Preface

Complex Networks are the heart of Operations Research and Operations Research is in the core of Complex Networks.

Panos Pardalos

This book comprises the recent results on studying stochastic dynamic programming models and solving optimal control problems on networks. The main attention is addressed to stochastic versions of classical discrete control problems, Markov decision processes, and a game-theoretical approach to these stochastic dynamic models. The authors included in the book their own results concerning the determination of the optimal solution of discrete optimal control problems on networks and solving the game variants of Markov decision problems in the sense of computational networks.

Investigations on elaborations of efficient methods and algorithms for modern stochastic dynamic programming problems represent a relevant topic in Operations Research. With respect to computational networks, stochastic dynamic optimization models are widely used for studying and solving many practical decision problems from diverse areas such as ecology, economics, engineering, communications systems, etc. Therefore, in the book an attempt is made to systematize the most important existing methods for the mentioned class of problems as well as to describe new algorithms for solving different classes of the stochastic dynamic programming problems.

The book consists of four chapters.

The first chapter studies the finite state space of Markov processes and gives a review of existing methods and algorithms for determining the main characteristics in Markov chains. New approaches based on dynamic programming and combinatorial methods for determining the state-time probabilities, the matrix of limiting probabilities, and differential matrices in a Markov chain are proposed and formulated. Based on a classical numerical methods in this chapter new polynomial-time algorithms for determining the limiting probabilities and differential matrices are described.

Along with well-known numerical methods for determining the basic characteristics in finite Markov processes, new calculation procedures and algorithms for their finding in the case of stationary and nonstationary discrete processes are presented.

Asymptotic behavior of the average and expected total rewards (costs) in Markov processes with rewards (costs) are analyzed and the corresponding asymptotic formulae are derived. Computational complexity aspects of the problems of determining the average and the discounted expected total rewards (costs) are analyzed and the corresponding procedures for calculating these characteristics are described.

Chapter 2 is dedicated to infinite horizon stochastic discrete optimal control models and Markov decision problems with average and expected total discounted optimization criteria. Necessary and sufficient conditions for determining the optimal stationary strategies in such problems are formulated and algorithms for determining their solutions are developed. The stochastic control problems are formulated on networks and the corresponding algorithms for determining their optimal solutions using a linear programming approach are proposed. Furthermore, a relationship between the class of stationary Markov decision problems and the class of stochastic control problems on networks is analyzed and procedures how to reduce one class of problems to another are described. The most important results of Chap. 2 are related to a linear programming approach for unichain and multichain Markov decision problems with average and expected total discounted costs optimization criteria. Based on such an approach new algorithms for solving problems in general form are derived. Afterwards, efficient iterative procedures for determining the optimal solutions of Markov decision problems and stochastic control problems on networks are described. Additionally, a new class of Markov decision problems and stochastic control problems with stopping states are introduced and the corresponding mathematical tool for solving this class of problems is developed. Some extensions and generalizations of the stochastic decision models are considered and their possible applications for solving classical optimization problems are suggested.

In Chap. 3 a special game-theoretical approach to Markov decision processes and stochastic discrete optimal control problems is developed. An essentially new class of stochastic positional games is formulated and studied applying the game-theoretical concept to Markov decision problems with average and expected total discounted costs optimization criteria. To formulate this class of games we assume that Markov decision processes may be controlled by several actors (players).

The set of states of the system in such processes is divided into several disjoint subsets which represent the corresponding position sets of the players. Each player has to determine which action should be taken in each state of his position set in order to minimize (or maximize) his own average cost per transition or the expected total discounted cost. For the stochastic discrete optimal control problems with infinite time horizon this approach is developed in a similar way and a new class of stochastic positional games on networks is obtained.

The main results we describe in this chapter are related to the existence of Nash equilibria for a considered class of stochastic positional games and an elaboration of the algorithms for determining the optimal stationary strategies of the players. We formulate and prove Nash equilibria conditions for the stochastic positional games with average and discounted payoff functions of the players and develop algorithms for determining the optimal strategies for different classes of games. These results are specified for antagonistic stochastic positional games and algorithms for determining the optimal strategies of the players are gained. In the following, we show that the obtained results generalize the well-known results for deterministic positional games and new conditions for determining the solutions of the problems can be derived. Moreover, we show that the considered class of stochastic positional games can be used for studying cyclic games and Shapley stochastic games. New polynomial-time algorithms for deterministic antagonistic positional games are described. The algorithms for determining the optimal strategies of the players in deterministic cases are developed for a more general class of positional games on networks. Additionally, the multi-criteria decision problems with Pareto and Stackelberg optimization principles are formulated and some approaches for determining the solutions of these problems are suggested.

Chapter 4 is devoted to finite horizon stochastic control problems and Markov decision processes. In this chapter dynamic programming algorithms for determining the optimal solutions of the problems using the network representation of the finite discrete processes are developed. We show that the solutions for the considered stochastic horizon decision problems can be efficiently found using a backward dynamic induction principle. The algorithms are described in general form for stationary and nonstationary cases of the problems. Moreover, the algorithms are developed for the case with varying time of states' transitions of the dynamical systems. These algorithms are a contribution to the important field of computational network theory.

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