Studies in Fuzziness and Soft Computing

Deng-Feng Li

Linear Programming Models and Methods of Matrix Games with Payoffs of Triangular Fuzzy Numbers

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The series "Studies in Fuzziness and Soft Computing" contains publications on various topics in the area of soft computing, which include fuzzy sets, rough sets, neural networks, evolutionary computation, probabilistic and evidential reasoning, multi-valued logic, and related fields. The publications within "Studies in Fuzziness and Soft Computing" are primarily monographs and edited volumes. They cover significant recent developments in the field, both of a foundational and applicable character. An important feature of the series is its short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

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To my wife, Wei Fei and To my son,
Wei-Long Li

Preface

Two-person zero-sum finite games, which often are called matrix games for short, are an important part of noncooperative games. Matrix games have been extensively studied and successfully applied to many fields such as management science, decision science, operational research, economics, finance, business, social science, and biology as well as engineering. However, the assumption that all payoffs are precise common knowledge to the players is not realistic in many competitive or antagonistic decision occasions. In fact, more often than not, in real competitive or antagonistic situations, the players cannot exactly estimate payoffs in the game due to lack of adequate information and/or imprecision of the available information on the environment. This lack of precision and certainty may be appropriately modeled by using the fuzzy set. Intervals and triangular fuzzy numbers, which are special and simple cases of the fuzzy sets, seem to be suitable and convenient for dealing with fuzziness or imprecision of payoffs in matrix games. On the other hand, in some real-life game problems, choice of strategies for the players is constrained due to some practical reason why this should be, i.e., not all mixed (or pure) strategies in a game are permitted for each player. As a result, there appear four important types of matrix games, which are interval-valued matrix games, matrix games with payoffs of triangular fuzzy numbers, interval-valued constrained matrix games, and constrained matrix games with payoffs of triangular fuzzy numbers. As far as I know, however, there is less investigation on them. Therefore, this book focuses on studying the concepts, properties, models, and methods of the aforementioned four types of matrix games.

This book is divided into two parts. Each part includes two chapters. Chapter 1 discusses interval-valued matrix games, mainly including interval-valued mathematical programming models of interval-valued matrix games, acceptability-degree-based linear programming models and method of interval-valued matrix games, the lexicographic method of interval-valued matrix games, and primal-dual linear programming models and method of interval-valued matrix games. Chapter 2 studies matrix games with payoffs of triangular fuzzy numbers, mainly including fuzzy multi-objective programming models and fuzzy linear programming method of matrix games with payoffs of triangular fuzzy numbers, two-level linear programming models and method of matrix games with payoffs of triangular fuzzy numbers, the lexicographic method of matrix games with payoffs of triangular fuzzy numbers, and Alfa-cut-based primal-dual linear programming models and method of matrix games with payoffs of triangular fuzzy numbers. Chapter 3 expatiates interval-valued constrained matrix games, including the concepts of solutions of interval-valued constrained matrix games and properties, and primal-dual linear programming models and method of interval-valued constrained matrix games. Chapter 4 expounds constrained matrix games with payoffs of triangular fuzzy numbers, mainly including fuzzy multi-objective programming models and method of constrained matrix games with payoffs of triangular fuzzy numbers, and Alfa-cut-based primal-dual linear programming models and method of constrained matrix games with payoffs of triangular fuzzy numbers. The aim of this book was to develop and establish simple, efficient, and effective linear programming models and methods for solving interval-valued matrix games, interval-valued constrained matrix games, matrix games with payoffs of triangular fuzzy numbers, and constrained matrix games with payoffs of triangular fuzzy numbers. I tried my best to ensure that the models and methods developed in this book are of practicability, maneuverability, and universality.

This book is addressed to people in theoretical researches and practical applications from different fields and disciplines such as decision science, game theory, management science, fuzzy sets or fuzzy mathematics, applied mathematics, optimizing design of engineering and industrial system, expert system, and social economy as well as artificial intelligence. Moreover, it is also addressed to teachers, postgraduates, and doctors in colleges and universities in different disciplines or majors: decision analysis, management, operation research, fuzzy mathematics, fuzzy system analysis, systems engineering, project management, industrial engineering, hydrology, and water resources.

First of all, special thanks are due to my coauthor Chun-Tian Cheng and my doctoral graduates Jiang-Xia Nan, Fang-Xuan Hong for completing and publishing several articles. This book was supported by the Key Program of the National Natural Science Foundation of China (No. 71231003), the National Natural Science Foundation of China (Nos. 71171055, 71101033, and 71001015), the "Chang-Jiang Scholars" Program (the Ministry of Education of China), the Program for New Century Excellent Talents in University (the Ministry of Education of China, NCET-10-0020), and the Specialized Research Fund for the Doctoral Program of Higher Education of China (No. 20113514110009) as well as "Science and Technology Innovation Team Cultivation Plan of Colleges and Universities in Fujian Province." I would like to acknowledge the encouragement and support of my wife as well as the understanding of my son.

Last but not least, I would like to acknowledge the encouragement and support of all my friends and colleagues.

Ultimately, I should claim that I am fully responsible for all errors and omissions in this book.

August 2015 Deng-Feng Li

About the Author

Deng-Feng Li was born in 1965. He received the B.Sc. and M.Sc. degrees in applied mathematics from the National University of Defense Technology, Changsha, China, in 1987 and 1990, respectively, and the Ph.D. degree in system science and optimization from the Dalian University of Technology, Dalian, China, in 1995.

From 2003 to 2004, he was a Visiting Scholar with the School of Management, University of Manchester Institute of Science and Technology, Manchester, UK. He is currently a Distinguished Professor of "Chang-Jiang Scholars" Program, Ministry of Education of China and "Min-Jiang Scholarship" Distinguished Professor with the School of Economics and Management, Fuzhou University, Fuzhou, China. He has been conferred the Outstanding Contribution Experts of the National Middle-Aged and Young of China and was approved as an expert of the Enjoyment of the State Council Special Allowance of China. He has authored or coauthored more than 300 journal papers and seven monographs. He has coedited one proceeding of the international conference and two special issues of journals and won 23 academic achievements and awards such as Chinese State Natural Science Award and 2013 IEEE Computational Intelligence Society IEEE Transactions on Fuzzy Systems Outstanding paper award. His current research interests include classical and fuzzy game theory, fuzzy decision analysis, group decision making, supply chain, fuzzy sets and system analysis, fuzzy optimization, and differential game. He is the Editor-in-chief of *International Journal of Fuzzy System Applications* and Associate Editors and/or Editors of several international journals.

Abstract

This book is an academic monograph based on the papers published in international famous journals by the author. The focus of this book is on theoretical models and methods of interval-valued constrained and unconstrained matrix games, and constrained and unconstrained matrix games with payoffs of triangular fuzzy numbers. This book includes four chapters. Chapter 1 mainly discusses interval-valued mathematical programming models of interval-valued matrix games, acceptability-degree-based linear programming models and method of interval-valued matrix games, the lexicographic method of interval-valued matrix games, and primal-dual linear programming models and method of interval-valued matrix games. Chapter 2 mainly studies fuzzy multi-objective programming models and fuzzy linear programming method of matrix games with payoffs of triangular fuzzy numbers, two-level linear programming models and method of matrix games with payoffs of triangular fuzzy numbers, the lexicographic method of matrix games with payoffs of triangular fuzzy numbers, and Alfa-cut-based primal-dual linear programming models and method of matrix games with payoffs of triangular fuzzy numbers. Chapter 3 expatiates the concepts of solutions of interval-valued constrained matrix games and properties, and primal-dual linear programming models and method of interval-valued constrained matrix games. Chapter 4 mainly expounds fuzzy multi-objective programming models and method of constrained matrix games with payoffs of triangular fuzzy numbers, and Alfa-cut-based primal-dual linear programming models and method of constrained matrix games with payoffs of triangular fuzzy numbers. The aim of this book was to develop and establish simple, efficient, and effective linear programming models and methods for solving interval-valued matrix games, interval-valued constrained matrix games, matrix games with payoffs of triangular fuzzy numbers, and constrained matrix games with payoffs of triangular fuzzy numbers.

This book is addressed to people in theoretical researches and practical applications from different fields and disciplines such as decision science, game theory, management science, fuzzy sets or fuzzy mathematics, applied mathematics, optimizing design of engineering and industrial system, expert system, and social economy as well as artificial intelligence. Moreover, it is also addressed to teachers, postgraduates, and doctors in colleges and universities in different disciplines or majors: decision analysis, management, operation research, fuzzy mathematics, fuzzy system analysis, systems engineering, project management, industrial engineering, applied mathematics, hydrology, and water resources.

Contents

Part I
Models and Methods of Matrix Games with Payoffs of Triangular Fuzzy Numbers

Chapter 1
Interval-Valued Matrix Games

1.1 Introduction

Game theory is engaged in competing and strategic interaction among players in management science, operational research, economics, finance, business, social science, biology, engineering, and others. It began in the 1920s and has achieved a great success [1, 2]. The simplest game is the zero-sum game involving only two players with finite pure strategies (i.e., options), which is often called the matrix game for short. A matrix game is usually expressed by a payoff matrix $\mathbf{A} = (a_{ij})_{m \times n}$, where a_{ij} is the amount of reward/loss which the player I wins (and hereby the player II loses) when the players I and II choose their pure strategies $\delta_i\,(i = 1, 2, \ldots, m)$ and $\beta_j\,(j = 1, 2, \ldots, n)$, respectively. Here, m and n are two arbitrary positive integers.

Traditionally, the payoffs a_{ij} are represented by crisp values, which indicate that they are precisely known. This assumption is reasonable for clearly defined games, which have many useful applications, especially in finance, management and decision making systems [3, 4]. In the real world, however, there are some cases in which the payoffs are not fixed numbers known and have to be estimated even though two players do not change their strategies. An example is one in which different advertising strategies of two competing companies lead to different market shares and the market shares must be estimated. Hence, fuzzy games have been extensively studied. Dubois and Prade [5] gave a brief overview and discussion on the fuzzy games with crisp sets of strategies and fuzzy payoffs due to the lack of precision on the knowledge of the associated payoffs. Nishizaki and Sakawa [2] and Bector and Chandra [4] made good overviews on update research of this topic. Bector et al. [6, 7] studied the matrix games with fuzzy goals and fuzzy payoffs by using the defined fuzzy linear programming duality, respectively. Campos [8], Campos and Gonzalez [9] and Campos et al. [10] proposed ranking function based

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