Preface

In real-life world, decision makers usually face multiple objectives and need to make the decision in a state of uncertainty. How do we obtain the optimal strategy in uncertain environments? The purpose of the book is to provide random-like multiple objective decision making to solve the question. This book aims at discussing a class of uncertain phenomenon, that is, random-like uncertainty including random phenomenon, bi-random phenomenon, random fuzzy phenomenon and random rough phenomenon. Then random multiple objective decision making, bi-random multiple objective decision making, random fuzzy multiple objective decision making and random rough multiple objective decision making will be introduced one by one.

It was generally believed that the study of probability theory was started by Pascal and Fermat in 1654 when they succeeded in deriving the exact probabilities for certain gambling problems. From then on, people have broadly paid close attention to the random phenomenon. Afterwards, probability theory was widely applied to many social and technology problems, such as, vital statistics, premium theory, astro observation, the theory of errors, quality control and so on. From the seventeenth to nineteenth century, many distinguished scholars such as Bernoulli, De-Moivre, Laplace, Gauss, Poisson, Tchebychev, and Markov made contributions to the development of the probability theory. As the probability theory was applied to more and more real-life problems in many fields, the basic definition proposed by Laplace proved to be limiting, and unable to be used to deal with the usual random events. Great progress was achieved when Von Mises initialized the concept of sample space, and filled the gape between probability theory and measure theory in 1931. Strict theoretical principles, however, did not exist until 1933, when the outstanding mathematician Kolmogorov from former Soviet Union published the famous paper "The basic concept of probability theory", in which he put forward the axiomatization structure which is considered the milestone and foundation of the development of probability theory. Since then, probability theory has been the foundation axioms system and has been widely applied to many fields. Soon after, Zadeh and Pawlak initialized the fuzzy set theory in 1965 and rough set theory in 1982, respectively. Generally, fuzzy events are regarded as an uncertainty that people subjectively know for example, the temperature of water, 'cold' and 'hot', which isn't marked by a crisp number. Rough sets are generally regarded as a tool to distinguish something which is not easily discriminated. However, many scholars believed that the traditional single-fold uncertain variables(random variables, fuzzy variables and rough variables) have some difficulties in clearly describing complicated, changeable realistic problems. In 1978, Kwakernaak combined randomness with fuzziness and initialized the concept of the fuzzy random variable, then introduced its basic definition and property. This viewpoint combining two different uncertain variables to describe complicated events received approval from many scholars and helped people move forward a further step in understanding uncertain events. Since then, the concept of the random fuzzy variable, bi-random variable and random rough variable have been proposed one by one by many scholars. Many papers and books about the two-fold uncertain theory were presented, which consequently promoted the development of two-fold uncertain theory. For example, the following description regarding the useful time of the spares in a factory proved the existence of a two-fold uncertain phenomenon. It might be known that the lifetime ξ of a modern engine is an exponentially distributed variable with an unknown mean $\tilde{\theta}$,

$$\phi(x) = \begin{cases} \frac{1}{\tilde{\theta}} e^{-x/\tilde{\theta}}, & \text{if } 0 \leq x < \infty \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

Generally, there is some relevant information in practice. It is thus possible to specify an interval in which the value of $\tilde{\theta}$ is likely to lie, or give an approximate estimation of the value of ξ. Here may be a random variable, or a fuzzy variable, or a rough variable, thus it is regarded as a random-like two-fold uncertain variable. Our research concentrates on random-like two-fold uncertain variables including bi-random variables, random fuzzy variables and random rough variables, and then deduces their properties and application to real-life world.

Multiobjective decision making problems are always a primary concern that many scholars pay attention to as it mainly provides decision makers with the help to find an optimal solution for many objectives with limited resources. Traditional multi-objective decision making usually consider problems with certain parameters. However, it is a usual phenomena that many decision making problems have abundant imprecise information. Hence, research into multiobjective decision making with random-like parameters is very necessary. To trace the origin of multiobjective decision making with certain parameters, we have to go to the eighteenth century. Franklin introduced how to coordinate multiple objectives in 1772. Cournot proposed the multi-objective decision making model from the standpoint of the economics in 1836. Pareto firstly presented an optimal solution to the multi-objective decision making model from the standpoint of the mathematics in 1896. The seeds of what is a strong branch of operations research can be traced to the early work of Kunh and Tucker and Koopmans in 1951. Later, Arrow proposed the concept of efficient points in 1953. Danzig claimed in the paper 'Review the origin of the linear programming' that stochastic programming would the most promising areas for future research in 1955. Then the single objective and multi-objective stochastic programming was widely researched and developed. As the fuzzy set theory was gradually perfected, it was rapidly and widely applied into the fileds of operations, management science, control theory and so on. In 1970, Bellman and Zadeh collaborated to propose a fuzzy decision making model based on multi-objective programming. Similarly, after rough set theory was founded in 1982, it was also applied to decision making problems. From then, it became an area that attracted an enormous amount of attention because it is so useful for real-world decision making. The monographs of Chankong and Hamies, Cohon, Hwang and Masud, Osyczka, Sawaragi et al., and Steuer provide an extensive overview of the area of multiobjective optimization. Theory and methods for multiobjective optimization have been developed chiefly during the last century. Here we do not go into the history as the orgin, the achievements and development can be found in the literature. As the theory of two-fold uncertainty was rapidly developed, it was also applied to the multiobjective decision making in recent years. Above all, the multi-objective decision making model with uncertain parameters can be summarized as follows:

$$\begin{array}{l} \max[f_1(\boldsymbol{x},\boldsymbol{\xi}), f_2(\boldsymbol{x},\boldsymbol{\xi}), \ldots, f_m(\boldsymbol{x},\boldsymbol{\xi})] \\ \text{s.t. } \boldsymbol{x} \in X \end{array} \tag{2}$$

where $\boldsymbol{x} \in X \subset \mathbf{R}^n$ is an n-dimension decision variable, X is the constraint set, f_i is the objective function, and $\boldsymbol{\xi}$ is a random or fuzzy or rough variable or a two-fold uncertain variable.

In this book, real-life problems are considered as the background, and we present the random-like multi-objective decision making research. The basic theory, model and algorithm are proposed and applied to solve realistic problems. This book consists of 6 chapters. Chapter 1 reviews some preliminary knowledge such as measure theory, probability theory, central limit theorem and the Monte Carlo simulation and so on. Chapter 2 introduces the multi-objective decision making with random parameters and its application to DCs location problem. This chapter first reviews the literature of DCs location problem, then proposes the random multi-objective decision making model. Three sections introduce the random expected value model, the random chance-constrained model and the random dependent-chance model. In each section, we deduce the equivalent model of those problems in which the random parameters have crisp distribution and linear relationships. We also propose the Monte Carlo simulation-based simulated annealing algorithm to deal with those problems with random parameters and the nonlinear relationship. Finally, in the last section, the proposed models and algorithms have been applied to solve a realistic problem to show the efficiency of the proposed models and algorithms. Chapters 3, 4 and 5 have the same structure as Chap. 2. Chapter 3 proposes the multi-objective decision making model with bi-random parameters and introduces its application to flow shop scheduling problems. The equivalent models of the bi-random expected value model, bi-random chance-constrained model and bi-random dependent-chance model with crisp distribution are deduced and the interactive fuzzy programming technique is proposed to solve them. Then Ra-Ra simulation-based genetic algorithm is presented to solve the Ra-Ra multi-objective decision making problems with unknown distributions. Finally, the proposed models and algorithms are used to deal with a realistic flow shop scheduling problem with bi-random parameters. Chapter 4 proposes the multi-objective decision making model with random fuzzy parameters and introduced its application to the supply chain problems. The equivalent models of the random fuzzy expected value model, random fuzzy chance-constrained model and random fuzzy dependent-chance model with crisp distribution are deduced and the interactive fuzzy programming technique is proposed to solve them. Then a random fuzzy simulation-based genetic algorithm is presented to solve the random fuzzy multi-objective decision making problems with unknown distribution. Finally, the proposed models and algorithms are used to deal with realistic supply chain problems with random fuzzy parameters. Chapter 5 proposes the multi-objective decision making model with random rough parameters and introduces its application to the inventory problems. The equivalent models of the random rough expected value model, random rough chance-constrained model and random rough dependent-chance model with crisp distributions are deduced and the interactive fuzzy programming technique is proposed to solve them. Then the random rough simulation-based genetic algorithm is presented to solve the random rough multi-objective decision making problems with unknown distribution. Finally, the proposed models and algorithms are used to deal with realistic inventory problems with random rough parameters. Chapter 6 gives the methodological system of the whole book including the motivation for researching random-like multi-objective decision making, physics-based model system, mathematical model system, model analysis system, algorithm systems, and research ideas and paradigm: 5MRP. Readers can understand the current research of random-like multiobjective decision making and prepare for future research.

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