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PREFACE

A Special Issue on Extensions of Ordinary Fuzzy Sets with Theory and Applications

Zadeh's ordinary fuzzy sets are represented by a degree of membership, μ and a degree of non-membership which is the complement of membership, 1-μ. To deal with the weaknesses of ordinary fuzzy sets, they have been extended to several new types by various researchers defining membership functions by more detailed parameters. Type-2 fuzzy sets handle the vagueness in membership functions as an extension of ordinary fuzzy sets as a third dimension. Intuitionistic fuzzy sets were introduced by Atanassov (1986), which are composed of a degree of membership and a degree of non-membership whose sum is not necessarily equal to 1. Their objective is to take the hesitancy of experts into consideration. Hesitant fuzzy sets (HFSs) introduced by Torra (2010) have been used to handle the potential membership degrees of an element in a fuzzy set. After intuitionistic type-2 fuzzy sets (IFS2) are proposed by Atanassov (1989), Yager (2013) called them as Pythagorean fuzzy sets (PFSs) represented with a larger domain area for membership and non-membership degrees. q-rung orthopair fuzzy sets (Q-ROFSs) developed by Yager (2017) are the generalization of IFSs and PFSs. Neutrosophic sets developed by Smarandache (1998) involve degrees of truthiness, indeterminacy, and falsity for each element in the universe. The sum of these independent three degrees can be at most equal to 3. Picture fuzzy sets and spherical fuzzy sets characterized by the degrees of membership, non-membership, and hesitancy for each element in a set have been introduced by Coung (2015) and by Kahraman and Kutlu Gündoğdu (2018), respectively.

This issue includes 10 innovative papers on ordinary fuzzy sets and their recent extensions such as intuitionistic fuzzy sets, Pythagorean fuzzy sets, spherical fuzzy sets, type-2 fuzzy sets, and picture fuzzy sets. These papers are written by well-known researchers on their research areas such as Krassimir Atanassov, Oscar Castillo, Cengiz Kahraman, Dorota Kuchta and Vladik Kreinovich. Most of these papers are on the modelling of decision making problems.

The first paper is on intuitionistic fuzzy sets (IFS) of second type (1989) and more generally of n-th type, Temporal IFS (TIFS) and others. Different relations, operations and operators are introduced over IFSs. The operators over IFS are of modal, topological, level and other types. As a continuation and fusion of the ideas of TIFS and of level operations over IFSs, temporal-level operators are introduced and some of their basic properties are studied by Prof. Krassimir Atanassov.

The second paper compares the fuzzy set extensions of TOPSIS method based on the same decision making problem. The fuzzy set extensions of TOPSIS handled in this paper are based on interval-valued type-2 fuzzy sets, interval-valued picture fuzzy sets, interval-valued Pythagorean fuzzy sets, interval-valued intuitionistic fuzzy sets, and interval-valued spherical fuzzy sets.

In the third paper, the authors show that, by going beyond the traditional "and"- and "or"-operations, they can find a natural estimate that takes all available information into account – and thus, hopefully, leads to a more accurate estimate.

In the fourth paper, rough sets, which are a pair of lower and upper approximations, and rules induced from them are described by an approach using coverings in an information table with similarity of values. Lots of possible coverings on a set of attributes are derived in an information table with incomplete information whereas only one covering is derived in an information table with complete information.

The fifth paper takes a closer look at the success factors and challenges for the advancement of technology in agricultural management. A model is presented that evaluates the success factors and challenges of sustainable agriculture within the scope of digitalization. After determining the main and sub-criteria of the problem addressed with a comprehensive literature review and expert opinions, the interval valued intuitionistic fuzzy analytic hierarchy process (IVIF-AHP) method is used to assess the critical success factors and difficulties of smart agriculture management that has emerged with the technological developments.

The next paper uncovers three so far unsolved problems with Aristotelian categorical propositions (ACPs), which puzzle modern logic to assimilate ACPs in representing and deducting knowledge: the inconsistency of particular quantifier resulted from confusing universe-restrictive and -unrestrictive readings, lack of a manifested quantifier on y, and localization.

The seventh paper tests the method of critical path calculation with fuzzy activity durations in different possible scenarios and suggest method's improvements. The method uses Z-fuzzy numbers and incorporates historical records to assess credibility. Normal distribution was used to reflect the behavior of human estimators.

The eighth paper develops a hybrid parallel kangaroo algorithm (HPKA) and prepare realistic project schedules that could be executed in time with the

minimum risk of being late. The objective is to find a schedule that minimizes schedule risk and maximizes the minimum satisfaction degrees of all activities. The proposed hybrid algorithm is tested with the benchmark problems from the literature. The proposed HPKA is then used to solve a disc mower manufacturing project scheduling problem of a real-world company that manufactures agricultural machinery.

The next paper proposes the use of fuzzy logic for dynamic parameter adaptation in the Multiverse Optimizer algorithm. The authors use the typical unimodal and multimodal benchmark functions for comparing results with respect to the original algorithm, and for the control problems, they use some benchmark fuzzy controllers. The considered problems are tipper problem, cruise control, temperature control in a shower, inverted pendulum control, which are the test control problems used for optimization in fuzzy logic controllers.

The last paper extends the classical TOPSIS method, which is one of the most used multi-criteria decision making methods by interval valued picture fuzzy sets for the first time in the literature. The proposed interval valued picture fuzzy TOPSIS is applied to a supplier selection problem and a sensitivity analysis is conducted for checking the robustness of the given decisions.

I thank the anonymous reviewers for their hard works in selecting high-quality papers of this issue. This issue would be impossible without their invaluable efforts. I would also like to express my sincere thanks to Editor-in-Chief of the journal, Prof. Dan Simovici for his continuous supports and helps.

Cengiz Kahraman
Guest Editor