

# Dynamic Programming and Optimal Control

Dimitri P. Bertsekas



# Dynamic Programming And Optimal Control

**Donald E. Kirk**



## **Dynamic Programming And Optimal Control:**

*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

**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

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* Dimitri P. Bertsekas, 2017 the first volume is oriented towards modeling conceptualization and finite horizon problems but also includes a substantive introduction to infinite horizon problems that is suitable for classroom use The second volume is oriented towards mathematical analysis and computation treats infinite horizon problems extensively and provides an up to date account of approximate large scale dynamic programming and reinforcement learning The text contains many illustrations worked out examples and exercises

**Dynamic programming and optimal control, vol. 2** Dimitri P. Bertsekas, 2000      **Dynamic Programming and Optimal Control: Notes, Sources, and exercises, p.156** Dimitri P. Bertsekas, 2012      **Optimal Control Theory** Donald E. Kirk, 2012-04-26 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

**Adaptive Dynamic Programming with Applications in Optimal Control** Derong Liu, Qinglai Wei, Ding Wang, Xiong Yang, Hongliang Li, 2017-01-04 This book covers the most recent developments in adaptive dynamic programming ADP The text begins with a thorough background review of ADP making sure that readers are sufficiently familiar with the fundamentals In the core of the book the authors address first discrete and then continuous time systems Coverage of discrete time systems starts with a more general form of value iteration to demonstrate its convergence optimality and stability with complete and thorough theoretical analysis A more realistic form of value iteration is studied where value function approximations are assumed to have finite errors Adaptive Dynamic Programming also details another avenue of the ADP approach policy iteration Both basic and generalized forms of policy iteration based ADP are studied with complete and thorough theoretical analysis in terms of convergence optimality stability and error bounds Among continuous time systems the control of affine and nonaffine nonlinear systems is studied using the ADP approach which is then extended to other branches of control theory including decentralized control robust and guaranteed cost control and game theory In the last part of the book the real world significance of ADP theory is presented focusing on three application examples developed from the authors work renewable energy scheduling for smart power grids coal gasification processes and water gas shift reactions Researchers studying intelligent control methods and practitioners looking to apply them in the chemical process and power supply industries will find much to interest them in this thorough treatment of an advanced approach to control

*Stochastic Optimal Control: The Discrete-Time Case* Dimitri Bertsekas, Steven E. Shreve, 1996-12-01 This research monograph first published in 1978 by Academic Press remains the authoritative and comprehensive treatment of the mathematical foundations of stochastic optimal control of discrete time systems including the treatment of the intricate measure theoretic issues It is an excellent supplement to the first author's *Dynamic Programming and Optimal Control* Athena Scientific 2018 Review of the 1978 printing Bertsekas and Shreve have written a fine book The exposition is

extremely clear and a helpful introductory chapter provides orientation and a guide to the rather intimidating mass of literature on the subject Apart from anything else the book serves as an excellent introduction to the arcane world of analytic sets and other lesser known byways of measure theory Mark H A Davis Imperial College in IEEE Trans on Automatic Control Among its special features the book 1 Resolves definitively the mathematical issues of discrete time stochastic optimal control problems including Borel models and semi continuous models 2 Establishes the most general possible theory of finite and infinite horizon stochastic dynamic programming models through the use of analytic sets and universally measurable policies 3 Develops general frameworks for dynamic programming based on abstract contraction and monotone mappings 4 Provides extensive background on analytic sets Borel spaces and their probability measures 5 Contains much in depth research not found in any other textbook      *Optimal Control* Frank L. Lewis, Dragana Vrabie, Vassilis L. Syrmos, 2012-03-20

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

*The Application of Dynamic Programming to Optimal Control of a Second Order Process* Dennis LeRoy Dutcher, 1967

**Dynamic Programming and Optimal Control: Discounted problems - theory** Dimitri P. Bertsekas, 2017 the first volume is oriented towards modeling conceptualization and finite horizon problems but also includes a substantive introduction to infinite horizon problems that is suitable for classroom use The second volume is oriented towards mathematical analysis and computation treats infinite horizon problems extensively and provides an up to date account of approximate large scale dynamic programming and reinforcement learning The text contains many illustrations worked out examples and exercises      **Stochastic Optimal Control in Infinite Dimension** Giorgio Fabbri, Fausto Gozzi, Andrzej Świąch, 2017-06-22 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

**Self-Learning Optimal Control of Nonlinear Systems** Qinglai Wei,Ruizhuo Song,Benkai Li,Xiaofeng Lin,2017-06-13 This book presents a class of novel self learning optimal control schemes based on adaptive dynamic programming techniques which quantitatively obtain the optimal control schemes of the systems It analyzes the properties identified by the programming methods including the convergence of the iterative value functions and the stability of the system under iterative control laws helping to guarantee the effectiveness of the methods developed When the system model is known self learning optimal control is designed on the basis of the system model when the system model is not known adaptive dynamic programming is implemented according to the system data effectively making the performance of the system converge to the optimum With various real world examples to complement and substantiate the mathematical analysis the book is a valuable guide for engineers researchers and students in control science and engineering

**Optimal Control Theory** Zhongjing Ma,Suli Zou,2021-01-30 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

An Introduction to Optimal Control Theory

Onésimo Hernández-Lerma,Leonardo R. Laura-Guarachi,Saul Mendoza-Palacios,David González-Sánchez,2023-02-21 This book introduces optimal control problems for large families of deterministic and stochastic systems with discrete or continuous time parameter These families include most of the systems studied in many disciplines including Economics Engineering Operations Research and Management Science among many others The main objective is to give a concise systematic and reasonably self contained presentation of some key topics in optimal control theory To this end most of the analyses are based on the dynamic programming DP technique This technique is applicable to almost all control problems that appear in theory and applications They include for instance finite and infinite horizon control problems in which the underlying dynamic system follows either a deterministic or stochastic difference or differential equation In the infinite horizon case it also uses DP to study undiscounted problems such as the ergodic or long run average cost After a general introduction to control problems the book covers the topic dividing into four parts with different dynamical systems control of discrete time deterministic systems discrete time stochastic systems ordinary differential equations and finally a general continuous time MCP with applications for stochastic differential equations The first and second part should be accessible to undergraduate students with some knowledge of elementary calculus linear algebra and some concepts from probability theory random variables expectations and so forth Whereas the third and fourth part would be appropriate for advanced undergraduates or graduate students who have a working knowledge of mathematical analysis derivatives integrals and stochastic processes *Dynamic Programming and Its Application to Optimal Control* Hui Li,Yongsui Wen,2018-04

### **Differential Dynamic Programming and Optimal Control of Quality Constrained Continuous Dynamic Systems**

David J. W. Ruxton,1991 **Dynamic programming and its application to optimal control** R. Boudarel,J. Delmas,P. Guichet,1971 *Optimal Event-Triggered Control Using Adaptive Dynamic Programming* Sarangapani Jagannathan,Vignesh Narayanan,Avimanyu Sahoo,2024-06-21 Optimal Event triggered Control using Adaptive Dynamic Programming discusses event triggered controller design which includes optimal control and event sampling design for linear and nonlinear dynamic systems including networked control systems NCS when the system dynamics are both known and uncertain The NCS are a first step to realize cyber physical systems CPS or industry 4 0 vision The authors apply several powerful modern control techniques to the design of event triggered controllers and derive event trigger condition and demonstrate closed loop stability Detailed derivations rigorous stability proofs computer simulation examples and downloadable MATLAB codes are included for each case The book begins by providing background on linear and nonlinear systems NCS networked imperfections distributed systems adaptive dynamic programming and optimal control stability theory and optimal adaptive event triggered controller design in continuous time and discrete time for linear nonlinear and distributed systems It lays the foundation for reinforcement learning based optimal adaptive controller use for infinite horizons The text then Introduces event triggered control of linear and nonlinear systems describing the design of adaptive controllers for them Presents neural



network based optimal adaptive control and game theoretic formulation of linear and nonlinear systems enclosed by a communication network Addresses the stochastic optimal control of linear and nonlinear NCS by using neuro dynamic programming Explores optimal adaptive design for nonlinear two player zero sum games under communication constraints to solve optimal policy and event trigger condition Treats an event sampled distributed linear and nonlinear systems to minimize transmission of state and control signals within the feedback loop via the communication network Covers several examples along the way and provides applications of event triggered control of robot manipulators UAV and distributed joint optimal network scheduling and control design for wireless NCS CPS in order to realize industry 4 0 vision An ideal textbook for senior undergraduate students graduate students university researchers and practicing engineers Optimal Event Triggered Control Design using Adaptive Dynamic Programming instills a solid understanding of neural network based optimal controllers under event sampling and how to build them so as to attain CPS or Industry 4 0 vision

## Decoding **Dynamic Programming And Optimal Control**: Revealing the Captivating Potential of Verbal Expression

In a period characterized by interconnectedness and an insatiable thirst for knowledge, the captivating potential of verbal expression has emerged as a formidable force. Its power to evoke sentiments, stimulate introspection, and incite profound transformations is genuinely awe-inspiring. Within the pages of "**Dynamic Programming And Optimal Control**," a mesmerizing literary creation penned by way of a celebrated wordsmith, readers attempt an enlightening odyssey, unraveling the intricate significance of language and its enduring impact on our lives. In this appraisal, we shall explore the book's central themes, evaluate its distinctive writing style, and gauge its pervasive influence on the hearts and minds of its readership.

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## **Dynamic Programming And Optimal Control Introduction**

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