

Editorial

Special Issue on Fuzzy Decision-Making and Consensus: New Trends and Real-Life Applications

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Over the last few decades, fuzzy decision-making has attracted the attention of researchers and practitioners, offering as it does a way to represent and capture decision-making and consensual processes in a more flexible, human-like way. The importance of fuzzy reasoning in decision-making and consensus measurement lies in modelling forms of uncertainty that cannot be fully described by the use of numerical models and probability theory. In addition, the development of formal mathematical models to support experts in decision-making is of great importance for ensuring the validity of the actions arising from a decision outcome. This is of special relevance in decision contexts where the information on the problem at hand cannot be modelled in a quantitative and precise way. This type of decision-making is now being described as decision-making under uncertainty in inconsistent and dynamic environments. In this direction, methodologies and tools using fuzzy reasoning to address this type of complex decision-making are used in a wide range of disparate fields, such as Engineering, Operations Research, Economics and Management.

This special issue presents seventeen new contributions on the development of fuzzy models for decision-making and consensus reaching, as well as formal approaches that support incomplete or missing information. Special attention is paid to the rigorous motivation of the approaches put forward and to the validation support using real practical applications. Accordingly, the submissions can be split into three groups. The first one includes three papers analysing decision-making tools with preference modelling from a theoretical point of view. The second group includes eight papers presenting novel consensus measures taking into account different types of information and consensus-reaching processes. The third group covers six real-life applications of fuzzy decision-making and consensus.

The first group of papers considers several theoretical aspects of fuzzy decision-making with interval-valued fuzzy preferences, intuitionistic fuzzy preferences and pair-wise comparisons to represent preferences, respectively.

- Bentkowska et al. in ‘**Decision-making with an Interval-valued Fuzzy Preference Re-**

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lation and Admissible Orders' examine the conditions under which interval-valued fuzzy relations should be used in decision-making problems. On the one hand, they propose a non-dominance algorithm for the interval-valued case and prove its suitability in several different linear orders. On the other hand, they address some transitivity properties of interval-valued fuzzy relations. In particular they characterise weak transitivity and 0.5-transitivity and analyse the behaviour of interval-valued reciprocal relations with respect to them.

- The second paper considered in this group, '**Revision of the Individual Pair-wise Comparison Matrices under Consensus in AHP-GDM**', introduces a Bayesian revision method for improving the individual pair-wise comparison matrices under the assumption of the existence of consensus among decision-makers. The method is based on the multiplicative AHP model with log-normal errors.
- The last paper of this first group, '**Consistency of the Fused Intuitionistic Fuzzy Preference Relation in Group Intuitionistic Fuzzy Analytic Hierarchy Process**', introduces a new type of simple intuitionistic fuzzy weighted geometric operator to synthesise individual intuitionistic fuzzy preference relations. Some properties regarding the consistency of this type of operators are studied and proven. In addition, a new procedure to aid group decision-making processes is defined based on the conditions studied.

The second group of contributions includes technical and theoretical papers analysing consensus measures and models for consensus-reaching in fuzzy environments.

- Wu et al. in '**Trust Based Consensus Model for Social Network in an Incomplete Linguistic Information Context**' propose a novel trust propagation method to complete a connected, but not necessarily fully connected, trust network. The trust score induced ordered weighted averaging operator is presented to aggregate the orthopairs of trust/distrust values obtained from different trust paths. This operator takes into account the risk attitude of experts. In addition, a recommendation mechanism is defined to provide individualised advice to those experts who are identified as contributing least to consensus. A visual consensus model mechanism is developed and studied, which includes a visual identification to support experts so that they can easily see their consensus position within the group.
- Gong et al., in their paper entitled '**On Consensus Models with Utility Preferences and Limited Budget**', propose several consensus models using simple trapezoidal membership functions. The economic significance of these models and the changes in the optimal consensus opinion when individual decision-makers' utility changes are explored. Furthermore, the role played by the moderator in the group decision-making processes by dominating the trends in the whole process, is also verified by adding utility constraints.

- In the paper ‘**An Improved Consensus-based Group Decision Making Model with Heterogeneous Information**’, by Zhang et al., a new method is proposed for decision-making with the capability of handling heterogeneous information provided by the decision-makers. Six types of preferences are investigated, namely: ordinal; interval; fuzzy number; linguistic; intuitionistic fuzzy set; real numbers in two evaluation modes (direct and indirect).
- The paper ‘**Ordinal Proximity Measures in the Context of Unbalanced Qualitative Scales and Some Applications to Consensus and Clustering**’ introduces ordinal proximity measures in the setting of unbalanced qualitative scales by comparing linguistic proximities using a purely ordinal approach. A measure of consensus in a set of agents that assess a set of alternatives through an unbalanced qualitative scale is provided, and an agglomerative hierarchical clustering procedure based on that consensus measures is considered.
- D’Aniello et al.’s paper ‘**A Multi-Agent Fuzzy Consensus Model in a Situation Awareness Framework**’ examines the problem of handling the redundancy of discordant information related to the same phenomenon and stemming from multiple sources. Two main results are obtained. The first one considers a definition of Situation Awareness framework and includes a multi-agent architecture with the adoption of semantic technologies to sustain computational cognitive processes. The second one relates to the description of a fuzzy consensus model integrated in the aforementioned architecture to support the agreement process among sources providing discordant opinions on the same phenomenon.
- Quesada et al.’s paper entitled ‘**Managing Experts’ Behavior in Large-Scale Consensus Reaching Processes with Uninorm**’ presents an approach to detect and deal with experts’ non-cooperative behaviour, which is based on uninorm aggregation operators, fuzzy sets and the methodology of computing with words. This approach assigns different importance weights to experts in the light of their overall behaviour throughout the consensus-reaching process and the way their behaviour evolves during the discussion.
- A comparative experimental study is conducted in the paper ‘**Unifying Approaches to Consensus across Different Preference Representations**’, in which the authors analyse distance metrics used to construct consensus measures in different contexts. In addition, the authors consider some extensions of the Kemeny distance to real evaluations and pairwise preference for this purpose.
- The last paper in this group, ‘**Consensus-building in Multiperson Decision-making with Heterogeneous Preference Representation Structures: A Perspective Based on Prospect Theory**’, by Dong et al., presents a novel framework for multiperson decision-making problems with heterogeneous preference representation structures. The framework takes decision-makers’

psychological behaviours into consideration based on the prospect theory. In addition, the authors prove two significant features in this framework. First, the use of different reference points yield different outputs in the selection process; and, second, the pace of consensus-reaching speeds up when adjusting both the preference evaluations and the preference-approval information.

The last group of contributions includes applications covering both fuzzy decision-making and consensus.

- The first paper of this group by Mezei et al., ‘**An Improved Consensus-based Group Decision Making Model with Heterogeneous Information**’, covers a new web-based application of interval-valued fuzzy numbers, fuzzy ontologies, and aggregation operators. The authors use a wine ontology as a case study to describe the main features of the application. In addition they identify important similar event reports in other complex industrial processes. To conclude, they present an approach for using the framework to find consensual solutions in situations involving several experts.
- The paper ‘**Consensus in Innovation Contest Categorisation by means of Fuzzy Partitions**’ presents a fuzzy measure of agreement through fuzzy kappa based on fuzzy partitions. Then a real-life experiment is conducted, based on an innovation contest to show the feasibility of using confidence degrees in real-life applications as compared to traditional decision-making. Fuzzy partitions are built for each decision-maker that take into account how confident he or she is when categorizing a set of alternatives. The use of confidence degrees improves the level of agreement in the consensus decision-making process through fuzzy kappa coefficients and it also improves the level of agreement in the consensus decision-making process.
- Kulak et al.’s paper ‘**New Multi Criteria Decision Making Approach for Medical Imaging Systems Considering Risk Factors**’ presents an application of three different approaches to MCDM problems concerning the selection of medical imaging systems for a university hospital. The proposed approach integrates the risk factors in each criterion and calculates the information content to compare alternatives.
- The paper ‘**A Consensus Model for Delphi processes with Linguistic Terms and its Application to Chronic Pain in Neonates Definition**’ tackles the problem of establishing the features for defining a type of chronic disease. A new model of consensus based on linguistic terms involving qualitative reasoning techniques and based on the concept of entropy is proposed. It is able to reach consensus automatically, without the need of a moderator or a final interaction among experts or panellists. In addition, it allows panellists to answer with different levels of precision, depending on their knowledge on each question.

- Montes et al. in ‘**A Linguistic Multiple-expert Multi-criteria Decision-making Model and Supporting Web Tool**’ present a real-case application to the housing market. The web tool is integrated with the usual catalogue of resources for rental or for sale, enriched with the possibility of ranking a subset of properties according to the client’s preferences and the internal knowledge associated to each property. The quantitative description of a property is enriched with the qualitative information corresponding to assessments made by housing agents, who are considered experts on market conditions. The 2-tuple linguistic representation model to keep accuracy in the processes of computing with words and the hesitant fuzzy linguistic term sets are considered.
- The last paper in this group, ‘**Fuzzy Decision Method to Improve the Information Exchange in a Vehicle Sensor Tracking System**’, by Cueva-Fernández et al., presents a new application on ‘the Internet of things’ field. In particular, a fuzzy method is considered that can be used to improve the performance of mobile clients in real-time systems. The proposed algorithm is integrated in the mobile clients of a platform that sends all the vehicle and sensor data to a centralised server. Based on some cases where the information can be merged, especially if the data does not have to up to the minute, the proposed algorithm reduces the data sent from the mobile clients to the server. Evaluations performed in real scenarios reveal that the proposed algorithm makes much smaller data traffic demands on the mobile network.

As Guest Editors, we would like to thank the Editor-in-Chief of Applied Soft Computing journal for giving us the opportunity of preparing this Special Issue. We would also like to thank the managing editor and the Elsevier team for operational support, all the authors for their submissions and the anonymous referees who have put in the hard work and long hours needed to review each paper in a timely and professional manner. We hope that this collection of research papers will reveal the new research trends and challenges in fuzzy decision-making and consensus-reaching and will also spur new advances and real applications in this exciting research field.