

# Preface

This volume is dedicated to Prof. Mario Fedrizzi, Full Professor at the Department of Industrial Engineering at the University of Trento, Italy, as a token of appreciation for his scientific and scholarly achievements, and his long time service to many communities, notably those of fuzzy logic, operations research, decision analysis and sciences, and mathematical economics. The topic of this volume, chosen after a long deliberation, is related to the areas in which Prof. Fedrizzi has been active for some decades and has obtained valuable results, that is, group decision-making and consensus reaching.

Of course, since these areas are vast and involve aspects that range over an extremely wide spectrum of fields exemplified by psychology, and social and political sciences, decision analysis and decision sciences, data analysis and data mining, computational sciences, artificial and computational intelligence, systems research, just to name a few, the selected contributions cover a range of them. The purpose has been that of providing a bird's view account of some novel directions in the broadly perceived area of group decision-making and consensus modeling. We are glad to note that many well-known researchers and scholars have very positively responded to our initiative to publish this volume and contributed with their latest work.

The volume starts with some philosophical and foundational considerations, then presents some more general economic considerations, before going forward to a the presentation of some promising models for the analysis of data and decision-making processes. The contributions in the volume have collected inspiration from previous research from fields such as social and political sciences, systems modeling, optimization under imprecise (fuzzy) data, artificial and computational intelligence, and naturally consensus reaching modeling and the results are not only conceptual or theoretical, but include also a high real-world implementation potential.

We will now provide a short summary of the contributions to help the interested reader more easily navigate the volume:

Part I contains a selection of more general papers on issues broadly related to social and economic aspects.

Vladik Kreinovich and Thongchai Dumrongpookaphoan consider in their paper “Optimal Group Decision Making Criterion and How it can Help to Decrease Poverty, Inequality, and Discrimination” the traditional approach to group decision-making in economics, in which the goal is to maximize the Gross Domestic Product (GDP), while hoping that the increased wealth will be equally distributed across the society. Though this may, at least theoretically, sometimes happen the reality is usually different in that in spite of an increase in the GDP, much inequality remains, as some (often most) people remain poor, some social groups continue to face economic discrimination, and so forth. The contribution indicates that the maximization of the overall gain may not always be the best criterion in group decision-making connected to social issues. The authors propose a group decision-making criterion, which is in a specific sense optimal and show that by using this optimality criterion one can attain a solution that can indeed help to decrease poverty, inequality, and discrimination.

In his paper “An Overview and Re-Interpretation of Paradoxes of Responsiveness” Hannu Nurmi provides a comprehensive discussion and a desiderata of democratic decision-making, including the “notion” that the political outcomes (policies, elected persons, legislation) should be responsive to popular opinions. In representative forms of governance, this responsiveness is however not expected to pertain to every single outcome, but the very idea of going “to the people” seems to presuppose some degree of responsiveness. In social choice theory, several notions that aim to capture aspects of responsiveness have been introduced and related to other desiderata of social choice, and those which are more relevant are discussed from the point of view of their relevance in democratic decision-making. The author then considers the paradoxes related to non-responsiveness from a novel point of view in that he tries to determine their significance for multiple-criteria decision-making (MCDM). It turns out that the use of some methods of aggregating the performance criteria of policy alternatives can be ruled out, because of their strange and unacceptable behavior in some decision settings.

Jacek Mercik in “Veto in Yes-no and Yes-no-abstain Voting Systems” is concerned, from a theoretical point of view, with a transformation from simple “yes-no” cooperative games to simple cooperative games in which players have more than two actions available to them by introducing abstentions into the yes-no voting system. The results obtained so far in this respect have rather been pessimistic exemplified by Felsenthal and Machover (2013) who even call them “the curious case of the absent abstention”. The author discusses the relation between the right of veto, weights of the players and quotas. The results obtained clarify some general properties and make an a priori analysis possible to gain a better understanding of the decision-making mechanism of such decisive bodies. An example of the United Nations Security Council is used to illustrate the discussion.

In “Power Indices for Finance” Cesarino Bertini, Gianfranco Gambarelli, Izabella Stach, and Maurizio Zola consider the use of power indices for the determination of the weight of the share stock of a company to quantify the possibility for each shareholder to get majority positions by coalitions with other

shareholders. They indicate the potential of this approach, for building effective and efficient models for forecasting, simulation, and regulation in many financial, political, and economic fields.

Silvia Bortot, Ricardo Alberto Marques Pereira and Anastasia Stamatopoulou (“The Binomial Decomposition of the Single Parameter Family of GB Welfare Functions”) consider the binomial decomposition of the generalized Gini welfare functions in terms of the binomial welfare functions and examine the weighting structure of the binomial welfare functions which progressively focus on the poorest part of the population. A parametric family of income distributions is dealt with and the numerical behavior of the single parameter family of GB welfare functions with respect to those income distributions. The binomial decomposition of the GB welfare functions is considered and the dependence of the binomial decomposition coefficients is analyzed in relation to a single parameter which describes the family.

Part II encompasses some papers on formal foundations related to logics and mathematics.

In the paper “The Logic of Information and Processes in System-of-Systems Applications”, P. Eklund, M. Johansson and J. Kortelainen propose a new logic and an approach to many-valuedness, which can make it possible to describe underlying logical structures of information as represented in industrial processes, and as a part of their respective markets. The authors emphasize the importance of introducing classification structures in order to devise tools and techniques for the management of information granularity within, and across subsystems in the system-of-systems (SoS) context. The proposal of the logic of information and process is a main contribution of this paper, and the authors’ focus on the system-of-systems concept proceeds within the field of energy. In their process view, they look closer into the power market with all its stakeholders, exemplified by those related to renewable energy. Supply, demand, and pricing models are shown to be subjected to logical analyses. The authors show how information and information structures are integrated into processes and their structures. The Business Process Modeling Notation (BPMN) paradigm is adopted for the modeling.

Sarka Hoskova-Mayerova and Antonio Maturo (“Decision-making Process Using Hyperstructures and Fuzzy Structures in Social Sciences”) consider algebraic hyper-structures, which is an interesting field of algebra and important, both from the theoretical and the applications point of view. The authors show that a hyper-groupoid structure can be associated with any social relationship. These hyper-groupoids become hyper-groups under some conditions, exemplified by a condition concerning outer individuals. By way of analysis one can establish, in a natural way, when social relationships become optimal. Relations between people are a crucial topic in the social sciences and are usually described by linguistic propositions. Obviously, the binary context is not always sufficient and often a correct and complete modeling of such relations can only be obtained, if a degree of the strength of a relation is used. Assuming such a context, the authors discuss various decision-making problems and their solutions.

Antonio Di Nola, Massimo Squillante, and Gaetano Vitale (“Social Preferences Through Riesz Spaces: A First Approach”) propose to employ the Riesz spaces as general framework to be used in the context of pairwise comparison matrices to deal with definable properties, real situations, and the aggregation of preferences. Some significant examples are presented to describe how properties of the Riesz spaces can be used to express preferences. It is shown that the Riesz spaces make it possible to combine advantages of many approaches. The authors also provide a characterization of collective choice-rules, which satisfy some classic criteria assumed in the social choice theory. They also propose an abstract approach to social welfare functions.

In their paper “Coherent Conditional Plausibility: A Tool for Handling Fuzziness and Uncertainty Under Partial Information” Giulianella Coletti and Barbara Vantaggi consider some important issues related to non-additive measures. These may be a powerful tool for the analysis of problems, when only a partial, or indirect, information about the events of interest is available, or when imprecision and ambiguity of agents is considered. The authors focus their attention on one non-additive measure—the plausibility measure. They mainly study inferential processes, where information is expressed in natural language and the uncertainty measure is either partially or imprecisely evaluated.

The cases considered are such, where partial assessments are consistent with a conditional plausibility, and it is assumed that the interpretation of the membership function of a fuzzy set, in terms of coherent conditional plausibility, is regarded as a function of the conditioning event. This kind of interpretation is particularly useful for computing the measure of uncertainty of a fuzzy event, when knowledge about a variable is imprecise and can be managed via a non-additive measure of uncertainty. A simple situation related to a Zadeh’s example can be the following: a ball will be drawn from an urn containing balls of different colors and different diameters, but one knows only the distribution of the different colors. The purpose is to compute the uncertainty measure of the fuzzy event “a small ball is drawn” taking into consideration the possible logical constraints among the particular colors and the ball diameter—a new method is proposed.

Krassimir T. Atanassov, Vassia Atanassova, Eulalia Szmidt, and Janusz Kacprzyk (“Intuitionistic Fuzzy Interpretations of Some Formulas for Estimation of Preference Degree”) propose a new interpretation of a degree of preference, using some concepts, tools, and techniques of the theory of Atanassov’s intuitionistic fuzzy sets. Then, this interpretation is used for the derivation of a degree of consensus in a group of agents following the approach of Fedrizzi et al. and Peneva and Popchev.

Part III is concerned with various aspects of judgments and aggregation, taking into account both human-related and formal aspects.

Jan Stoklasa, Tomáš Talášek, and Pasi Luukka (“Fuzzified Likert Scales in Group Multiple-criteria Evaluation”) discuss Likert scales, which are widely used for the representation of attitudes in many fields of social science. The authors consider their use in multiple-criteria multi-expert evaluations. They propose a methodology that deals with the non-uniformity of the distribution of linguistic

labels along the evaluation universe and also with a possible response bias (central tendency and extreme-response tendency). The methodology represents the Likert-type evaluations of an alternative, with respect to various criteria using histograms. The histograms are used in the process of aggregation of information, because the underlying evaluation scale is ordinal. A transformation of the multi-expert multiple-criteria evaluation represented by a histogram into a 3-bin histogram to control for the response bias is performed, and an ideal-evaluation 3-bin histogram is defined. The authors propose a distance-measure to assess the closeness of the overall evaluation to the ideal, and suggest the use of its values interpretation/evaluation fuzzy rules. Some examples showing the effectiveness and efficiency of the proposed approach are presented.

Robert Fullér and Christer Carlsson (“Maximal Entropy and Minimal Variability OWA Operator Weights: A Short Survey of Recent Developments”) consider a very important problem of weights of the ordered weighted averaging (OWA) operator. First, a comprehensive and critical analysis of the existing approaches is given. The chapter starts with the early approach by O’Hagan, who proposed to determine a special class of the OWA operators having the maximum entropy of the OWA weights for a given level of the degree of orness, which boiled down to the solution of a constrained optimization problem. Then, Fullér and Majlender proposed the use of the method of Lagrange multipliers that boiled down to the analytical solution of a constrained optimization problem, which gave the optimal weighting vector. Then, the same authors computed the exact minimal variability weighting vector for any level of orness, using the Karush-Kuhn-Tucker second-order sufficiency conditions for optimality. The problem of maximizing an OWA aggregation of a group of variables that are interrelated and constrained by a collection of linear inequalities was first considered by Yager in 1996, where he showed how this problem can be represented by the solution of a mixed integer linear programming problem. Then, Carlsson, Fullér, and Majlender derived an algorithm for solving the constrained OWA aggregation problem under a simple linear constraint that the sum of the variables is less than, or equal, to one. After the above pioneering works, many other approaches have been proposed. The purpose of this paper is to present a survey and analysis of these works essence and properties.

József Mezei and Matteo Brunelli (“A Closer Look at the Relation Between Orness and Entropy of OWA Function”) discuss some important problems related to the ordered weighted averaging (OWA) functions that have been extensively used to model the problem of choice and consensus in the presence of multiple experts and decision-makers. Since each OWA operator is associated with a weight vector, a critical problem that has been studied for years and by many authors has focused on the determination of the weight vector. In this paper, the authors consider the degree of orness and entropy, two characterizing measures of the priority vectors, and they study their interplay from a graphical point of view.

Michele Fedrizzi and Silvio Giove (“Rank Reversal in the AHP with Consistent Judgements: A Numerical Study in Single and Group Decision Making”) analyze, by using numerical simulations, the influence of some relevant factors on the

well-known rank reversal (RR) phenomenon in Saaty's Analytic Hierarchy Process (AHP). The authors consider both the case of a single decision maker and of a group of decision-makers. Their idea is to concentrate on a condition, which preserves RR and on how to relax it step-by-step. First, they study how the estimated probability of RR depends on the distribution of the criteria weights and more precisely on the entropy of this distribution. Entropy is relevant since it is known that RR does not occur in the zero entropy case of weight concentration. The authors show an interesting "increasing behaviour" of the estimated RR probability as a function of the entropy of weights. Additionally, the chapter focuses on the aggregation of local weight vectors and on a more general aggregation rule, based on the weighted power mean, for which the weighted geometric mean and the weighted arithmetic mean are particular cases. Finally, the authors repeat their analysis for the case of a group decision-making problem and observe that the estimated probability of RR decreases by the aggregation of preferences of the decision-makers, suggesting an inverse relationship between consensus and rank reversal, under the assumption that all judgements are totally consistent.

In "Estimating One-Off Operational Risk Events with the Lossless Fuzzy Weighted Average Method" Pasi Luukka, Mikael Collan, Fai Tam, and Yuri Lawryshyn consider the problem of determining an estimate for the size of possible one-off negative operational events. The problem is very important for banks, who are required by the Basel II Accord to report these risks. The typical way to produce these estimates is to use a quantitative value-at-risk methodology that is based on limited data. This is interesting, because also the use of qualitative expert estimate-based methodologies is allowed by the regulations. The final estimations are typically obtained by fusing the input from multiple experts. The authors propose a new approach that is based on the author's original idea of a new lossless fuzzy weighted averaging. They show how to use this method for the problem considered and why it is a good tool for the aggregation of expert estimates in the context of bank risk management. The method proposed is simple to use, intuitive to understand, and does not suffer from the loss of information associated with the use of many other weighted averaging methods.

The paper "Fuzzy Signature Based Methods for Modelling the Structural Condition of Residential Buildings" by Ádám Bukovics, István Á. Harmati and László T. Kóczy deals with some issues related to a very important problem of the conservation, extension, or renovation of residential buildings. The focus is on the proper use of available financial resources and it is shown that an incorrect assessment of the scope and extent of renovation or reconstruction needs may cause a considerable financial loss. The authors present, through a survey of a real stock of buildings, an analysis of what kind of examinations and research should precede the quantitative decision support stage of renovation decisions. The authors introduce three fuzzy signature based methods, which are shown to be suitable for determining the condition of a bigger stock of buildings and for ranking them. These methods are suitable for the aggregation of expert evaluations of different detail and depth. Finally, the authors consider a very relevant issue of the sensitivity analysis of the method and present results of some computational examples.

Ronald R. Yager (“Retrieval from Uncertain Data Bases”) investigates tools that can enrich the process of querying databases. He shows how to include soft conditions with the use of fuzzy sets and describes some techniques for aggregating the satisfaction of the individual conditions, based on the inclusion of importance and the use of the OWA operator. The author discusses a method for aggregating the individual satisfactions that can model a lexicographic relation between the individual requirements. Finally, the author looks at querying databases, in which the information can exhibit some probabilistic uncertainty.

Part IV includes chapters on various issues related to decision-making and optimization in various settings and under various kinds of imperfect information.

José Luis García-Lapresta and Raquel González del Pozo (“An Ordinal Multi-criteria Decision-making Procedure in the Context of Uniform Qualitative Scales”) propose a multi-criteria decision-making procedure for the purely ordinal context, in which agents evaluate the alternatives regarding several criteria by assigning one, or two, consecutive terms of a uniform ordered qualitative scale to each alternative in each criterion. The weights assigned to criteria are dealt with by replications of the corresponding ratings and alternatives are ranked according to the medians of their ratings, after the replications. The new method and its properties are discussed and illustrated with examples.

In “FRIM—Fuzzy Reference Ideal Method in Multicriteria Decision Making” E. Cables, M.T. Lamata, and J.L. Verdegay consider TOPSIS, one of numerous compensatory multi-criteria decision methods, because of its rationality, intuitive appeal, and easy applicability. This method is based on the concept of scoring alternatives based on their distance to a positive ideal-solution (shorter the better) and simultaneously on their distance to a negative ideal-solution (longer the better). Based on this idea, the Reference Ideal Method (RIM), proposed by the authors, can be considered as an extension of the TOPSIS method, while considering that the ideal solution does not have to be the maximum or the minimum value, but may be a value in-between these. The RIM method yields good solutions, but does not always obtain a solution in the case of using fuzzy numbers. An extension of the RIM is proposed in the paper for making it possible to deal with vagueness and uncertainty, resulting in the Fuzzy Reference Ideal Method (FRIM). Its applicability is shown with practical examples.

In their paper “A new approach for solving CCR data envelopment analysis model under uncertainty” Bindu Bhardwaj, Jagdeep Kaur, and Amit Kumar critically analyze Wang and Chin’s approach to the optimistic and pessimistic fuzzy CCR data envelopment analysis (DEA) model, and—after pointing out some of its deficiencies—propose a novel approach that makes it possible to alleviate the observed deficiencies. Moreover, they also propose a new approach to solve the proposed fuzzy CCR DEA models for evaluating the relative geometric efficiency of decision-making units (DMUs).

Then, in the paper “A New Fuzzy CCR Data Envelopment Analysis Model and Its Application to Manufacturing Enterprises” Bindu Bhardwaj, Jagdeep Kaur and Amit Kumar consider the problem of fuzzy data envelopment analysis based on fuzzy arithmetic with an application to the performance assessment of

manufacturing enterprises in which the solution is obtained by solving a fuzzy fractional programming problem transformed into a fuzzy linear programming problem as proposed by Wang et al. The authors first show some of the original approach, and propose a new approach to overcome this flaw. Then they present the application a real life planning problem in a manufacturing company.

Part V cover various aspects, approaches, tools and techniques, and algorithms that are relevant for various problems in a large area of multi-person decision-making and consensus reaching.

Francisco Javier Cabrerizo, Francisco Chiclana, Ignacio Javier Pérez, Francisco Mata, Sergio Alonso, and Enrique Herrera-Viedma propose in their paper “A Feedback Mechanism Based on Granular Computing to Improve Consensus in GDM” consider a very important problem of group decision-making, the essence of which is to obtain the best solution to a particular problem according to opinions (testimonies) given by a set of decision-makers, or—more generally—of some agents. Usually, this process proceeds better, when the group is at an agreement, or at consensus. An important issue is the level of consensus achieved among the decision-makers before making a decision. This may be supported by different feedback mechanisms, which can help the decision-makers reach the highest possible degree of consensus, many such mechanisms have been proposed in the previous literature. In this work, the authors present a new feedback mechanism that is based on granular computing and an effective and efficient framework of designing, processing, and interpretation of information granules, to improve (the degree of) consensus in group decision-making problems. The approach proposed provides flexibility required to improve the level of consensus within the group of decision-makers.

In their paper “A Method for the Team Selection Problem Between Two Decision-Makers Using the Ant Colony Optimization” Marilyn Bello, Rafael Bello, Ann Nowé, and María M. García-Lorenzo consider the problem of team selection, which consists of how to perform a personnel selection process to form some collaborating and cooperating teams according to some preferences. This is a clearly important in the field of human resources. This type of selection process usually proceeds by the ranking of candidates based on preferences of decision-makers and by then allowing the decision-makers to select a specific candidate, or candidates. This simple process may be viewed as unfair, because it often leads to an unfair allocation of candidates to different teams, i.e., the quality of the teams formed may not follow the rankings articulated by the decision-makers. A new approach to the team selection problem is proposed, in which two employers form their teams by selecting their members from a set of candidates that is common to both and then each decision maker reveals his or her personal ranking of those candidates. The method proposed is shown to lead to teams of a high quality, according to the valuations of each of the decision-makers, and also to a (more) fair composition of teams. The Ant-Colony Optimization meta-heuristic is employed and its effectiveness and efficiency is shown on some quite large examples.



Mingwei Lin and Zeshui Xu (“Probabilistic Linguistic Distance Measures and Their Applications in Multi-Criteria Group Decision Making”) consider a new and interesting topic of probabilistic linguistic term sets, which can express not only the decision-makers’ several possible linguistic assessment values, but also the weight of each linguistic assessment value. The authors advocate the use of the probabilistic linguistic term sets in various fields, specifically they focus on the distance measures for the probabilistic linguistic term sets and their applications in multi-criteria group decision-making. They first define the distance between two elements of the probabilistic linguistic term set. A variety of distance measures are proposed to calculate the distance between two probabilistic linguistic term sets. Then, these distance measures are further extended to compute the distance between two collections of probabilistic linguistic term sets, by considering the weight information of each criterion. Finally, the concept of the satisfaction degree of an alternative is proposed and used to rank the alternatives in multi-criteria group decision-making. A real-world example is given to show the use of these distance measures and to compare the probabilistic linguistic term sets with hesitant fuzzy linguistic term sets.

Antonio Maturo and Aldo G.S. Ventre (“Fuzzy Numbers and Consensus”) consider a frequently encountered case in multi-group decision and consensus reaching processes, when in a group of decision-makers there is a considerable variability in the scores that they assign to given alternatives. The authors propose to represent this variability with fuzzy numbers and then present an algorithm for reaching a consensus in the setting assumed, i.e., based on fuzzy numbers, preorder and order relations in the sets of fuzzy numbers, and on a procedure to decrease the spreads resulting from operations on fuzzy numbers.

Janusz Kacprzyk and Sławomir Zadrozny (“Reaching Consensus in a Group of Agents: Supporting a Moderator Run Process via Linguistic Summaries”) present an account and a critical analysis of works on consensus reaching processes driven by a moderator, a “super-agent” who is in charge of running the process in an effective and efficient way. The authors assume the classic approach to the evaluation of the degree of consensus of Kacprzyk and Fedrizzi, in which a soft degree of consensus is a degree, in which, e.g., “most of the important individuals agree on with regards to almost all of the relevant options”, with the fuzzy “most” majority assumed to be a fuzzy linguistic quantifier, as proposed by Kacprzyk. Typically, this kind of situations are handled via Zadeh’s classic calculus of linguistically quantified propositions, or by some other method, notably Yager’s OWA (ordered weighted average) operators.

Additional information, which can be very useful to the moderator and the agents, is provided by a novel combination of using a soft degree of consensus alone within a decision support system setting and the linguistic data summaries in Yager’s sense, in particular, in its protoform-based version proposed by Kacprzyk and Zadrozny. They are intended to indicate, in a natural language, some interesting relations between individuals and options to help the moderator identify crucial (pairs of) individuals and/options, which pose some threats to the reaching of (a sufficient degree of) consensus. The use of a so-called action rule that in the

context of the chapter means “to find best concessions to be offered to the individuals for changing their preferences to increase the degree of consensus” is employed. New results on the use of the concepts of a consensory and dissensory agents are also presented.

In “Consensus in Multiperson Decision Making Using Fuzzy Coalitions” Fabrizio Maturo and Viviana Ventre consider the problem of group decisions, in which the decision-makers have different opinions or interests. The authors propose various metric spaces for the representation of movements of decision-makers for reaching a consensus. They also introduce the concept of a fuzzy coalition for developing an algorithm for building a feasible fuzzy coalition, defined as the union of winning maximum coalitions that solve the issue of consensus among decision-makers.

We would like to express our gratitude to all the authors for their interesting, novel, and inspiring contributions. Peer-reviewers also deserve a deep appreciation, because their insightful and constructive remarks and suggestions have considerably improved many contributions.

And last but not least, we wish to thank Dr. Tom Ditzinger, Dr. Leontina di Cecco, and Mr. Holger Schaepe for their dedication and help to implement and finish this large publication project on time maintaining the highest publication standards.

Lappeenranta, Finland  
Warsaw, Poland  
Spring 2017

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Soft Computing Applications for Group Decision-making  
and Consensus Modeling

Collan, M.; Kacprzyk, J. (Eds.)

2018, XXV, 488 p. 66 illus., 10 illus. in color., Hardcover

ISBN: 978-3-319-60206-6