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VOLUME 2

Dynamic Programming and Optimal Control

DIMITRI P. BERTSEKAS



Dynamic Programming And Optimal Control Vol Ii

Clifford Lane



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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

Dynamic Programming and Optimal Control Dimitri Bertsekas, 2012 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 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 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

Dynamic Optimization Karl Hinderer, Ulrich Rieder, Michael Stieglitz, 2017-01-12 This book explores discrete time dynamic optimization and provides a detailed introduction to both deterministic and stochastic models Covering problems with finite and infinite horizon as well as Markov renewal programs Bayesian control models and partially observable processes the book focuses on the precise modelling of applications in a variety of areas including operations research computer science mathematics statistics engineering economics and finance Dynamic Optimization is a carefully presented textbook which starts with discrete time deterministic dynamic optimization problems providing readers with the tools for sequential decision making before proceeding to the more complicated stochastic models The authors present complete and simple proofs and illustrate the main results with numerous examples and exercises without solutions With relevant material covered in four appendices this book is completely self contained

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

MATHEMATICAL MODELS OF LIFE SUPPORT SYSTEMS - Volume II Valeri I. Agoshko , Jean-Pierre Puel,2009-10-10 Mathematical Models of Life Support Systems is a component of Encyclopedia of Mathematical Sciences in which is part of the global Encyclopedia of Life Support Systems EOLSS an integrated compendium of twenty one Encyclopedias The Theme is organized into several topics which represent the main scientific areas of the theme The first topic Introduction to Mathematical Modeling discusses the foundations of mathematical modeling and computational experiments which are formed to support new methodologies of scientific research The succeeding topics are Mathematical Models in Water Sciences Climate Environmental Pollution and Degradation Energy Sciences Food and Agricultural Sciences Population Immunology Medical Sciences and Control of Catastrophic Processes These two volumes are aimed at the following five major target audiences University and College students Educators Professional practitioners Research personnel and Policy analysts managers and decision makers and NGOs

Encyclopedia of Optimization Christodoulos A. Floudas,Panos M. Pardalos,2008-09-04 The goal of the Encyclopedia of Optimization is to introduce the reader to a complete set of topics that show the spectrum of research the richness of ideas and the breadth of applications that has come from this field The second edition builds on the success of the former edition with more than 150 completely new entries designed to ensure that the reference addresses recent areas where optimization theories and techniques have advanced Particularly heavy attention resulted in health science and transportation with entries such as Algorithms for Genomics Optimization and Radiotherapy Treatment Design and Crew Scheduling

Handbook On Computer Learning And Intelligence (In 2 Volumes) Plamen Parvanov Angelov,2022-06-29 The Handbook on Computer Learning and Intelligence is a second edition which aims to be a one stop

shop for the various aspects of the broad research area of computer learning and intelligence This field of research evolved so much in the last five years that it necessitates this new edition of the earlier Handbook on Computational Intelligence This two volume handbook is divided into five parts Volume 1 covers Explainable AI and Supervised Learning Volume 2 covers three parts Deep Learning Intelligent Control and Evolutionary Computation The chapters detail the theory methodology and applications of computer learning and intelligence and are authored by some of the leading experts in the respective areas The fifteen core chapters of the previous edition have been written and significantly refreshed by the same authors Parts of the handbook have evolved to keep pace with the latest developments in computational intelligence in the areas that span across Machine Learning and Artificial Intelligence The Handbook remains dedicated to applications and engineering orientated aspects of these areas over abstract theories Related Link s *Control in Transportation Systems ...* ,2003

Mathematical Models in Economics - Volume II Wei-Bin Zhang,2010-06-10 Mathematical Models in Economics is a component of Encyclopedia of Mathematical Sciences in which is part of the global Encyclopedia of Life Support Systems EOLSS an integrated compendium of twenty one Encyclopedias This theme is organized into several different topics and introduces the applications of mathematics to economics Mathematical economics has experienced rapid growth generating many new academic fields associated with the development of mathematical theory and computer Mathematics is the backbone of modern economics It plays a basic role in creating ideas constructing new theories and empirically testing ideas and theories Mathematics is now an integral part of economics The main advances in modern economics are characterized by applying mathematics to various economic problems Many of today s profound insights into economic problems could hardly be obtained without the help of mathematics The concepts of equilibrium versus non equilibrium stability versus instability and steady states versus chaos in the contemporary literature are difficult to explain without mathematics The theme discusses on modern versions of some classical economic theories taking account of balancing between significance of economic issues and mathematical techniques These two volumes are aimed at the following five major target audiences University and College students Educators Professional practitioners Research personnel and Policy analysts managers and decision makers and NGOs *Control in Transportation Systems 2003* International Federation of Automatic Control,2004-08-02 The Symposium covers the system control aspects of all transportation modes road public rail air maritime and will host a variety of contributed invited and plenary papers from academia traffic and transportation administrations consultants and industry It will cover theoretical and methodological results recent research new trends practical operation and evaluation of transportation systems Provides the latest research on Transportation Systems Contains contributions written by experts in the field Part of the IFAC Proceedings Series which provides a comprehensive overview of the major topics in control engineering **Algorithms for Reinforcement Learning** Csaba Szepesvári,2022-05-31 Reinforcement learning is a learning paradigm concerned with learning to control a system so as to maximize a numerical

performance measure that expresses a long term objective What distinguishes reinforcement learning from supervised learning is that only partial feedback is given to the learner about the learner's predictions Further the predictions may have long term effects through influencing the future state of the controlled system Thus time plays a special role The goal in reinforcement learning is to develop efficient learning algorithms as well as to understand the algorithms' merits and limitations Reinforcement learning is of great interest because of the large number of practical applications that it can be used to address ranging from problems in artificial intelligence to operations research or control engineering In this book we focus on those algorithms of reinforcement learning that build on the powerful theory of dynamic programming We give a fairly comprehensive catalog of learning problems describe the core ideas note a large number of state of the art algorithms followed by the discussion of their theoretical properties and limitations Table of Contents Markov Decision Processes Value Prediction Problems Control For Further Exploration

Neural Networks and Learning Machines Simon S. Haykin, 2009 For graduate level neural network courses offered in the departments of Computer Engineering Electrical Engineering and Computer Science Renowned for its thoroughness and readability this well organized and completely up to date text remains the most comprehensive treatment of neural networks from an engineering perspective Matlab codes used for the computer experiments in the text are available for download at <http://www.pearsonhighered.com/haykin> Refocused revised and renamed to reflect the duality of neural networks and learning machines this edition recognizes that the subject matter is richer when these topics are studied together Ideas drawn from neural networks and machine learning are hybridized to perform improved learning tasks beyond the capability of either independently

Nonlinear Programming Dimitri Bertsekas, 2016-09-01 This book provides a comprehensive and accessible presentation of algorithms for solving continuous optimization problems It relies on rigorous mathematical analysis but also aims at an intuitive exposition that makes use of visualization where possible It places particular emphasis on modern developments and their widespread applications in fields such as large scale resource allocation problems signal processing and machine learning The 3rd edition brings the book in closer harmony with the companion works *Convex Optimization Theory* Athena Scientific 2009 *Convex Optimization Algorithms* Athena Scientific 2015 *Convex Analysis and Optimization* Athena Scientific 2003 and *Network Optimization* Athena Scientific 1998 These works are complementary in that they deal primarily with convex possibly nondifferentiable optimization problems and rely on convex analysis By contrast the nonlinear programming book focuses primarily on analytical and computational methods for possibly nonconvex differentiable problems It relies primarily on calculus and variational analysis yet it still contains a detailed presentation of duality theory and its uses for both convex and nonconvex problems This on line edition contains detailed solutions to all the theoretical book exercises Among its special features the book Provides extensive coverage of iterative optimization methods within a unifying framework Covers in depth duality theory from both a variational and a geometric point of view Provides a detailed treatment of interior point methods for

linear programming Includes much new material on a number of topics such as proximal algorithms alternating direction methods of multipliers and conic programming Focuses on large scale optimization topics of much current interest such as first order methods incremental methods and distributed asynchronous computation and their applications in machine learning signal processing neural network training and big data applications Includes a large number of examples and exercises Was developed through extensive classroom use in first year graduate courses *Forthcoming Books* Rose Arny,2001-08 *A Course in Reinforcement Learning* Dimitri Bertsekas,2023-06-21 These lecture notes were prepared for use in the 2023 ASU research oriented course on Reinforcement Learning RL that I have offered in each of the last five years Their 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 There are two major methodological RL approaches approximation in value space where we approximate in some way the optimal value function and approximation in policy space whereby we construct a generally suboptimal policy by using optimization over a suitably restricted class of policies The lecture notes focus primarily on approximation in value space with limited coverage of approximation in policy space However they are structured so that they can be easily supplemented by an instructor who wishes to go into approximation in policy space in greater detail using any of a number of available sources including the author s 2019 RL book While in these notes we deemphasize mathematical proofs there is considerable related analysis which supports our 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 SIGMETRICS '07 ,2007

Manufacturing & Service Operations Management ,2003

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