Weldon A. Lodwick and Janusz Kacprzyk (Eds.)

Fuzzy Optimization

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Fuzzy Optimization

Recent Advances and Applications

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Foreword

Optimisation and decision making has always been one of the main focuses of operations research, decision theory, management science and economic theory. Until the beginning of the 1970's the mathematical tools used were predominantly "crisp" and the rationality of decisions in decision logic was defined on the basis of dual logic. If uncertainty was included at all in decision calculi or optimisation algorithms, it was done by using probability theory, for instance, in stochastic linear programming. The basis for any kind of analysis in decision theory and operations research was the asymmetric choice model in which decision alternatives (or feasible solutions) were modelled either by enumeration or by constraints as an unordered solution space and in which an order in this space was generated by the objective function, utility function, or any other order generating tool.

This had three major consequences:

1. Models were rather unstable because a minimal violation of a single constraint led to infeasibility,
2. All considerations of uncertainty had to be cast into probabilistic models, and
3. If more than one objective function was to be considered the problem became complicated due to the several orders that were generated in the solution space.

These limitations also often reduced the degree to which the model adequately modelled the real problem.

It should probably also be mentioned that the "knowledge-based" systems (expert systems), that were emerging as an alternative to mathematical optimisation at the beginning of the 1970's as a way to find not optimal but good heuristic solutions, were also based on dual logic and were, therefore, not really "knowledge based" but rather symbol (truth values) processing systems.

Many things have changed since then: The phenomenon of uncertainty has drawn much more attention and several "uncertainty theories" have been developed. (There exist more than twenty by now). Fuzzy sets theory has grown tremendously which led to more than 50 000 publications by now. Multi criteria decision making (MCDM) has become a very large area with many different approaches to handle the problem of several objective functions. In addition to the asymmetric choice model of classical decision logic the symmetrical decision model of fuzzy set theory and MCDM has been suggested. The rationality of decision making has been reconsidered on the basis of fuzzy logic. Several new "bio-inspired" areas (such as artificial neural networks, evolutionary computation, swarm theory and others) have also been developed. Partly they have been pooled into "Computational Intelligence" or into "Soft Computing" and generated new hybrid models and theories. As one reaction to uncertainty in real applications the demand for "robust solutions" has appeared besides the request for optimal solutions. Also one major change in the relationship between these theories has occurred: to a large degree they are no longer considered as competitors but rather as complements which has even more strengthened the development of hybrid theories and techniques.

Publications in these areas are distributed over a very wide range of journals and books, making it very difficult, even for a scientist, to stay up-to-date. It is even more difficult for a practitioner to oversee which new tools, models, and techniques are available to solve his or her optimisation problems as adequately as possible. It is, therefore, extremely valuable that a book appears that surveys as many of these new possibilities as one book can cover. It not only surveys these theories but it also investigates the relationships between these theories and a very important question: "Which theory should be applied, under which circumstances, to real problems?"

The editors of this book have done an excellent job in inviting and getting the participation of top authors working in theory as well as in applications. In order to make this volume more readable it has been structured into a number of parts, which are not independent of each other but complement each other very well: Part 1 leads the reader from classical decision theory and optimisation into the area of fuzziness and fuzzy optimisation. Even though the main focus of this volume is fuzzy optimisation, other uncertainty theories, such as the Dempster-Shafer theory, possibility theory, etc. are also introduced and their interrelationships discussed. Part 2 is devoted to a very central problem of optimisation, the aggregation of the different parts of optimisation models, i.e. constraints and objective functions. This, from the very beginning of fuzzy decision making theory, has been one of the most interesting areas. Part 3 then turns to developments in different areas of fuzzy optimisation. It is not surprising that a major part is devoted to variations of mathematical programming. While classical linear programming, or even the different kinds of non-linear programming, are characterized by specific clear-cut models, this changes immediately when fuzzy set theory (or other similar uncertainty theories) are applied. Thus, while crisp linear programming is well described by one typical model, fuzzy linear programming is a family of very different models, depending on the membership functions used, the type of aggregation operators introduced and the degrees to which a crisp linear programming model is "fuzzified". Even the solvability of such a fuzzy linear programming model can vary from being easy to solve (as an equivalent crisp linear program) to unsolvable. In addition to those families of fuzzy mathematical programming models there are, of course, various other fuzzy optimisation models, which are also investigated in this part of the book.

One part of (linear) mathematical programming has gained particular importance during the last decade: combinatorial programming. It is, therefore, justified that the next part of the book is devoted to fuzzified versions of this type of linear programming. Three rather different models are presented, which indicate the wide and not yet well-developed area of these models.

The final Part 5 of the volume is devoted to applications of theories considered in the first four parts to models of real problems. The seven examples cover a wide scope of areas from feature selection via investment and portfolio selection problems to biological circuit design and a real problem of the Spanish football league. These examples can certainly serve as an inspiration to numerous other applications in the real world.

Altogether this book is an excellent piece of theoretical and applied literature. The editors and the authors have to be congratulated to their work. I am sure that this book will be of great benefit to scientists and practitioners and I can only hope that it will lead to many further developments in the area of fuzzy optimisation.

Aachen
February 2010

Hans-Jürgen Zimmermann

Preface

Optimization is an extremely important area in science and technology which provides powerful and useful tools and techniques for the formulation and solution of a multitude of problems in which we wish, or need, to find a best possible option or solution. It has been an important area of research for more than half a century, and particularly since the advent of digital computers. Over those years great progress has been attained in the area with the development of powerful theoretical and algorithmic results. A multitude of academic and commercial software packages have been developed which have made it possible to solve virtually all kinds of optimization problems. Applications of optimization tools and techniques span practically the entire spectrum of science and technology.

Real applications of optimization often contain information and data that is imperfect. Thus, attempts have been made since the early days to develop optimization models for handling such cases. As the first, natural approaches in this respect one can mention value intervals and probability distributions as representations of uncertain data. They have led to the development of various interval and stochastic optimization models.

Fuzzy sets theory has provided conceptually powerful and constructive tools and techniques to handle another aspect of imperfect information related to vagueness and imprecision. This has resulted in the emergence – more or less in the mid-1970s—of a new field, called fuzzy optimization (and its related fuzzy mathematical programming), in which many powerful theoretical and algorithmic results have been proposed too. Many books and edited volumes, and a multitude of articles have been published. Moreover, numerous applications have been reported too.

Due to the importance and a constant growth of interest, both among theoreticians and practitioners, we have decided to prepare this edited volume on fuzzy optimization. A substantial number of the most active researchers and practitioners in the field have responded positively to our application, and therefore we have been able to present to the readers a comprehensive account of many new and relevant developments in fuzzy optimization, in its theoretical direction and also in real world applications.

The volume is divided into a coupe of parts which present various aspects of fuzzy optimization, some related more general issues, and applications.

Part I, “Introductory Sections”, is concerned with a comprehensive survey of some basic issues related to broadly perceived choice, decision making, and optimization. Aspects of utility, preferences, uncertain and imprecise information are discussed. Moreover, an account of how these aspects can be incorporated in operational optimization models are surveyed.

Kofi K. Dompere (“Fuzziness, Rationality, Optimality and Equilibrium in Decision and Economic Theories”) discusses some basic issues related to decision making and optimization, and puts them in a perspective of fuzziness. The paper is an essay which presents main categories of theories of optimization. It begins with the classical system leading to the establishment of a point of departure for fuzzy optimization from the point of view of classical optimization. The author distinguishes the following four categories of optimization problems: the first two, i.e. exact (non-fuzzy) and non-stochastic, and exact (non-fuzzy) and stochastic follow somehow classical laws of thought and mathematics. On the other hand, the other two, i.e. fuzzy and non-stochastic, and fuzzy-stochastic problems are associated with laws of thought characteristic for fuzzy logic and mathematics. From these structures, similarities and differences in the problem structures and corresponding solutions are abstracted and discussed. They are attributed to properties of exactness and completeness about information-knowledge structures underlying the optimization problems. The assumed degrees of exactness and completeness establish defective information-knowledge structure that generates uncertainties and produces inter-category differences in the optimization problem. The differences of intra-category algorithms are attributed to differences in the assumed functional relationships of the variables that occur in the objective and constraint sets. A taxonomy of solution structures is provided and a discussion on future research directions is given.

W.A. Lodwick and E. Untiedt (“Introduction to Fuzzy and Possibilistic Optimization”) provide a comprehensive introduction to various aspects of broadly perceived fuzzy and possibilistic optimization. However, as opposed to previous survey articles of that type, they go much deeper, providing insight into decision making, optimization and mathematical programming in general. First, they give an overview of various perspectives, points of view, on uncertain, imprecise, and incomplete, information and summarize various mathematical modeling attempts and algorithms. Differences between representations based on interval mathematics, probability theory, the Dempster-Shafer theory, fuzzy sets theory, possibility theory, and related issues are considered. Problems related to the choice of optimal (best) options or courses of action are mentioned. Finally, a review of rationale, fundamental features and solution techniques for basic classes of fuzzy optimization and fuzzy mathematical programming are analyzed.

Part II, “Basic Issues”, is concerned with some foundational issues that are relevant for fuzzy optimization, both in the theoretical and algorithmic sense. The main concern in this part is an omnipresent problem of aggregation of partial scores, pieces of evidence, preferences, etc.

Vicenç Torra (“Aggregation Operators for Evaluating Alternatives”) reviews the use of aggregation functions and operators in the field of decision making, and hence in optimization as a consequence. The author first presents an overview of main decision making problems, and then shows that aggregation operators are commonly employed for their solution. Then, a comprehensive review of various aggregation operators is provided, and their formal properties, features and differences are pointed out.

Gleb Beliakov ("Optimization and Aggregation Functions") looks at connections between aggregation functions and optimization from two main perspectives. The insight into the connections is that of aggregation functions which are used to transform a multiobjective optimization problem into a single objective problem by combining several criteria into one. The second insight into connections of aggregation functions and optimization is that the construction of aggregation functions often involves an optimization problem. Aggregation functions, or operators, are functions that combine several input values into one output value which can be used to evaluate or rank the alternatives. The author concentrates on aggregation functions that take the inputs from a closed interval, like [0,1], and produce the output in the same interval; they are widely used, in virtually all areas. Since the choice of an aggregation function is application specific, and is frequently performed in ad hoc manner, there are natural attempts to try to automate their choice, in particular when data are available from which information needed can be extracted. This can be exemplified by an analysis of customers' responses to recommendations which can provide suitable aggregation rules. It is possible to construct suitable application specific aggregation functions from the recorded data by solving a regression problem, which for the weighted mean operators boils down to a standard quadratic programming, though for other aggregation functions, the solution may be much more difficult. In this contribution the author presents various alternative methods suitable for the construction of aggregation functions.

Pingke Li and Shu-Cherng Fang ("Chebyshev Approximation of Inconsistent Fuzzy Relational Equations with Max-T Composition") consider an important problem associated with fuzzy relational equations which are a powerful tool for the formulation of many problems. The authors deal with resolving the inconsistency of a system of fuzzy relational equations with the max-T composition by simultaneously modifying the coefficient matrix and the right hand side vector. They show that resolving the inconsistency of fuzzy relational equations with the max-T composition by means of the Chebyshev approximation is closely related to the generalized solvability of interval-valued fuzzy relational equations with the max-T composition. An efficient procedure is proposed to obtain a consistent system with the smallest perturbation in the sense of the Chebyshev distance.

Part III, "Various Types of Fuzzy Optimization and Fuzzy Mathematical Programming Models", is devoted to a comprehensive presentation of some important classes of fuzzy optimization and fuzzy mathematical programming problems that are relevant both from the theoretical and practical points of view.

Ricardo C. Silva, Carlos Cruz, José L. Verdegay and Akebo Yamakami ("A Survey of Fuzzy Convex Programming Models") consider some basic issues related to convex optimization which is characterized by a convex objective function and convex constraint functions over a convex set of the decision variables. This can be viewed, on the one hand, as a particular case of nonlinear programming and, on the other hand, as a general case of linear programming. Since in many cases when we use convex optimization, we deal with data that cannot be formulated precisely, then it makes sense to apply fuzzy set theory as a way to mathematically describe this imperfect information. In this paper the authors review the theory of fuzzy convex optimization and describe some flexible and possibilistic programming models to solve fuzzy convex programming problems. Flexible programming uses fuzzy sets to represent the imprecisely specified decision maker's aspirations and constraints, while possibilistic programming models handle imprecise or ambiguous data by possibility distributions.

Masahiro Inuiguchi ("Approaches to Linear Programming Problems with Interactive Fuzzy Numbers") considers the following crucial problem. Though most fuzzy mathematical programming models have been developed under the assumption of non-interaction among fuzzy coefficients, this is not always, maybe rarely, the case in real world problems. Therefore, several approaches have been proposed to deal with the interaction among fuzzy coefficients. The author provides a comprehensive and critical review of how the interaction among fuzzy coefficients in fuzzy linear programming problems can be dealt with. Using a necessity fractile model of a simple linear program with fuzzy coefficients, he shows differences between the non-interactive and interactive problems. Then, a review of five approaches to interactive fuzzy numbers, i.e., weak independent fuzzy numbers, fuzzy vector with a quadratic membership function, scenario decomposed fuzzy numbers, an oblique fuzzy vector, and a fuzzy polytope is provided.

Alexander Yazenin and Ilia Soldatenko ("Possibilistic Optimization Tasks with Mutually *T*-related Parameters: Solution Methods and Comparative Analysis") consider the problems of possibilistic linear programming. The T-norms are used to describe the interaction (relatedness) of fuzzy parameters. Solution methods are proposed, models of possibilistic optimization are compared for different T-norms. Basically, in traditional works the relatedness of fuzzy parameters in possibilistic optimization problems was based generally on the standard conjunction operation that is widely used in fuzzy logic which may often be not quite appropriate. For example, using the standard conjuction operator leads to the linear growth of result's fuzziness, which is not always reasonable. The methods based on T-norms provide more flexibility in controlling fuzziness in decision-making. The authors follow this line of investigation with regard to possibilistic linear programming tasks. For the case of TW-norm, they study two models of possibilistic linear programming problems, and propose methods which are combinations of the indirect method and genetic algorithms use for their solution. A comparison of models of possibilistic optimization for the TW-norm and TM-norm is given.

Elizabeth Untiedt ("A Parametrized Model for Optimization with Mixed Fuzzy and Possibilistic Uncertainty") considers the problem when fuzzy and possibilistic uncertainty, which very closely related, and sometimes coexist in optimization under uncertainty problems. Basically fuzzy uncertainty in mathematical programming problems typically represents flexibility on the part of the decision make while possibilistic uncertainty generally expresses a lack of information about the values the parameters will assume. First, the author briefly surveys several existing models for mixed fuzzy and possibilistic programming problems and indicates that the semantic interpretation of these models may be of questionable value. Namely, the mixed models in the literature find solutions in which the fuzzy uncertainty (or flexibility) and the possibilistic uncertainty (or lack of confidence in the outcome) are held to the same levels. The author proposes a new mixed model which allows a trade-off between fuzzy and possibilistic uncertainty and this trade-off corresponds to a semantic interpretations consistent with human decision-making. The new model shares characteristics with multi-objective programming and the Markowitz models, and its structure, semantic justification, and solution approaches are articulated.

Włodzimierz Ogryczak and Tomasz Śliwiński ("On Solving Optimization Problems with Ordered Average Criteria and Constraints") discuss the problem of aggregating multiple numerical attributes to form an overall measure of broadly perceived performance or utility. The use of Yager's ordered weighted averaging (OWA) aggregation, which use the weights assigned to the ordered values rather than to the specific attributes, makes it possible to model various aggregation preferences, preserving simultaneously the impartiality (neutrality) with respect to the individual attributes. However, the more general importance weighted averaging is a central task in multiattribute decision problems of many kinds, and can be performed by the Weighted OWA (WOWA) aggregation though the importance weights make the WOWA concept much more complicated than the original OWA. The authors analyze some novel solution procedures for optimization problems with the ordered average objective functions or constraints, and show that the WOWA aggregation with monotonic preferential weights can be reformulated in a way that makes it possible to introduce linear programming models, similar to the optimization models developed earlier by the authors for the OWA aggregation. Numerical results justify the computational efficiency of the proposed models.

Gia Sirbiladze ("Fuzzy Dynamic Programming Problem for Extremal Fuzzy Dynamic System") deals some problem related to the so-called Extremal Fuzzy Continuous Dynamic System (EFCDS) optimization developed by the author. The basic properties of extended extremal fuzzy measure are considered and several variants of their representation are given. For extremal fuzzy measures several transformation theorems are represented for extended lower and upper Sugeno integrals. Values of extended extremal conditional fuzzy measures are defined as a levels of expert knowledge reflections of EFCDS states in the fuzzy time intervals. The notions of extremal fuzzy time moments and intervals are introduced and their monotone algebraic structures that form the most important part of the fuzzy instrument of modeling extremal fuzzy dynamic systems are discussed. Some new approaches in modeling of EFCDS are developed, and fuzzy processes with possibilistic uncertainty, the source of which is extremal fuzzy time intervals, are constructed. Dynamics of EFCDS's is described, and the ergodicity of EFCDS's is considered. Fuzzy-integral representations of controllable extremal fuzzy processes are given. Sufficient and necessary conditions are presented for the existence of an extremal fuzzy optimal control processes using Bellman's optimality principle and taking into account the gain-loss fuzzy process. A separate consideration is given to the case where an extremal fuzzy control process acting on the EFCDS does not depend on an EFCDS state. Applying Bellman's optimality principle and assuming that the gain-loss process exists for the EFCDS, a variant of the fuzzy integral representation of an optimal control is given for the EFCDS. This variant employs the extended extremal fuzzy composition measures. An example of how to construct the EFCDS optimal control is presented.

Milan Mareš ("Vaguely Motivated Cooperation") considers the transferable utility cooperative games which are used as an effective mathematical representation of cooperation and coalitions forming. The author discusses a modified form of such games in which the expected pay-offs of coalitions are known only vaguely, where the vagueness is modeled by means of fuzzy quantities and some other fuzzy set theoretical concepts. Then, for such games the author discusses an extension of their cores and Shapley values, as well as some other properties, from the point of view of the motivation of players to cooperate in coalitions, as well as the relation between the willingness to cooperate and the ability to find the conditions under that the cooperation can be perceived as fair. The usefulness of some fuzzy and possibilistic optimization type tools is indicated.

Part IV, "Fuzzy Network and Combinatorial Optimization", is mainly concerned with broadly perceived fuzzy integer programming, or – more generally – broadly perceived fuzzy combinatorial optimization models, notably those related to network optimization.

Adam Kasperski and Paweł Zieliński ("Computing min-max Regret Solutions in Possibilistic Combinatorial Optimization Problems") discuss a wide class of combinatorial optimization problems with a linear sum and a bottleneck cost function. First, the authors consider the case when the weights in the problem are modeled as closed intervals, and show how the concept of optimality can be extended by using the concept of a deviation interval. For choosing a solution to the problem considered, the authors adopt a robust approach by seeking a solution that minimizes the maximal regret, that is, the maximal deviation from the optimum over all weight realizations, called scenarios, which may occur. Then, they explore the case in which the weights are specified as fuzzy intervals and show that under the fuzzy weights the problem has an interpretation which is consistent with possibility theory. Namely, the fuzzy weights induce a possibility distribution over the set of scenarios and the possibility and necessity measures can be used to extend the optimality evaluation and the min-max regret approach.

Yue Ge and Hiroaki Ishii ("Stochastic Bottleneck Spanning Tree Problem on a Fuzzy Network") consider a fuzzy network version of the stochastic bottleneck spanning tree problem. The existence of each edge is not necessary certain and it is given by a certain value between 0 and 1, with 1 standing for that it exists certainly and 0 for that it does not exist. For intermediate numbers, a higher value corresponds to a higher possibility of existence. Furthermore each edge has a random cost independent to other edges. The probability that the maximum burden among these selected edges is not greater than the capacity should be not less than the fixed probability. In this setting, the authors look for a spanning tree minimizing the capacity and maximizing the minimal existence possibility among these selected edges. Since usually there is no spanning tree optimizing simultaneously these two objectives, the authors develop an efficient solution procedure to obtain a set of some non-dominated spanning trees.

Dorota Kuchta ("The Use of Fuzzy Numbers in Practical Project Planning and Control") proposes how to use fuzzy numbers in project planning and control in such a way that it would meet requirements and expectations of practitioners. The method proposed is fairly general and is meant for all the projects, but especially for those where in the initial phase knowledge about the project is very incomplete and is made stepwise more precise during the project execution, and also for those in which initial assumptions about the project execution times are due to later changes. The method proposed requires the users to think while estimating project parameters in terms of trapezoidal fuzzy numbers, which in fact means only giving four parameters: an optimistic one, a pessimistic one and one or the two medium ones, which may also be equal to each other. The approach requires in each control moment, not an automatic generation of numbers which do not take into account the really important information about the project history and its future, but a deeper insight into the development of the project, the influence of its environment and the interdependencies between various project elements (activities, resources etc.).

Part V, "Applications", presents some examples of successful applications of broadly perceived fuzzy optimization and fuzzy mathematical programming in diverse areas, from economic and management, through technological to biological problems.

Susana M. Vieira, João M. C. Sousa and Uzay Kaymak ("Ant Feature Selection Using Fuzzy Decision Functions") consider feature selection, one of the most important stages in data preprocessing for data mining. Real-world data analysis, data mining, classification and modeling problems usually involve a large number of candidate inputs or features, and less relevant or highly correlated features decrease in general the classification accuracy, and enlarge the complexity of the classifier. Basically, feature selection is a multi-criteria optimization problem with contradictory objectives which are difficult to properly describe by conventional cost functions. The authors propose the use of fuzzy optimization to improve the performance of this type of system, since it allows for an easier and more transparent description of the criteria used in the feature selection process. This paper is an extension of the authors' previous work in which an ant colony optimization algorithm for feature selection was proposed which minimized two objectives: the number of features and classification error. Now, in this chapter, the authors propose a fuzzy objective function to cope with the difficulty of weighting the different criteria involved in the optimization algorithm. They show an application of fuzzy feature selection to two benchmark problems that justify the usefulness of the proposed approach.

Hiroshi Tsuda and Seiji Saito ("Application of Fuzzy Theory to the Investment Decision Process") propose a new approach to portfolio optimization that allows portfolio managers to construct portfolios that reflect their views about risk assets by applying fuzzy sets theory. The proposed approach to the investment decision process is based on the mean-variance approach proposed by Markowitz and uses the concept of asset market equilibrium proposed by Sharpe. For portfolio managers, it is very meaningful to use the equilibrium expected excess returns associated with the capital market as a reference. The proposed approach enables a new method for incorporating the views of portfolio managers to aid in the investment decision process. Moreover, in order to estimate the distribution of an unknown true membership function of the views of portfolio managers concerning risk assets, the authors propose a fuzzy information criterion to evaluate the fitness of the distribution between an unknown true membership function and a hypothetical membership function. In particular, the proposed approach enables a group of portfolio managers of pension funds to obtain an important solution that realizes optimal expected excess returns of risky assets by specifying the vague views of portfolio managers as a fuzzy number.

Anna M. Gil-Lafuente, José M. Merigó ("Decision Making Techniques in Political Management") develop a new decision making model meant for selecting the best governmental policy of different types such as fiscal, monetary and commercial, and the authors employ a framework based on the use of ideals in the decision process and several similarity measures. For each similarity measure, different aggregation operators are applied exemplified by the simple and weighted average, the ordered weighted averaging (OWA) operator and its generalizations. Basically, the approach deals with multiple attributes and different scenarios for the selection of policies arising in various institutions. The authors develop different techniques using as a starting point a selection process based on attributes under the assumption that the requirements for each attribute is different depending on the environment of the economy.

Takashi Hasuike and Hiroaki Ishii ("Mathematical Approaches for Fuzzy Portfolio Selection Problems with Normal Mixture Distributions") consider some versatile portfolio selection models with general normal mixture distributions and fuzzy or interval numbers. They develop some fuzzy optimization models to obtain an optimal portfolio. Basically, they formulate the proposed portfolio selection problems minimizing the total variance and maximizing the total future return with normal mixture distributions, respectively. They introduce uncertainty sets for the mean values, weights and probabilities as fuzzy numbers. Taking into account several portfolio selection problems including randomness and fuzziness, the authors construct a novel solution method. The results obtained are compared on numerical examples with standard approaches, and some advantages of the approach proposed are pointed out.

Shuming Wang and Junzo Watada ("Fuzzy Random Redundancy Allocation Problems") consider some relevant problems in reliability related to the fuzzy random parallel systems. Namely, due to subjective judgment, imprecise human knowledge and perception in capturing statistical data, the real data of lifetimes in many systems are both random and fuzzy in nature. Based on the fuzzy random variables that are used to characterize the lifetimes, the authors study the redundancy allocation problems to a fuzzy random parallel-series system. Two fuzzy random redundancy allocation models (FR-RAM) are developed through reliability maximization and cost minimization, respectively. Some properties of the FR-RAM are obtained, where an analytical formula of reliability with convex lifetimes is derived and the sensitivity of the reliability is discussed. To solve the FR-RAMs, the authors first address the computation of reliability. A random simulation method based on the derived analytical formula is proposed to compute the reliability with convex lifetimes. As for the reliability with non-convex lifetimes, the technique of fuzzy random simulation together with the discretization method of fuzzy random variable is employed to compute the reliability, and a convergence theorem of the fuzzy random simulation is proved. This fuzzy approach is then combined with the use of a genetic algorithm (GA) to search for the approximately optimal redundancy allocation of the models. Numerical examples provided illustrate the performance of the solution algorithm.

Eva Sciacca and Salvatore Spinella ("Reliable Biological Circuit Design Including Uncertain Kinetic Parameters") deal with biological design problems which should be particularly important in the near future when it will be possible to produce biological entities and synthetic organisms for pharmacological and medical usage. The biological systems are considered in terms of performance or key features of the system. The idea adopted is that the set of parameters involved in the model can be classified into two different typologies: the uncertain kinetic parameters and the control design parameters. In order to design a robust and reliable biological system with respect to a target performance, the design parameter values are set up to balance the uncertainty of the kinetic parameters. To take into account these uncertainties arising from the estimations of the kinetic parameters, the function representing feedback is fuzzified and a measure of failure of the designed biological circuit is minimized to reach the required performance. For illustration, a case study of an autonomously oscillatory system is provided, namely the Drosophila Period Protein which is a central component of the Drosophila circadian clocks. The results compared with a deterministic method and advantages are shown.

Zach Richards ("Fuzzy Optimal Algorithms for Multiple Target Convergence") proposes the use of fuzzy algorithms for a networked swarm of autonomous vehicles, such as those used in planet exploration, and to be used in target location determination and convergence. In particular, an algorithm of this type could be used in an Autonomous Stratospheric Aircraft (ASA), thus having the possibility of being used for the exploration of a planet as well as many other space, military and civil applications. Upon finding an unknown location of a specified target, the algorithm would then swarm and eventually converge upon the location. The author proposes two similar, but fundamentally different algorithms which are capable of locating and converging upon multiple targeted locations simultaneously. This project is inspired by the current thought of NASA in the search of life on Mars with the targeted location to be a water source. The algorithms proposed by the author make use of combining a modified Particle Swarm Optimization algorithm combined with fuzzy variables for added intelligence. An analysis of them is presented and efficiency is discussed.

J.M. Cadenas, V. Liern, R. Sala and J.L. Verdegay ("Fuzzy Linear Programming in Practice: An Application to the Spanish Football League") consider fuzzy linear programming problems as a hybridization of fuzzy sets theory and linear programming. In particular, they present a novel application of fuzzy linear programming to the formulation and solution of some problems arising in the Spanish football (or soccer) league. Basically, the main motivation is that uncertainty inherently associated with the parameters related to soccer teams in the Spanish league may best be handled using fuzzy tools and techniques. Fuzzy linear programming models are developed which optimize the returns on investments made to maintain a high quality competition, which is finally given in an efficiency measure of the different teams that can be classified. Fuzzy data envelopment analysis models are used to provide team predictions as to their efficiency score. First, the author briefly present some basic elements of fuzzy sets theory and a brief review of the most typical problems and methods in fuzzy linear programming. Next, they develop an application of some selected fuzzy linear programming model to the problem considered. An example is solved using real data from the Spanish football in the season 2006/07.

We wish to thank all the contributors for their excellent work. We hope that the volume will be interesting and useful to the fuzzy optimization research community as well as other communities in which people may find fuzzy optimization tools and techniques useful to formulate and solve their specific problems.

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