from several sources including robotics control theory artificial intelligence and algorithms The treatment is centered on robot motion planning but integrates material on planning in discrete spaces A major part of the book is devoted to planning under uncertainty including decision theory Markov decision processes and information spaces which are the configuration spaces of all sensor based planning problems The last part of the book delves into planning under differential constraints that arise when automating the motions of virtually any mechanical system This text and reference is intended for students engineers and researchers in robotics artificial intelligence and control theory as well as computer graphics algorithms and computational biology   **Recent Advances in Reinforcement Learning** Leslie Pack Kaelbling,2007-08-28 Recent Advances in Reinforcement Learning addresses current research in an exciting area that is gaining a great deal of popularity in the Artificial Intelligence and Neural Network communities Reinforcement learning has become a primary paradigm of machine learning It applies to problems in which an agent such as a robot a process controller or an information retrieval engine has to learn how to behave given only information about the success of its current actions This book is a collection of important papers that address topics including the theoretical foundations of dynamic programming approaches the role of prior knowledge and methods for improving performance of reinforcement learning techniques These papers build on previous work and will form an important resource for students and researchers in the area Recent Advances in Reinforcement Learning is an edited volume of peer reviewed original research comprising twelve

invited contributions by leading researchers This research work has also been published as a special issue of Machine Learning Volume 22 Numbers 1 2 and 3 **Encyclopedia of Financial Models, Volume III** Frank J. Fabozzi,2012-09-12 Volume 3 of the Encyclopedia of Financial Models The need for serious coverage of financial modeling has never been greater especially with the size diversity and efficiency of modern capital markets With this in mind the Encyclopedia of Financial Models has been created to help a broad spectrum of individuals ranging from finance professionals to academics and students understand financial modeling and make use of the various models currently available Incorporating timely research and in depth analysis Volume 3 of the Encyclopedia of Financial Models covers both established and cutting edge models and discusses their real world applications Edited by Frank Fabozzi this volume includes contributions from global financial experts as well as academics with extensive consulting experience in this field Organized alphabetically by category this reliable resource consists of forty four informative entries and provides readers with a balanced understanding of today s dynamic world of financial modeling Volume 3 covers Mortgage Backed Securities Analysis and Valuation Operational Risk Optimization Tools Probability Theory Risk Measures Software for Financial Modeling Stochastic Processes and Tools Term Structure Modeling Trading Cost Models and Volatility Emphasizes both technical and implementation issues providing researchers educators students and practitioners with the necessary background to deal with issues related to financial modeling The 3 Volume Set contains coverage of the fundamentals and advances in financial modeling and provides the mathematical and statistical techniques needed to develop and test financial models Financial models have become increasingly commonplace as well as complex They are essential in a wide range of financial endeavors and the Encyclopedia of Financial Models will help put them in perspective Optimization Elijah Polak,2012-12-06 This book deals with optimality conditions algorithms and discretization tech niques for nonlinear programming semi infinite optimization and optimal con trol problems The unifying thread in the presentation consists of an abstract theory within which optimality conditions are expressed in the form of zeros of optimality junctions algorithms are characterized by point to set iteration maps and all the numerical approximations required in the solution of semi infinite optimization and optimal control problems are treated within the context of con sistent approximations and algorithm implementation techniques Traditionally necessary optimality conditions for optimization problems are presented in Lagrange F John or Karush Kuhn Tucker multiplier forms with gradients used for smooth problems and subgradients for nonsmooth prob lems We present these classical optimality conditions and show that they are satisfied at a point if and only if this point is a zero of an upper semicontinuous optimality junction The use of optimality functions has several advantages First optimality functions can be used in an abstract study of optimization algo rithms Second many optimization algorithms can be shown to use search directions that are obtained in evaluating optimality functions thus establishing a clear relationship between optimality conditions and algorithms Third estab lishing optimality conditions for highly complex problems such as optimal con trol

problems with control and trajectory constraints is much easier in terms of optimality functions than in the classical manner In addition the relationship between optimality conditions for finite dimensional problems and semi infinite optimization and optimal control problems becomestransparent   <u>Automated Technology for Verification and Analysis</u> Cyrille Artho,Axel Legay,Doron Peled,2016-10-07 This book constitutes the proceedings of the 14th International Symposium on Automated Technology for Verification and Analysis ATVA 2016 held in Chiba Japan in October 2016 The 31 papers presented in this volume were carefully reviewed and selected from 82 submissions They were organized in topical sections named keynote Markov models chains and decision processes counter systems automata parallelism concurrency complexity decidability synthesis refinement optimization heuristics partial order reductions solving procedures model checking and program analysis   **Mobile Networks** Jesús Hamilton Ortiz,2012-05-09 The growth in the use of mobile networks has come mainly with the third generation systems and voice traffic With the current third generation and the arrival of the 4G the number of mobile users in the world will exceed the number of landlines users Audio and video streaming have had a significant increase parallel to the requirements of bandwidth and quality of service demanded by those applications Mobile networks require that the applications and protocols that have worked successfully in fixed networks can be used with the same level of quality in mobile scenarios Until the third generation of mobile networks the need to ensure reliable handovers was still an important issue On the eve of a new generation of access networks 4G and increased connectivity between networks of different characteristics commonly called hybrid satellite ad hoc sensors wired WIMAX LAN etc it is necessary to transfer mechanisms of mobility to future generations of networks In order to achieve this it is essential to carry out a comprehensive evaluation of the performance of current protocols and the diverse topologies to suit the new mobility conditions   <u>Einführung in Operations Research</u> Wolfgang Domschke,Andreas Drexl,Robert Klein,Armin Scholl,2015-10-01 Didaktisch effektives und effizientes Standardwerk in der 9 Auflage Dieses Buch entstand aus Vorlesungen zur Einf hrung in Operations Research OR f r Studierende der Betriebs und Volkswirtschaftslehre des Wirtschaftsingenieurwesens der Wirtschaftsinformatik und der Wirtschaftsmathematik Es zeichnet sich in der Vermittlung der Grundlagen des OR durch eine gelungene didaktische Aufbereitung des Stoffes aus und ist auch zum Selbststudium geeignet Die Autoren beschreiben Verfahren algorithmisch und verdeutlichen sie anhand von aussagekr ftigen Beispielen Der Text behandelt lineare ganzzahlige und kombinatorische dynamische sowie nichtlineare Optimierung Graphen und Warteschlangentheorie Netzplantechnik und Simulation Das Schlusskapitel vermittelt die L sung von OR Problemen mittels Tabellenkalkulationssoftware Zur Vertiefung und Anwendung der vorgestellten Methoden wird das Buch bungen und Fallbeispiele zum Operations Research derselben Autoren empfohlen Es enth lt eine gro e Anzahl an bungsaufgaben und eine Einf hrung in die Optimierung mit Standardsoftware   **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

Computational Context William F. Lawless,Ranjeev Mittu,Donald Sofge,2018-12-07 This volume addresses context from three comprehensive perspectives first its importance the issues surrounding context and its value in the laboratory and the field second the theory guiding the AI used to model its context and third its applications in the field e g decision making This breadth poses a challenge The book analyzes how the environment context influences human perception cognition and action While current books approach context narrowly the major contribution of this book is to provide an in depth review over a broad range of topics for a computational context no matter its breadth The volume outlines numerous strategies and techniques from world class scientists who have adapted their research to solve different problems with AI in difficult environments and complex domains to address the many computational challenges posed by context Context can be clear uncertain or an illusion Clear contexts A father praising his child a trip to the post office to buy stamps a policewoman asking for identification Uncertain contexts A sneak attack a surprise witness in a courtroom a shout of Fire Fire Contexts as illusion Humans fall prey to illusions that machines do not Adelson s checkerboard illusion versus a photometer Determining context is not easy when disagreement exists interpretations vary or uncertainty reigns Physicists like Einstein relativity Bekenstein holographs and Rovelli universe have written that reality is not what we commonly believe Even outside of awareness individuals act differently whether alone or in teams Can computational context with AI adapt to clear and uncertain contexts to change over time and to individuals machines or robots as well as to teams If a program automatically knows the context that improves performance or decisions does it matter whether context is clear uncertain or illusory Written and edited by world class leaders from across the field of autonomous systems research this volume carefully considers the computational systems being constructed to determine context for individual agents or teams the challenges they face and the advances they expect for the science of context **16. Internationales Stuttgarter Symposium** Michael Bargende,Hans-Christian Reuss,Jochen Wiedemann,2016-04-27 Die Anforderungen an Forschung und Entwicklung in der Automobilindustrie ndern sich kontinuierlich Hersteller und Zulieferer m ssen einerseits globale L sungen entwickeln andererseits aber Kundenbed rfnisse und legislative Vorgaben einzelner M rkte ber cksichtigen Selbst bei der Emissionsgesetzgebung herrscht alles andere als globale Einigkeit In Europa wird ab September 2017 die Messung der real driving emissions RDE eingef hrt Damit wird die Bewertung der Schadstoffemissionen vom Pr fstand auf die Stra e verlagert mit umfassenden Konsequenzen f r die Antriebsentwicklung Zudem wird in verschiedenen Weltregionen die lokale Einf hrung von Zonen mit

schadstoffemissionsfreiem Verkehr gefordert berlagert wird all dies durch die laufende Absenkung der CO2 Grenzwerte f r die Fahrzeugflotten Alle Weltregionen haben hier unterschiedliche Absenkungsschritte definiert Dies alles wird noch getoppt von steigenden Anspr chen an Komfort und Emotionalit t des Automobils Wie reagiertnun die Automobilindustrie im Spannungsfeld zwischen zunehmender Globalisierung und m glichst global zu vermarktender Produkte auf der einen Seite und den neuen von Regionen abh ngigen Anforderungen an das Fahrzeug und der dazugeh rigen Variantenvielfalt auf der anderen Seite Welche technischen Konsequenzen ergeben sich hieraus Dar ber und ber vieles mehr werden Experten aus Industrie und Wissenschaft beim Symposium berichten **Proceedings of the 10th Hydrogen Technology Convention, Volume 3** Hexu Sun,Wei Pei,Yan Dong,Hongmei Yu,Shi You,2024-01-09 These proceedings highlight the latest advances in fundamental research technologies and applications of hydrogen energy and fuel cells In recent years energy conversion between electricity and hydrogen energy has attracted increasing attention as a way to adjust the load of the grid These conference records discuss and exchange cutting edge findings and technological developments in fields such as new proton exchange membrane electrolysers new electrode materials and catalysts renewable energy off grid grid connected water electrolysis for hydrogen production key materials and components of fuel cells high temperature solid oxide water electrolysis energy storage technologies and research CO2 hydrogenation to methanol nitrogen to ammonia and other applications with industrial potential The main topics of the proceedings include 1 Policies and strategies for hydrogen energy and fuel cells 2 Advanced proton exchange membranes electrodes and catalyst materials for water electrolysis 3 Advanced hydrogen compression storage transportation and distribution technologies 4 Safety and related standards 5 Manufacture and R D of key materials and components of fuel cells and stack systems

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