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Editorial

Summary of the Special Issue "Neutrosophic Information Theory and Applications" at "Information" Journal

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Received: 27 February 2018; Accepted: 27 February 2018; Published: 28 February 2018

Abstract: Over a period of seven months (August 2017–February 2018), the Special Issue dedicated to "Neutrosophic Information Theory and Applications" by the "Information" journal (ISSN 2078-2489), located in Basel, Switzerland, was a success. The Guest Editors, Prof. Dr. Florentin Smarandache from the University of New Mexico (USA) and Prof. Dr. Jun Ye from the Shaoxing University (China), were happy to select—helped by a team of neutrosophic reviewers from around the world, and by the "Information" journal editors themselves—and publish twelve important neutrosophic papers, authored by 27 authors and coauthors. There were a variety of neutrosophic topics studied and used by the authors and coauthors in Multi-Criteria (or Multi-Attribute and/or Group) Decision-Making, including Cross Entropy-Based MAGDM, Neutrosophic Hesitant Fuzzy Prioritized Aggregation Operators, Biparametric Distance Measures, Pattern Recognition and Medical Diagnosis, Intuitionistic Neutrosophic Graph, NC-TODIM-Based MAGDM, Neutrosophic Cubic Set, VIKOR Method, Neutrosophic Multiple Attribute Group Decision-Making, Competition Graphs, Intuitionistic Neutrosophic Environment, Neutrosophic Commutative *N*-Ideals, Neutrosophic *N*-Structures Applied to BCK/BCI-Algebras, Neutrosophic Similarity Score, Weighted Histogram, Robust Mean-Shift Tracking, and Linguistic Neutrosophic Cubic Numbers.

Neutrosophic logic, symbolic logic, set, probability, statistics, etc., are, respectively, generalizations of fuzzy and intuitionistic fuzzy logic and set, classical and imprecise probability, classical statistics, and so on. Neutrosophic logic, symbol logic, and set are gaining significant attention in solving many real-life problems that involve uncertainty, impreciseness, vagueness, incompleteness, inconsistency, and indeterminacy. A number of new neutrosophic theories have been proposed and have been applied in computational intelligence, multiple-attribute decision making, image processing, medical diagnosis, fault diagnosis, optimization design, etc. This *Special Issue* gathers original research papers that report on the state of the art, as well as on recent advancements in neutrosophic information theory in soft computing, artificial intelligence, big and small data mining, decision-making problems, pattern recognition, information processing, image processing, and many other practical achievements.

In the first chapter (*NS-Cross Entropy-Based MAGDM under Single-Valued Neutrosophic Set Environment*), the authors Surapati Pramanik, Shyamal Dalapati, Shariful Alam, Florentin Smarandache, Tapan Kumar Roy propose a new cross entropy measure under a single-valued neutrosophic set (SVNS) environment, namely NS-cross entropy, and prove its basic properties. Additionally, they define the weighted NS-cross entropy measure, investigate its basic properties, and develop a novel multi-attribute group decision-making (MAGDM) strategy that is free from the drawbacks of asymmetrical behavior and undefined phenomena. It is capable of dealing with an unknown weight of attributes and an unknown weight of decision-makers. Finally, a numerical example of multi-attribute

group decision-making problem of investment potential is solved to show the feasibility, validity and efficiency of the proposed decision-making strategy.

Single-valued neutrosophic hesitant fuzzy set (SVNHFS) is a combination of a single-valued neutrosophic set and a hesitant fuzzy set, and its aggregation tools play an important role in the multiple criteria decision-making (MCDM) process. The second paper (*Generalized Single-Valued Neutrosophic Hesitant Fuzzy Prioritized Aggregation Operators and Their Applications to Multiple Criteria Decision-Making*) investigates MCDM problems in which the criteria under SVNHF environment are in different priority levels. First, the generalized single-valued neutrosophic hesitant fuzzy prioritized weighted average operator and generalized single-valued neutrosophic hesitant fuzzy prioritized weighted geometric operator are developed based on the prioritized average operator. Second, some desirable properties and special cases of the proposed operators are discussed in detail. Third, an approach combining the proposed operators and the score function of single-valued neutrosophic hesitant fuzzy element is constructed to solve MCDM problems. Finally, the authors Rui Wang, Yanlai Li provide the example of investment selection to illustrate the validity and rationality of the proposed method.

Single-valued neutrosophic sets (SVNSs) handling the uncertainties characterized by truth, indeterminacy, and falsity membership degrees are a more flexible way of capturing uncertainty. In the third paper (*Some New Biparametric Distance Measures on Single-Valued Neutrosophic Sets with Applications to Pattern Recognition and Medical Diagnosis*), the authors Harish, Garg and Nancy propose some new types of distance measures, overcoming the shortcomings of the existing measures, for SVNSs with two parameters along with their proofs. The various desirable relations between the proposed measures are also derived. A comparison between the proposed and existing measures is performed in terms of counter-intuitive cases for showing its validity. The proposed measures are illustrated with case studies of pattern recognition, as well as medical diagnoses, along with the effect of the different parameters on the ordering of the objects.

A graph structure is a generalization of simple graphs. Graph structures are very useful tools for the study of different domains of computational intelligence and computer science. In the fourth research paper, *Certain Concepts in Intuitionistic Neutrosophic Graph Structures*, the authors Muhammad Akram and Muzzamal Sitara introduce certain notions of intuitionistic neutrosophic graph structures, illustrating these notions with several examples. They investigate some related properties of intuitionistic neutrosophic graph structures, and also present an application of intuitionistic neutrosophic graph structures.

A neutrosophic cubic set is the hybridization of the concept of a neutrosophic set and an interval neutrosophic set. A neutrosophic cubic set has the capacity to express the hybrid information of both the interval neutrosophic set and the single valued neutrosophic set simultaneously. Since the neutroaophic cubic sets have only recently been defined, not much research on the operations and applications of neutrosophic cubic sets is currently available in the literature. In the fifth paper, *NC-TODIM-Based MAGDM under a Neutrosophic Cubic Set Environment*, the authors Surapati Pramanik, Shyamal Dalapati, Shariful Alam and Tapan Kumar Roy propose score and accuracy functions for neutrosophic cubic sets and prove their basic properties. They also develop a strategy for ranking of neutrosophic cubic numbers based on the score and accuracy functions. The authors firstly develop a TODIM (Tomada de decisao interativa e multicritévio) in the neutrosophic cubic set (NC) environment, which is called the NC-TODIM. They establish a new NC-TODIM strategy for solving multi-attribute group decision-making (MAGDM) problems in neutrosophic cubic set environments. They illustrate the proposed NC-TODIM strategy for solving a multi-attribute group decision-making problem to show the applicability and effectiveness of the developed strategy. They also conduct sensitivity analysis to show the impact of the ranking order of the alternatives on the different values of the attenuation factor of losses for multi-attribute group decision-making strategies.

In the sixth paper, *VIKOR Method for Interval Neutrosophic Multiple Attribute Group Decision-Making*, the authors Yu-Han Huang, Gui-Wu Wei and Cun Wei extend the VIKOR method to multiple-attribute

group decision-making (MAGDM) with interval neutrosophic numbers (INNs). Firstly, the basic concepts of INNs are briefly presented. The method first aggregates all individual decision-makers' assessment information based on an interval neutrosophic weighted averaging (INWA) operator, and then employs the extended classical VIKOR method to solve MAGDM problems with INNs. The validity and stability of this method are verified by example analysis and sensitivity analysis, and its superiority is illustrated by a comparison with the existing methods.

The concept of intuitionistic neutrosophic sets provides an additional possibility for representing imprecise, uncertain, inconsistent and incomplete information that exists in real situations. The seventh research article (*Certain Competition Graphs Based on Intuitionistic Neutrosophic Environment*) presents the notion of intuitionistic neutrosophic competition graphs. Then, the authors Muhammad Akram and Maryam Nasir discuss p-competition intuitionistic neutrosophic graphs and m-step intuitionistic neutrosophic competition graphs. Further, applications of intuitionistic neutrosophic competition graphs in ecosystem and career competition are described.

The notion of a neutrosophic commutative N-ideal in BCK-algebras is introduced in the eighth paper (*Neutrosophic Commutative N-Ideals in BCK-Algebras*), and several properties are investigated. Relations between a neutrosophic N-ideal and a neutrosophic commutative N-ideal are discussed by the authors Seok-Zun Song, Florentin Smarandache, and Young Bae Jun. Characterizations of a neutrosophic commutative N-ideal are considered.

Neutrosophic N-Structures Applied to BCK/BCI-Algebras is the title of the ninth paper. The notions of a neutrosophic N-subalgebra and a (closed) neutrosophic N-ideal in a BCK/BCI-algebra are introduced by authors Young Bae Jun, Florentin Smarandache and Hashem Bordbar, and several related properties are investigated. Characterizations of a neutrosophic N-subalgebra and a neutrosophic N-ideal are considered, and relations between a neutrosophic N-subalgebra and a neutrosophic N-ideal are stated. The conditions for a neutrosophic N-ideal being a closed neutrosophic N-ideal are provided.

Recently, TODIM has been used to solve multiple attribute decision making (MADM) problems. Single-valued neutrosophic sets (SVNSs) are useful tools for depicting the uncertainty of the MADM. In the tenth paper, *TODIM Method for Single-Valued Neutrosophic Multiple Attribute Decision Making*, Dong-Sheng Xu, Cun Wei and Gui-Wu Wei extend the TODIM method to the MADM with the single-valued neutrosophic numbers (SVNNs). Firstly, the definition, comparison, and distance of SVNNs are briefly presented, and the steps of the classical TODIM method for MADM problems are introduced. Then, an extended classical TODIM method is proposed for dealing with MADM problems with SVNNs, its significant characteristic being that it can fully consider the decision makers' bounded rationality, which is a real factor in decision-making. Furthermore, the authors extend the proposed model to interval neutrosophic sets (INSs). Finally, a numerical example is proposed.

Visual object tracking is a critical task in computer vision. Challenging things always exist when an object needs to be tracked. For instance, background clutter is one of the most challenging problems. The mean-shift tracker is quite popular because of its efficiency and performance under a range of conditions. However, the challenge of background clutter also disturbs its performance. In the eleventh article, *Neutrosophic Similarity Score Based Weighted Histogram for Robust Mean-Shift Tracking*, the authors Keli Hu, En Fan, Jun Ye, Changxing Fan, Shigen Shen and Yuzhang Gu propose a novel weighted histogram based on neutrosophic similarity score to help the mean-shift tracker discriminate the target from the background. The authors utilize the single-valued neutrosophic set (SVNS), which is a subclass of NS, to improve the mean-shift tracker. First, two kinds of criteria are considered—object feature similarity and background feature similarity—and each bin of the weight histogram is represented in the SVNS domain via three membership functions: T(Truth), I(indeterminacy), and F(Falsity). Second, the neutrosophic similarity score function is introduced to fuse those two criteria and to build the final weighted histogram. Finally, a novel neutrosophic weighted mean-shift tracker is proposed. The proposed tracker is compared with several mean-shift-based trackers on a dataset of 61 public sequences. The results reveal that this method outperforms other trackers, especially when confronting background clutter.

To describe both certain linguistic neutrosophic information and uncertain linguistic neutrosophic information simultaneously in the real world, Jun Ye proposes in the twelfth paper (*Linguistic Neutrosophic Cubic Numbers and Their Multiple Attribute Decision-Making Method*) the concept of a linguistic neutrosophic cubic number (LNCN), including an internal LNCN and external LNCN. In LNCN, its uncertain linguistic neutrosophic number consists of the truth, indeterminacy, and falsity uncertain linguistic variables, and its linguistic neutrosophic number consists of the truth, indeterminacy, and falsity linguistic variables to express their hybrid information. Then, the author presents the operational laws of LNCNs and the score, accuracy, and certain functions of LNCN for comparing/ranking LNCNs. Next, the author proposes a LNCN weighted arithmetic averaging (LNCNWAA) operator and a LNCN weighted geometric averaging (LNCNWGA) operator to aggregate linguistic neutrosophic cubic information and discuss their properties. Further, a multiple attribute decision-making method based on the LNCNWAA or LNCNWGA operator is developed under a linguistic neutrosophic cubic environment. Finally, an illustrative example is provided to indicate the application of the developed method.