

## Markov Decision Process

Markov decision process is a discrete time stochastic control process where states are partly random and partly under control of a decision

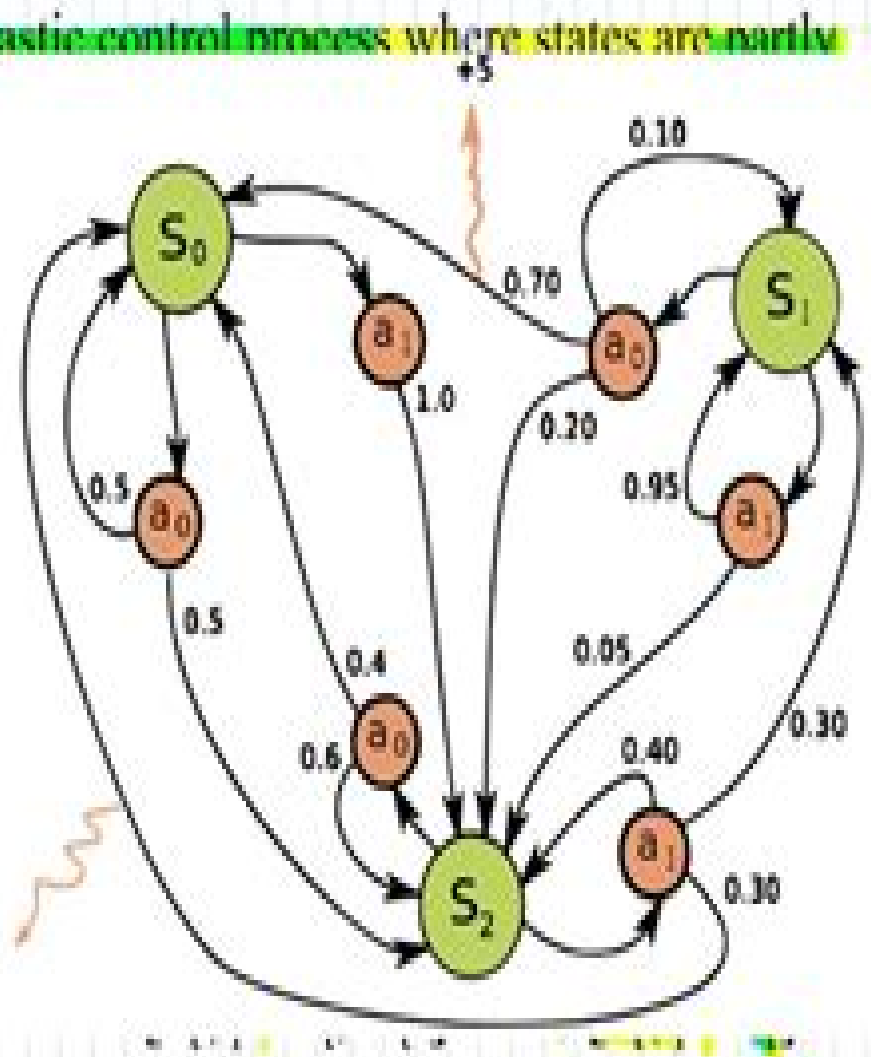
The process also satisfies Markov property.

At each time step, the process is in some state in state  $s_t$ . The process responds at the next time agent a corresponding reward  $r_{a_t}(s_t, s_{t+1})$ . As a property the probability of transitioning from:

$$P[s_{t+1} / s_0, s_1, \dots, s_t, a_0, a_1, \dots, a_t]$$

If we combine a Markov decision process with an agent will choose when in state  $s_t$ , i.e.,  $a_t = \pi(s_t)$

$$P[s_{t+1} / s_0, s_1, \dots, s_t, a_0, a_1, \dots, a_t]$$



# Markov Decision Processes

**A.V. Gheorghe**



## **Markov Decision Processes:**

**Markov Decision Processes with Their Applications** Qiying Hu, Wuyi Yue, 2007-09-14 Markov decision processes MDPs also called stochastic dynamic programming were first studied in the 1960s MDPs can be used to model and solve dynamic decision making problems that are multi period and occur in stochastic circumstances There are three basic branches in MDPs discrete time MDPs continuous time MDPs and semi Markov decision processes Starting from these three branches many generalized MDPs models have been applied to various practical problems These models include partially observable MDPs adaptive MDPs MDPs in stochastic environments and MDPs with multiple objectives constraints or imprecise parameters Markov Decision Processes With Their Applications examines MDPs and their applications in the optimal control of discrete event systems DESs optimal replacement and optimal allocations in sequential online auctions The book presents four main topics that are used to study optimal control problems a new methodology for MDPs with discounted total reward criterion transformation of continuous time MDPs and semi Markov decision processes into a discrete time MDPs model thereby simplifying the application of MDPs MDPs in stochastic environments which greatly extends the area where MDPs can be applied applications of MDPs in optimal control of discrete event systems optimal replacement and optimal allocation in sequential online auctions This book is intended for researchers mathematicians advanced graduate students and engineers who are interested in optimal control operation research communications manufacturing economics and electronic commerce

**Markov Decision Processes in Artificial Intelligence** Olivier Sigaud, Olivier Buffet, 2013-03-04 Markov Decision Processes MDPs are a mathematical framework for modeling sequential decision problems under uncertainty as well as reinforcement learning problems Written by experts in the field this book provides a global view of current research using MDPs in artificial intelligence It starts with an introductory presentation of the fundamental aspects of MDPs planning in MDPs reinforcement learning partially observable MDPs Markov games and the use of non classical criteria It then presents more advanced research trends in the field and gives some concrete examples using illustrative real life applications

**Markov Decision Processes** Paul R. Thie, 1983

**Markov Decision Processes with Applications to Finance** Nicole Bäuerle, Ulrich Rieder, 2011-06-06 The theory of Markov decision processes focuses on controlled Markov chains in discrete time The authors establish the theory for general state and action spaces and at the same time show its application by means of numerous examples mostly taken from the fields of finance and operations research By using a structural approach many technicalities concerning measure theory are avoided They cover problems with finite and infinite horizons as well as partially observable Markov decision processes piecewise deterministic Markov decision processes and stopping problems The book presents Markov decision processes in action and includes various state of the art applications with a particular view towards finance It is useful for upper level undergraduates Master s students and researchers in both applied probability and finance and provides exercises without solutions

**Handbook of Markov**

**Decision Processes** Eugene A. Feinberg, Adam Schwartz, 2012-12-06 Eugene A Feinberg Adam Schwartz This volume deals with the theory of Markov Decision Processes MDPs and their applications Each chapter was written by a leading expert in the respective 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 of Section 1.2 Most chapters 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 studies sequential optimization of discrete time stochastic systems The basic object is a discrete time stochastic 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 of impacts i they cost or save time 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 of future events MDPs model this paradigm and provide results on the structure and existence of good policies and on methods for their calculation

Examples in Markov Decision Processes A. B. Piunovskiy, 2013 This invaluable book provides approximately eighty examples illustrating the theory of controlled discrete time Markov processes Except for applications of the theory to real life problems like stock exchange queues gambling optimal search etc the main attention is paid to counter intuitive unexpected properties of optimization problems Such examples illustrate the importance of conditions imposed in the theorems on Markov Decision Processes Many of the examples are based upon examples published earlier in journal articles or textbooks while several other examples are new The aim was to collect them together in one reference book which should be considered as a complement to existing monographs on Markov decision processes The book is self contained and unified in presentation The main theoretical statements and constructions are provided and particular examples can be read independently of others Examples in Markov Decision Processes is an essential source of reference for mathematicians and all those who apply the optimal control theory to practical purposes When studying or using mathematical methods the researcher must understand what can happen if some of the conditions imposed in rigorous theorems are not satisfied Many examples confirming the importance of such conditions were published in different journal articles which are often difficult to find This book brings together examples based upon such sources along with several new ones In addition it indicates the areas where Markov decision processes can be used Active researchers can refer to this book on applicability of mathematical methods and theorems It is also suitable reading for graduate and research students where they will better understand the theory

Examples In Markov Decision Processes Alexey B Piunovskiy, 2012-09-21 This invaluable book

provides approximately eighty examples illustrating the theory of controlled discrete time Markov processes Except for applications of the theory to real life problems like stock exchange queues gambling optimal search etc the main attention is paid to counter intuitive unexpected properties of optimization problems Such examples illustrate the importance of conditions imposed in the theorems on Markov Decision Processes Many of the examples are based upon examples published earlier in journal articles or textbooks while several other examples are new The aim was to collect them together in one reference book which should be considered as a complement to existing monographs on Markov decision processes The book is self contained and unified in presentation The main theoretical statements and constructions are provided and particular examples can be read independently of others Examples in Markov Decision Processes is an essential source of reference for mathematicians and all those who apply the optimal control theory to practical purposes When studying or using mathematical methods the researcher must understand what can happen if some of the conditions imposed in rigorous theorems are not satisfied Many examples confirming the importance of such conditions were published in different journal articles which are often difficult to find This book brings together examples based upon such sources along with several new ones In addition it indicates the areas where Markov decision processes can be used Active researchers can refer to this book on applicability of mathematical methods and theorems It is also suitable reading for graduate and research students where they will better understand the theory

Markov Decision Processes Martin L. Puterman, 2014-08-28 The Wiley Interscience Paperback Series consists of selected books that have been made more accessible to consumers in an effort to increase global appeal and general circulation With these new unabridged softcover volumes Wiley hopes to extend the lives of these works by making them available to future generations of statisticians mathematicians and scientists This text is unique in bringing together so many results hitherto found only in part in other texts and papers The text is fairly self contained inclusive of some basic mathematical results needed and provides a rich diet of examples applications and exercises The bibliographical material at the end of each chapter is excellent not only from a historical perspective but because it is valuable for researchers in acquiring a good perspective of the MDP research potential Zentralblatt für Mathematik it is of great value to advanced level students researchers and professional practitioners of this field to have now a complete volume with more than 600 pages devoted to this topic Markov Decision Processes Discrete Stochastic Dynamic Programming represents an up to date unified and rigorous treatment of theoretical and computational aspects of discrete time Markov decision processes Journal of the American Statistical Association

*Continuous-Time Markov Decision Processes* Xianping Guo, Onésimo Hernández-Lerma, 2009-09-18 Continuous time Markov decision processes MDPs also known as controlled Markov chains are used for modeling decision making problems that arise in operations research for instance inventory manufacturing and queueing systems computer science communications engineering control of populations such as fisheries and epidemics and management science among many other fields This volume provides a unified systematic self contained

presentation of recent developments on the theory and applications of continuous time MDPs The MDPs in this volume include most of the cases that arise in applications because they allow unbounded transition and reward cost rates Much of the material appears for the first time in book form

*Competitive Markov Decision Processes* Jerzy Filar, Koos Vrieze, 2012-12-06 This book is intended as a text covering the central concepts and techniques of Competitive Markov Decision Processes It is an attempt to present a rigorous treatment that combines two significant research topics Stochastic Games and Markov Decision Processes which have been studied extensively and at times quite independently by mathematicians operations researchers engineers and economists Since Markov decision processes can be viewed as a special noncompetitive case of stochastic games we introduce the new terminology Competitive Markov Decision Processes that emphasizes the importance of the link between these two topics and of the properties of the underlying Markov processes The book is designed to be used either in a classroom or for self study by a mathematically mature reader In the Introduction Chapter 1 we outline a number of advanced undergraduate and graduate courses for which this book could usefully serve as a text A characteristic feature of competitive Markov decision processes and one that inspired our long standing interest is that they can serve as an orchestra containing the instruments of much of modern applied and at times even pure mathematics They constitute a topic where the instruments of linear algebra applied probability mathematical programming analysis and even algebraic geometry can be played sometimes solo and sometimes in harmony to produce either beautifully simple or equally beautiful but baroque melodies that is theorems

*Decision Processes in Dynamic Probabilistic Systems* A.V. Gheorghe, 2012-12-06 Et moi si j'avait su comment en revenir One service mathematics has rendered the journey would be human race It has put common sense back where it belongs on the topmost shelf next Jules Verne The dusty canister labelled discarded nonsense The series is divergent therefore we may be able to do something with it Eric T Bell On Heaviside Mathematics is a tool for thought A highly necessary tool in a world where both feedback and nonlinearities abound Similarly all kinds of parts of mathematics serve as tools for other parts and for other sciences Applying a simple rewriting rule to the quote on the right above one finds such statements as One service topology has rendered mathematical physics One service logic has rendered computer science One service category theory has rendered mathematics All arguably true And all statements obtainable this way form part of the raison d'être of this series

Markov Decision Processes in Practice Richard J. Boucherie, Nico M. van Dijk, 2017-03-10 This book presents classical Markov Decision Processes MDP for real life applications and optimization MDP allows users to develop and formally support approximate and simple decision rules and this book showcases state of the art applications in which MDP was key to the solution approach The book is divided into six parts Part 1 is devoted to the state of the art theoretical foundation of MDP including approximate methods such as policy improvement successive approximation and infinite state spaces as well as an instructive chapter on Approximate Dynamic Programming It then continues with five parts of specific and non exhaustive

application areas Part 2 covers MDP healthcare applications which includes different screening procedures appointment scheduling ambulance scheduling and blood management Part 3 explores MDP modeling within transportation This ranges from public to private transportation from airports and traffic lights to car parking or charging your electric car Part 4 contains three chapters that illustrates the structure of approximate policies for production or manufacturing structures In Part 5 communications is highlighted as an important application area for MDP It includes Gittins indices down to earth call centers and wireless sensor networks Finally Part 6 is dedicated to financial modeling offering an instructive review to account for financial portfolios and derivatives under proportional transactional costs The MDP applications in this book illustrate a variety of both standard and non standard aspects of MDP modeling and its practical use This book should appeal to readers for practicing academic research and educational purposes with a background in among others operations research mathematics computer science and industrial engineering

### **Planning with Markov Decision Processes**

Mausam Natarajan, Andrey Kolobov, 2022-06-01 Markov Decision Processes MDPs are widely popular in Artificial Intelligence for modeling sequential decision making scenarios with probabilistic dynamics They are the framework of choice when designing an intelligent agent that needs to act for long periods of time in an environment where its actions could have uncertain outcomes MDPs are actively researched in two related subareas of AI probabilistic planning and reinforcement learning Probabilistic planning assumes known models for the agent's goals and domain dynamics and focuses on determining how the agent should behave to achieve its objectives On the other hand reinforcement learning additionally learns these models based on the feedback the agent gets from the environment This book provides a concise introduction to the use of MDPs for solving probabilistic planning problems with an emphasis on the algorithmic perspective It covers the whole spectrum of the field from the basics to state of the art optimal and approximation algorithms We first describe the theoretical foundations of MDPs and the fundamental solution techniques for them We then discuss modern optimal algorithms based on heuristic search and the use of structured representations A major focus of the book is on the numerous approximation schemes for MDPs that have been developed in the AI literature These include determinization based approaches sampling techniques heuristic functions dimensionality reduction and hierarchical representations Finally we briefly introduce several extensions of the standard MDP classes that model and solve even more complex planning problems

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Approximation Algorithms Advanced Notes

Markovian Decision Processes Hisashi Mine, Shunji Osaki, 1970 Markovian

decision processes with discounting Markovian decision processes with no discounting Dynamic programming viewpoint of markovian decision processes Semi markovian decision processes Generalized markovian decision processes The principle of contraction mappings in markovian decision processes

Constrained Markov Decision Processes Eitan Altman, 1999-03-30

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 Lagrangian 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

**Markov Chains and Decision Processes for Engineers and Managers** Theodore J. Sheskin, 2016-04-19 Recognized as a powerful tool for dealing with uncertainty Markov modeling can enhance your ability to analyze complex production and service systems However most books on Markov chains or decision processes are often either highly theoretical with few examples or highly prescriptive with little justification for the steps of the algorithms

**Simulation-Based Algorithms for Markov Decision Processes** Hyeon Soo Chang, Jiaqiao Hu, Michael C. Fu, Steven I. Marcus, 2013-02-26 Markov decision process MDP models are widely used for modeling sequential decision making problems that arise in engineering economics computer science and the social sciences Many real world problems modeled by MDPs have huge state and or action spaces giving an opening to the curse of dimensionality and so making practical solution of the resulting models intractable In other cases the system of interest is too complex to allow explicit specification of some of the MDP model parameters but simulation samples are readily available e g for random transitions and costs For these settings various sampling and population based algorithms have been developed to overcome the difficulties of computing an optimal solution in terms of a policy and or value function Specific approaches include adaptive sampling evolutionary policy iteration evolutionary random policy search and model reference adaptive search This substantially enlarged new edition reflects the latest developments in novel algorithms and their underpinning theories and presents an updated account of the topics that have emerged since the publication of the first edition Includes innovative material on MDPs both in constrained settings and with uncertain transition properties game theoretic method for solving MDPs theories for developing roll out based algorithms and details of approximation stochastic annealing a population based on line simulation based algorithm The self contained approach of



this book will appeal not only to researchers in MDPs stochastic modeling and control and simulation but will be a valuable source of tuition and reference for students of control and operations research      *Learning Representation and Control in Markov Decision Processes* Sridhar Mahadevan,2009 Provides a comprehensive survey of techniques to automatically construct basis functions or features for value function approximation in Markov decision processes and reinforcement learning      **Markov Processes and Controlled Markov Chains** Zhenting Hou,Jerzy A. Filar,Anyue Chen,2002-09-30 The general theory of stochastic processes and the more specialized theory of Markov processes evolved enormously in the second half of the last century In parallel the theory of controlled Markov chains or Markov decision processes was being pioneered by control engineers and operations researchers Researchers in Markov processes and controlled Markov chains have been for a long time aware of the synergies between these two subject areas However this may be the first volume dedicated to highlighting these synergies and almost certainly it is the first volume that emphasizes the contributions of the vibrant and growing Chinese school of probability The chapters that appear in this book reflect both the maturity and the vitality of modern day Markov processes and controlled Markov chains They also will provide an opportunity to trace the connections that have emerged between the work done by members of the Chinese school of probability and the work done by the European US Central and South American and Asian scholars      Markov Decision Processes ,1991

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