Approximate Dynamic Programming Solving The Curse

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LOWERY EILEEN

Markov Decision Processes John Wiley & Sons
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.
Handbook of Learning and Approximate Dynamic Programming Springer
The Wiley-Interscience Paperback Series consists of selected booksthat have been made more accessible to consumers in an effort toincrease global appeal and general circulation. With these newunabridged softcover volumes, Wiley hopes to extend the lives ofthese works by making them available to future generations ofstatisticians, mathematicians, and scientists. "This text is unique in bringing together so many resultshitherto found only in part in other texts and papers. . . . Thetext is fairly self-contained, inclusive of some basic mathematicalresults needed, and provides a rich diet of examples, applications,and exercises. The bibliographical material at the end of eachchapter is excellent, not only from a historical perspective, butbecause it is valuable for researchers in acquiring a goodperspective of the MDP research potential." —Zentralblatt fur Mathematik ". . . it is of great value to advanced-level students,researchers, and professional practitioners of this field to havenow a complete volume (with more than 600 pages) devoted to thistopic. . . . Markov Decision Processes: Discrete Stochastic DynamicProgramming represents an up-to-date, unified, and rigoroustreatment of theoretical and computational aspects of discrete-timeMarkov decision processes." —Journal of the American Statistical Association
Stochastic Decomposition Athena Scientific
This book provides a unified approach for the study of constrained Markov decision processes with a finite state space and unbounded costs. Unlike the single controller case considered in many other books, the author considers a single controller with several objectives, such as minimizing delays and loss, probabilities, and maximization of throughputs. It is desirable to design a controller that minimizes one cost objective, subject to inequality constraints on other cost objectives. This framework describes dynamic decision problems arising frequently in many engineering fields. A thorough overview of these applications is presented in the introduction. The book is then divided into three sections that build upon each other. The first part explains the theory for the finite state space. The author characterizes the set of achievable expected occupation measures as well as performance vectors, and identifies simple classes of policies among which optimal policies exist. This allows the reduction of the original dynamic into a linear program. A Lagranian approach is then used to derive the dual linear program using dynamic programming techniques. In the second part, these results are extended to the infinite state space and action spaces. The author provides two frameworks: the case where costs are bounded below and the contracting framework. The third part builds upon the results of the first two parts and examines asymptotical results of the convergence of both the value and the policies in the time horizon and in the discount factor. Finally, several state truncation algorithms that enable the approximation of the solution of the original control problem via finite linear programs are given.
Robust Adaptive Dynamic Programming John Wiley & Sons
Praise for the First Edition "Finally, a book devoted to dynamic programming and written using the language of operations research (OR)! This beautiful book fills a gap in the libraries of OR specialists and practitioners." —Computing Reviews This new edition showcases a focus on modeling and computation for complex classes of approximate dynamic programming problems Understanding approximate dynamic programming (ADP) is vital in order to develop practical and high-quality solutions to complex industrial problems, particularly when those problems involve making decisions in the presence of uncertainty. Approximate Dynamic Programming, Second Edition uniquely integrates four distinct disciplines—Markov decision processes, mathematical programming, simulation, and statistics—to demonstrate how to successfully approach, model, and solve a wide range of real-life problems using ADP. The book continues to bridge the gap between computer science, simulation, and operations research and now adopts the notation and vocabulary of reinforcement learning as well as stochastic search and simulation optimization. The author outlines the essential algorithms that serve as a starting point in the design of practical solutions for real problems. The three curses of dimensionality that impact complex problems are introduced and detailed coverage of implementation challenges is provided. The Second Edition also features: A new chapter describing four fundamental classes of policies for working with diverse stochastic optimization problems: myopic policies, look-ahead policies, policy function approximations, and policies based on value function approximations A new chapter on policy search that brings together stochastic search and simulation optimization concepts and introduces a new class of optimal learning strategies Updated coverage of the exploration exploitation problem in ADP, now including a recently developed method for doing active learning in the presence of a physical state, using the concept of the knowledge gradient A new sequence of chapters describing statistical methods for approximating value functions, estimating the value of a fixed policy, and value function approximation while searching for optimal policies The presented coverage of ADP emphasizes models and algorithms, focusing on related applications and computation while also discussing the theoretical side of the topic that explores proofs of convergence and rate of convergence. A related website features an ongoing discussion of the evolving fields of approximation dynamic programming and reinforcement learning, along with additional readings, software, and datasets. Requiring only a basic understanding of statistics and probability, Approximate Dynamic Programming, Second Edition is an excellent book for industrial engineering and operations research courses at the upper-undergraduate and graduate levels. It also serves as a valuable reference for researchers and professionals who utilize dynamic programming, stochastic programming, and control theory to solve problems in their everyday work.
Reinforcement Learning, second edition Springer Science & Business Media
Eugene A. Feinberg Adam Shwartz This volume deals with the theory of Markov Decision Processes (MDPs) and their applications. Each chapter was written by a leading expert in the re spective area. The papers cover major research areas and methodologies, and discuss open questions and future research directions. The papers can be read independently, with the basic notation and concepts ofSection 1.2. Most chap ters should be accessible by graduate or advanced undergraduate students in fields of operations research, electrical engineering, and computer science. 1.1 AN OVERVIEW OF MARKOV DECISION PROCESSES The theory of Markov Decision Processes-also known under several other names including sequential stochastic optimization, discrete-time stochastic control, and stochastic dynamic programming-studiessequential optimization ofdiscrete time stochastic systems. The basic object is a discrete-time stochas tic system whose transition mechanism can be controlled over time. Each control policy defines the stochastic process and values of objective functions associated with this process. The goal is to select a "good" control policy. In real life, decisions that humans and computers make on all levels usually have two types ofimpacts: (i) they cost orsavetime, money, or other resources, or they bring revenues, as well as (ii) they have an impact on the future, by influencing the dynamics. In many situations, decisions with the largest immediate profit may not be good in view offuture events. MDPs model this paradigm and provide results on the structure and existence of good policies and on methods for their calculation.
Interactive Collaborative Information Systems "O'Reilly Media, Inc."
asfbgsdfg
Approximate Dynamic Programming Athena Scientific
A broad introduction to algorithms for decision making under uncertainty, introducing the underlying mathematical problem formulations and the algorithms for solving them. Automated decision-making systems or decision-support systems—used in applications that range from aircraft collision avoidance to breast cancer screening—must be designed to account for various sources of uncertainty while carefully balancing multiple objectives. This textbook provides a broad introduction to algorithms for decision making under uncertainty, covering the underlying mathematical problem formulations and the algorithms for solving them. The book first addresses the problem of reasoning about uncertainty and objectives in simple decisions at a single point in time, and then turns to sequential decision problems in stochastic environments where the outcomes of our actions are uncertain. It goes on to address model uncertainty, when we do not start with a known model and must learn how to act through interaction with the environment; state uncertainty, in which we do not know the current state of the environment due to imperfect perceptual information; and decision contexts involving multiple agents. The book focuses primarily on planning and reinforcement learning, although some of the techniques presented draw on elements of supervised learning and optimization. Algorithms are implemented in the Julia programming language. Figures, examples, and exercises convey the intuition behind the various approaches presented.
Reinforcement Learning and Optimal Control Springer
From household appliances to applications in robotics, engineered systems involving complex dynamics can only be as effective as the algorithms that control them. While Dynamic Programming (DP) has provided researchers with a way to optimally solve decision and control problems involving complex dynamic systems, its practical value was limited by algorithms that lacked the capacity to scale up to realistic problems. However, in recent years, dramatic developments in Reinforcement Learning (RL), the model-free counterpart of DP, changed our understanding of what is possible. Those developments led to the creation of reliable methods that can be applied even when a mathematical model of the system is unavailable, allowing researchers to solve challenging control problems in engineering, as well as in a variety of other disciplines, including economics, medicine, and artificial intelligence. Reinforcement Learning and Dynamic Programming Using Function Approximators provides a comprehensive and unparalleled exploration of the field of RL and DP. With a focus on continuous-variable problems, this seminal text details essential developments that have substantially altered the field over the past decade. In its pages, pioneering experts provide a concise introduction to classical RL and DP, followed by an extensive presentation of the state-of-the-art and novel methods in RL and DP with approximation. Combining algorithm development with theoretical guarantees, they elaborate on their work with illustrative examples and insightful comparisons. Three individual chapters are dedicated to representative algorithms from each of the major classes of techniques: value iteration, policy iteration, and policy search. The features and performance of these algorithms are highlighted in extensive experimental studies on a range of control applications. The recent development of applications involving complex systems has led to a surge of interest in RL and DP methods and the subsequent need for a quality resource on the subject. For graduate students and others new to the field, this book offers a thorough introduction to both the basics and emerging methods. And for those researchers and practitioners working in the fields of optimal and adaptive control, machine learning, artificial intelligence, and operations research, this resource offers a combination of practical algorithms, theoretical analysis, and comprehensive examples that they will be able to adapt and apply to their own work. Access the authors' website at

www.dcsc.tudelft.nl/rlbook/ for additional material, including computer code used in the studies and information concerning new developments.

Adaptive Dynamic Programming with Applications in Optimal Control Athena Scientific

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.

Anticipatory Optimization for Dynamic Decision Making Research Press

A complete and accessible introduction to the real-world applications of approximate dynamic programming With the growing levels of sophistication in modern-day operations, it is vital for practitioners to understand how to approach, model, and solve complex industrial problems. Approximate Dynamic Programming is a result of the author's decades of experience working in large industrial settings to develop practical and high-quality solutions to problems that involve making decisions in the presence of uncertainty. This groundbreaking book uniquely integrates four distinct disciplines—Markov design processes, mathematical programming, simulation, and statistics—to demonstrate how to successfully model and solve a wide range of real-life problems using the techniques of approximate dynamic programming (ADP). The reader is introduced to the three curses of dimensionality that impact complex problems and is also shown how the post-decision state variable allows for the use of classical algorithmic strategies from operations research to treat complex stochastic optimization problems. Designed as an introduction and assuming no prior training in dynamic programming of any form, Approximate Dynamic Programming contains dozens of algorithms that are intended to serve as a starting point in the design of practical solutions for real problems. The book provides detailed coverage of implementation challenges including: modeling complex sequential decision processes under uncertainty, identifying robust policies, designing and estimating value function approximations, choosing effective stepsize rules, and resolving convergence issues. With a focus on modeling and algorithms in conjunction with the language of mainstream operations research, artificial intelligence, and control theory, Approximate Dynamic Programming: Models complex, high-dimensional problems in a natural and practical way, which draws on years of industrial projects Introduces and emphasizes the power of estimating a value function around the post-decision state, allowing solution algorithms to be broken down into three fundamental steps: classical simulation, classical optimization, and classical statistics Presents a thorough discussion of recursive estimation, including fundamental theory and a number of issues that arise in the development of practical algorithms Offers a variety of methods for approximating dynamic programs that have appeared in previous literature, but that have never been presented in the coherent format of a book Motivated by examples from modern-day operations research, Approximate Dynamic Programming is an accessible introduction to dynamic modeling and is also a valuable guide for the development of high-quality solutions to problems that exist in operations research and engineering. The clear and precise presentation of the material makes this an appropriate text for advanced undergraduate and beginning graduate courses, while also serving as a reference for researchers and practitioners. A companion Web site is available for readers, which includes additional exercises, solutions to exercises, and data sets to reinforce the book's main concepts.

Adaptive Dynamic Programming for Control Wiley-Interscience

The capacitated lot-sizing problem (CLSP) is a core problem for successfully reducing overall costs in any production process. The exact approaches proposed for solving the CLSP are based on two major methods: mixed-integer programming and dynamic programming. This thesis provides a new idea for approximating the inventory cost function to be used in a truncated dynamic program for solving the CLSP. In the proposed method, by using only a partial dynamic process, the inventory cost function is approximated, and then the resulting approximate cost function is used as a value function in each stage of the approximate dynamic program. In this thesis, six different algorithms are developed for the CLSP, based on three different types of approximate dynamic programming approaches. The general methodology combines dynamic programming with data fitting and approximation techniques to estimate the inventory cost function at each stage of the dynamic program. Furthermore, three main algorithmic frameworks to compute a piecewise linear approximate inventory cost function for the CLSP are provided. The first approach integrates regression models into an approximate dynamic program. The second approach uses the information obtained by a partial dynamic process to approximate the piecewise linear inventory cost function. The third approach uses slope-check and bisection techniques to locate the breakpoints of the piecewise linear function in order to approximate the inventory cost function for the CLSP. The effectiveness of the proposed methods are analyzed on various types of CLSP instances with different cost and capacity characteristics. Computational results show that approximation approaches could considerably decrease the computational time required by the dynamic program and the integer program for different CLSP instances. Furthermore, in most cases, some of the proposed approaches can accurately capture the optimal solution of the problem.

Approximate Dynamic Programming Athena Scientific

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.

The Design of Approximation Algorithms Springer

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.

Adaptive Dynamic Programming: Single and Multiple Controllers John Wiley & Sons

This rapidly developing field encompasses many disciplines including operations research, mathematics, and probability. Conversely, it is being applied in a wide variety of subjects ranging from agriculture to financial planning and from industrial engineering to computer networks. This textbook provides a first course in stochastic programming suitable for students with a basic knowledge of linear programming, elementary analysis, and probability. The authors present a broad overview of the main themes and methods of the subject, thus helping students develop an intuition for how to model uncertainty into mathematical problems, what uncertainty changes bring to the decision process, and what techniques help to manage uncertainty in solving the problems. The early chapters introduce some worked examples of stochastic programming, demonstrate how a stochastic model is formally built, develop the properties of stochastic programs and the basic solution techniques used to solve them. The book then goes on to cover approximation and sampling techniques and is rounded off by an in-depth case study. A well-paced and wide-ranging introduction to this subject.

Dynamic Programming and Optimal Control Packt Publishing Ltd

Motivation Stochastic Linear Programming with recourse represents one of the more widely applicable models for incorporating uncertainty within in which the SLP optimization models. There are several arenas model is appropriate, and such models have found applications in air line yield management, capacity planning, electric power generation planning, financial planning, logistics, telecommunications network planning, and many more. In some of these applications, modelers represent uncertainty in terms of only a few seenarios and formulate a large scale linear program which is then solved using LP software. However, there are many applications, such as the telecommunications planning problem discussed in this book, where a handful of seenarios do not capture variability well enough to provide a reasonable model of the actual decision-making problem. Problems of this type easily exceed the capabilities of LP software by several orders of magnitude. Their solution requires the use of algorithmic methods that exploit the structure of the SLP model in a manner that will accommodate large scale applications.

Dynamic Programming and Optimal Control John Wiley & Sons

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.

Graph Algorithms Academic Press

The increasing complexity of our world demands new perspectives on the role of technology in decision making. Human decision making has its li- tations in terms of information-processing capacity. We need new technology to cope with the increasingly complex and information-rich nature of our modern society. This is particularly true for critical environments such as crisis management and tra?c management, where humans need to engage in close collaborations with arti?cial systems to observe and understand the situation and respond in a sensible way. We believe that close collaborations between humans and arti?cial systems will become essential and that the importance of research into Interactive Collaborative Information Systems (ICIS) is self-evident. Developments in information and communication technology have ra- cally changed our working environments. The vast amount of information available nowadays and the wirelessly networked nature of our modern so- ety open up new opportunities to handle di?cult decision-making situations such as computer-supported situation assessment and distributed decision making. To make good use of these new possibilities, we need to update our traditional views on the role and capabilities of information systems. The aim of the Interactive Collaborative Information Systems project is to develop techniques that support humans in complex information en- ronments and that facilitate distributed decision-making capabilities. ICIS emphasizes the

importance of building actor-agent communities: close c- laborations between human and arti?cial actors that highlight their comp- mentary capabilities, and in which task distribution is ?exible and adaptive.

Algorithms for Decision Making Springer Nature

Introduction to Stochastic Dynamic Programming presents the basic theory and examines the scope of applications of stochastic dynamic programming. The book begins with a chapter on various finite-stage models, illustrating the wide range of applications of stochastic dynamic programming. Subsequent chapters study infinite-stage models: discounting future returns, minimizing nonnegative costs, maximizing nonnegative returns, and maximizing the long-run average return. Each of these chapters first considers whether an optimal policy need exist—providing counterexamples where appropriate—and then presents methods for obtaining such policies when they do. In addition, general areas of application are presented. The final two chapters are concerned with more specialized models. These include stochastic scheduling models and a type of process known as a multiproject bandit. The mathematical prerequisites for this text are relatively few. No prior knowledge of dynamic programming is assumed and only a moderate familiarity with probability— including the use of conditional expectation—is necessary.

Artificial Intelligence with Python MIT Press

This handbook presents state-of-the-art research in reinforcement learning, focusing on its applications in the control and game theory of dynamic systems and future directions for related research and technology. The contributions gathered in this book deal with challenges faced when using learning and adaptation methods to solve academic and industrial problems, such as optimization in dynamic environments with single and multiple agents, convergence and performance analysis, and online implementation. They explore means by which these difficulties can be solved, and cover a wide range of related topics including: deep learning; artificial intelligence; applications of game theory; mixed modality learning; and multi-agent reinforcement learning. Practicing engineers and scholars in the field of machine learning, game theory, and autonomous control will find the Handbook of Reinforcement Learning and Control to be thought-provoking, instructive and informative.

sgfrgds Springer Science & Business Media

This tutorial reviews techniques for planning and learning in Markov Decision Processes (MDPs) with linear function approximation of the value function. Two major paradigms for finding optimal policies were considered: dynamic programming (DP) techniques for planning and reinforcement learning (RL).