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Editorial

Algebraic Structures of Neutrosophic Triplets, Neutrosophic Duplets, or Neutrosophic Multisets

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Neutrosophy (1995) is a new branch of philosophy that studies triads of the form (<A>, <neutA>, <antiA>), where <A> is an entity (i.e., element, concept, idea, theory, logical proposition, etc.), <antiA> is the opposite of <A>, while <neutA> is the neutral (or indeterminate) between them, i.e., neither <A> nor <antiA> [1].

Based on neutrosophy, the neutrosophic triplets were founded; they have a similar form: (x, neut(x), anti(x), that satisfy some axioms, for each element x in a given set [2–4].

This book contains the successful invited submissions [5–56] to a special issue of Symmetry, reporting on state-of-the-art and recent advancements of neutrosophic triplets, neutrosophic duplets, neutrosophic multisets, and their algebraic structures—that have been defined recently in 2016, but have gained interest from world researchers, and several papers have been published in first rank international journals.

The topics approached in the 52 papers included in this book are: neutrosophic sets; neutrosophic logic; generalized neutrosophic set; neutrosophic rough set; multigranulation neutrosophic rough set (MNRS); neutrosophic cubic sets; triangular fuzzy neutrosophic sets (TFNSs); probabilistic single-valued (interval) neutrosophic hesitant fuzzy set; neutro-homomorphism; neutrosophic computation; quantum computation; neutrosophic association rule; data mining; big data; oracle Turing machines; recursive enumerability; oracle computation; interval number; dependent degree; possibility degree; power aggregation operators; multi-criteria group decision-making (MCGDM); expert set; soft sets; LA-semihypergroups; single valued trapezoidal neutrosophic number; inclusion relation; Q-linguistic neutrosophic variable set; vector similarity measure; cosine measure; Dice measure; Jaccard measure; VIKOR model; potential evaluation; emerging technology commercialization; 2-tuple linguistic neutrosophic sets (2TLNSs); TODIM model; Bonferroni mean; aggregation operator; NC power dual MM (NCPDMM) operator; fault diagnosis; defuzzification; simplified neutrosophic weighted averaging operator; linear and non-linear neutrosophic number; de-neutrosophication methods; neutro-monomorphism; neutro-epimorphism; neutro-automorphism; fundamental neutro-homomorphism theorem; neutro-isomorphism theorem; quasi neutrosophic triplet loop; quasi neutrosophic triplet group; BE-algebra; cloud model; Maclaurin symmetric mean; pseudo-BCI algebra; hesitant fuzzy set; photovoltaic plan; decision-making trial and evaluation laboratory (DEMATEL); Choquet integral; fuzzy measure; clustering algorithm; and many more.

In the opening paper [5] of this book, the authors introduce refined concepts for neutrosophic quantum computing such as neutrosophic quantum states and transformation gates, neutrosophic Hadamard matrix, coherent and decoherent superposition states, entanglement and measurement notions based on neutrosophic quantum states. They also give some observations using these principles, and present a number of quantum computational matrix transformations based on neutrosophic logic, clarifying quantum mechanical notions relying on neutrosophic states. The paper is intended to extend the work of Smarandache [57–59] by introducing a mathematical framework for neutrosophic quantum computing and presenting some results.

The second paper [6] introduces oracle Turing machines with neutrosophic values allowed in the oracle information and then give some results when one is permitted to use neutrosophic sets and logic in relative computation. The authors also introduce a method to enumerate the elements of a neutrosophic subset of natural numbers.

In the third paper [7], a new approach and framework based on the interval dependent degree for MCGDM problems with SNSs is proposed. Firstly, the simplified dependent function and distribution function are defined. Then, they are integrated into the interval dependent function which contains interval computing and distribution information of the intervals. Subsequently, the interval transformation operator is defined to convert SNNs into intervals, and then the interval dependent function for SNNs is deduced. Finally, an example is provided to verify the feasibility and effectiveness of the proposed method, together with its comparative analysis. In addition, uncertainty analysis, which can reflect the dynamic change of the final result caused by changes in the decision makers' preferences, is performed in different distribution function situations. That increases the reliability and accuracy of the result.

Neutrosophic triplet structure yields a symmetric property of truth membership on the left, indeterminacy membership in the center and false membership on the right, as do points of object, center and image of reflection. As an extension of a neutrosophic set, the Q-neutrosophic set is introduced in the subsequent paper [8] to handle two-dimensional uncertain and inconsistent situations. The authors extend the soft expert set to the generalized Q-neutrosophic soft expert set by incorporating the idea of a soft expert set to the concept of a Q-neutrosophic set and attaching the parameter of fuzzy set while defining a Q-neutrosophic soft expert set. This pattern carries the benefits of Q-neutrosophic sets and soft sets, enabling decision makers to recognize the views of specialists with no requirement for extra lumbering tasks, thus making it exceedingly reasonable for use in decision-making issues that include imprecise, indeterminate and inconsistent two-dimensional data. Some essential operations, namely subset, equal, complement, union, intersection, AND and OR operations, and additionally several properties relating to the notion of a generalized Q-neutrosophic soft expert set are characterized. Finally, an algorithm on a generalized Q-neutrosophic soft expert set is proposed and applied to a real-life example to show the efficiency of this notion in handling such problems.

In the following paper [9], the authors extend the idea of a neutrosophic triplet set to non-associative semihypergroups and define neutrosophic triplet LA-semihypergroup. They discuss some basic results and properties, and provide an application of the proposed structure in football.

Single valued trapezoidal neutrosophic numbers (SVTNNs) are very useful tools for describing complex information, because of their advantage in describing the information completely, accurately and comprehensively for decision-making problems [60]. In the next paper [10], a method based on SVTNNs is proposed for dealing with MCGDM problems. Firstly, the new operation SVTNNs are developed for avoiding evaluation information aggregation loss and distortion. Then the possibility degrees and comparison of SVTNNs are proposed from the probability viewpoint for ranking and comparing the single valued trapezoidal neutrosophic information reasonably and accurately. Based on the new operations and possibility degrees of SVTNNs, the single valued trapezoidal neutrosophic power average (SVTNPA) and single valued trapezoidal neutrosophic power geometric (SVTNPG) operators are proposed to aggregate the single valued trapezoidal neutrosophic information. Furthermore, based on the developed aggregation operators, a single valued trapezoidal neutrosophic MCGDM method is developed. Finally, the proposed method is applied to solve the practical problem of the most appropriate green supplier selection and the rank results compared with the previous approach demonstrate the proposed method's effectiveness.

After the neutrosophic set (NS) was proposed [58], NS was used in many uncertainty problems. The single-valued neutrosophic set (SVNS) is a special case of NS that can be used to solve real-word problems. The next paper [11] mainly studies multigranulation neutrosophic rough sets (MNRSs) and their applications in multi-attribute group decision-making. Firstly, the existing definition of neutrosophic rough set (the authors call it type-I neutrosophic rough set (NRSI) in this paper) is analyzed, and then the definition of type-II neutrosophic rough set (NRSII), which is similar to NRSI, is given and its properties are studied. Secondly, a type-III neutrosophic rough set (NRSIII) is proposed and its differences from NRSI and NRSII are provided. Thirdly, single granulation NRSs are extended to multigranulation NRSs, and the type-I multigranulation neutrosophic rough set (MNRSI) is studied. The type-II multigranulation neutrosophic rough set (MNRSII) and type-III multigranulation neutrosophic rough set (MNRSIII) are proposed and their different properties are outlined. Finally, MNRSIII in two universes is proposed and an algorithm for decision-making based on MNRSIII is provided. A car ranking example is studied to explain the application of the proposed model.

Since language is used for thinking and expressing habits of humans in real life, the linguistic evaluation for an objective thing is expressed easily in linguistic terms/values. However, existing linguistic concepts cannot describe linguistic arguments regarding an evaluated object in two-dimensional universal sets (TDUSs). To describe linguistic neutrosophic arguments in decision making problems regarding TDUSs, the next article [12] proposes a Q-linguistic neutrosophic variable set (Q-LNVS) for the first time, which depicts its truth, indeterminacy, and falsity linguistic values independently corresponding to TDUSs, and vector similarity measures of Q-LNVSs. Thereafter, a linguistic neutrosophic MADM approach by using the presented similarity measures, including the cosine, Dice, and Jaccard measures, is developed under Q-linguistic neutrosophic setting. Lastly, the applicability and effectiveness of the presented MADM approach is presented by an illustrative example under Q-linguistic neutrosophic setting.

In the following article [13], the authors combine the original VIKOR model with a triangular fuzzy neutrosophic set [61] to propose the triangular fuzzy neutrosophic VIKOR method. In the extended method, they use the triangular fuzzy neutrosophic numbers (TFNNs) to present the criteria values in MCGDM problems. Firstly, they summarily introduce the fundamental concepts, operation formulas and distance calculating method of TFNNs. Then they review some aggregation operators of TFNNs. Thereafter, they extend the original VIKOR model to the triangular fuzzy neutrosophic environment and introduce the calculating steps of the TFNNs VIKOR method, the proposed method which is more reasonable and scientific for considering the conflicting criteria. Furthermore, a numerical example for potential evaluation of emerging technology commercialization is presented to illustrate the new method, and some comparisons are also conducted to further illustrate advantages of the new method.

Another paper [14] in this book aims to extend the original TODIM (Portuguese acronym for interactive multi-criteria decision making) method to the 2-tuple linguistic neutrosophic fuzzy environment [62] to propose the 2TLNNs TODIM method. In the extended method, the authors use 2-tuple linguistic neutrosophic numbers (2TLNNs) to present the criteria values in multiple attribute group decision making (MAGDM) problems. Firstly, they briefly introduce the definition, operational laws, some aggregation operators, and the distance calculating method of 2TLNNs. Then, the calculation steps of the original TODIM model are presented in simplified form. Thereafter, they extend the original TODIM model to the 2TLNNs environment to build the 2TLNNs TODIM model, the proposed method, which is more reasonable and scientific in considering the subjectivity of the decision makers' (DMs') behaviors and the dominance of each alternative over others. Finally, a numerical example for the safety assessment of a construction project is proposed to illustrate the new method, and some comparisons are also conducted to further illustrate the advantages of the new method.

The power Bonferroni mean (PBM) operator is a hybrid structure and can take the advantage of a power average (PA) operator, which can reduce the impact of inappropriate data given by the prejudiced decision makers (DMs) and Bonferroni mean (BM) operator, which can take into account the correlation between two attributes. In recent years, many researchers have extended the PBM operator to handle fuzzy information. The Dombi operations of T-conorm (TCN) and T-norm (TN), proposed by Dombi, have the supremacy of outstanding flexibility with general parameters. However, in the existing literature, PBM and the Dombi operations have not been combined for the above advantages for interval-neutrosophic sets (INSs) [63]. In the following paper [15], the authors define some operational laws for interval neutrosophic numbers (INNs) based on Dombi TN and TCN and discuss several desirable properties of these operational rules. Secondly, they extend the PBM operator based on Dombi operations to develop an interval-neutrosophic Dombi PBM (INDPBM) operator, an interval-neutrosophic weighted Dombi PBM (INWDPBM) operator, an interval-neutrosophic Dombi power geometric Bonferroni mean (INDPGBM) operator and an interval-neutrosophic weighted Dombi power geometric Bonferroni mean (INWDPGBM) operator, and discuss several properties of these aggregation operators. Then they develop a MADM method, based on these proposed aggregation operators, to deal with interval neutrosophic (IN) information. An illustrative example is provided to show the usefulness and realism of the proposed MADM method.

The neutrosophic cubic set (NCS) is a hybrid structure [64], which consists of INS [63] (associated with the undetermined part of information associated with entropy) and SVNS [60] (associated with the determined part of information). NCS is a better tool to handle complex DM problems with INS and SVNS. The main purpose of the next article [16] is to develop some new aggregation operators for cubic neutrosophic numbers (NCNs), which is a basic member of NCS. Taking the advantages of Muirhead mean (MM) operator and PA operator, the power Muirhead mean (PMM) operator is developed and is scrutinized under NC information. To manage the problems upstretched, some new NC aggregation operators, such as the NC power Muirhead mean (NCPMM) operator, weighted NC power Muirhead mean (WNCPMM) operator, NC power dual Muirhead mean (NCPMM) operator and weighted NC power dual Muirhead mean (WNCPDMM) operator are proposed and related properties of these proposed aggregation operators are conferred. The important advantage of the developed aggregation operator is that it can remove the effect of awkward data and it considers the interrelationship among aggregated values at the same time. Finally, a numerical example is given to show the effectiveness of the developed approach.

Smarandache defined a neutrosophic set [57] to handle problems involving incompleteness, indeterminacy, and awareness of inconsistency knowledge, and have further developed neutrosophic soft expert sets. In the next paper [17] of this book, this concept is further expanded to generalized neutrosophic soft expert set (GNSES). The authors then define its basic operations of complement, union, intersection, AND, OR, and study some related properties, with supporting proofs. Subsequently, they define a GNSES-aggregation operator to construct an algorithm for a GNSES decision-making method, which allows for a more efficient decision process. Finally, they apply the algorithm to a decision-making problem, to illustrate the effectiveness and practicality of the proposed concept. A comparative analysis with existing methods is done and the result affirms the flexibility and precision of the proposed method.

In the next paper [18], the authors define the neutrosophic valued (and generalized or G) metric spaces for the first time. Besides, they determine a mathematical model for clustering the neutrosophic big data sets using G-metric. Furthermore, relative weighted neutrosophic-valued distance and weighted cohesion measure are defined for neutrosophic big data set [65]. A very practical method for data analysis of neutrosophic big data is offered, although neutrosophic data type (neutrosophic big data) are in massive and detailed form when compared with other data types.

Bol-Moufang types of a particular quasi neutrosophic triplet loop (BCI-algebra), christened Fenyves BCI-algebras, are introduced and studied in another paper [19] of this book. 60 Fenyves BCI-algebras are introduced and classified. Amongst these 60 classes of algebras, 46 are found to be associative and 14 are found to be non-associative. The 46 associative algebras are shown to be Boolean groups. Moreover, necessary and sufficient conditions for 13 non-associative algebras to be associative are also obtained: p-semisimplicity is found to be necessary and sufficient for a F3, F5, F42, and F55 algebras to be associative while quasi-associativity is found to be necessary and sufficient for F19, F52, F56, and F59 algebras to be associative. Two pairs of the 14 non-associative algebras are found to be equivalent to associativity (F52 and F55, and F55 and F59). Every BCI-algebra is naturally a F54 BCI-algebra. The work is concluded with recommendations based on comparison between the behavior of identities of Bol-Moufang (Fenyves' identities) in quasigroups and loops and their behavior in BCI-algebra. It is concluded that results of this work are an initiation into the study of the classification of finite Fenyves' quasi neutrosophic triplet loops (FQNTLs) just like various types of finite loops have been classified. This research work has opened a new area of research finding in BCI-algebras, vis-a-vis the emergence of 540 varieties of Bol-Moufang type quasi neutrosophic triplet loops. A 'cycle of algebraic structures' which portrays this fact is provided.

The uncertainty and concurrence of randomness are considered when many practical problems are dealt with. To describe the aleatory uncertainty and imprecision in a neutrosophic environment and prevent the obliteration of more data, the concept of the probabilistic single-valued (interval) neutrosophic hesitant fuzzy set is introduced in the next paper [20]. By definition, the probabilistic single-valued neutrosophic hesitant fuzzy set (PSVNHFS) is a special case of the probabilistic interval neutrosophic hesitant fuzzy set (PINHFS). PSVNHFSs can satisfy all the properties of PINHFSs. An example is given to illustrate that PINHFS compared to PSVNHFS is more general. Then, PINHFS is the main research object. The basic operational relations of PINHFS are studied, and the comparison method of probabilistic interval neutrosophic hesitant fuzzy numbers (PINHFNs) is proposed. Then, the probabilistic interval neutrosophic hesitant fuzzy weighted averaging (PINHFWA) and the probability interval neutrosophic hesitant fuzzy weighted geometric (PINHFWG) operators are presented. Some basic properties are investigated. Next, based on the PINHFWA and PINHFWG operators, a decision-making method under a probabilistic interval neutrosophic hesitant fuzzy circumstance is established. Finally, the authors apply this method to the issue of investment options. The validity and application of the new approach is demonstrated.

Competition among different universities depends largely on the competition for talent. Talent evaluation and selection is one of the main activities in human resource management (HRM) which is critical for university development [21]. Firstly, linguistic neutrosophic sets (LNSs) are introduced to better express multiple uncertain information during the evaluation procedure. The authors further merge the power averaging operator with LNSs for information aggregation and propose a LN-power weighted averaging (LNPWA) operator and a LN-power weighted geometric (LNPWG) operator. Then, an extended technique for order preference by similarity to ideal solution (TOPSIS) method is developed to solve a case of university HRM evaluation problem. The main contribution and novelty of the proposed method rely on that it allows the information provided by different DMs to support and reinforce each other which is more consistent with the actual situation of university HRM evaluation. In addition, its effectiveness and advantages over existing methods are verified through sensitivity and comparative analysis. The results show that the proposal is capable in the domain of university HRM evaluation and may contribute to the talent introduction in universities.

The concept of a commutative generalized neutrosophic ideal in a BCK-algebra is proposed, and related properties are proved in another paper [22] of this book. Characterizations of a commutative generalized neutrosophic ideal are considered. Also, some equivalence relations on the family of all commutative generalized neutrosophic ideals in BCK-algebras are introduced, and some properties are investigated.

Fault diagnosis is an important issue in various fields and aims to detect and identify the faults of systems, products, and processes. The cause of a fault is complicated due to the uncertainty of the actual environment. Nevertheless, it is difficult to consider uncertain factors adequately with many traditional methods. In addition, the same fault may show multiple features and the same feature might be caused by different faults. In the next paper [23], a neutrosophic set based fault diagnosis method based on multi-stage fault template data is proposed to solve this problem. For an unknown fault sample whose fault type is unknown and needs to be diagnosed, the neutrosophic set based on multi-stage fault template data is generated, and then the generated neutrosophic set is fused via the simplified neutrosophic weighted averaging (SNWA) operator. Afterwards, the fault diagnosis results can be determined by the application of defuzzification method for a defuzzying neutrosophic set. Most kinds of uncertain problems in the process of fault diagnosis, including uncertain information and inconsistent information, could be handled well with the integration of multi-stage fault template data and the neutrosophic set. Finally, the practicality and effectiveness of the proposed method are demonstrated via an illustrative example.

The notions of neutrosophy, neutrosophic algebraic structures, neutrosophic duplet and neutrosophic triplet were introduced by Florentin Smarandache [57]. In another paper [24] of this book, some neutrosophic duplets are studied. A particular case is considered, and the complete characterization of neutrosophic duplets are given. Some open problems related to neutrosophic duplets are proposed.

In the next paper [25], the authors provide an application of neutrosophic bipolar fuzzy sets applied to daily life's problem related with the HOPE foundation, which is planning to build a children's hospital. They develop the theory of neutrosophic bipolar fuzzy sets, which is a generalization of bipolar fuzzy sets. After giving the definition they introduce some basic operation of neutrosophic bipolar fuzzy sets and focus on weighted aggregation operators in terms of neutrosophic bipolar fuzzy sets. They define neutrosophic bipolar fuzzy weighted averaging (NBFWA) and neutrosophic bipolar fuzzy ordered weighted averaging (NBFOWA) operators. Next they introduce different kinds of similarity measures of neutrosophic bipolar fuzzy sets. Finally, as an application, the authors give an algorithm for the multiple attribute decision making problems under the neutrosophic bipolar fuzzy environment by using the different kinds of neutrosophic bipolar fuzzy weighted/fuzzy ordered weighted aggregation operators with a numerical example related with HOPE foundation.

In the following paper [26], the authors introduce the concept of neutrosophic numbers from different viewpoints [57–65]. They define different types of linear and non-linear generalized triangular neutrosophic numbers which are very important for uncertainty theory. They introduce the de-neutrosophication concept for neutrosophic number for triangular neutrosophic numbers. This concept helps to convert a neutrosophic number into a crisp number. The concepts are followed by two applications, namely in an imprecise project evaluation review technique and a route selection problem.

In classical group theory, homomorphism and isomorphism are significant to study the relation between two algebraic systems. Through the next article [27], the authors propose neutro-homomorphism and neutro-isomorphism for the neutrosophic extended triplet group (NETG) which plays a significant role in the theory of neutrosophic triplet algebraic structures. Then, they define neutro-monomorphism, neutro-epimorphism, and neutro-automorphism. They give and prove some theorems related to these structures. Furthermore, the Fundamental homomorphism theorem for the NETG is given and some special cases are discussed. First and second neutro-isomorphism theorems are stated. Finally, by applying homomorphism theorems to neutrosophic extended triplet algebraic structures, the authors have examined how closely different systems are related.

It is an interesting direction to study rough sets from a multi-granularity perspective. In rough set theory, the multi-particle structure was represented by a binary relation. The next paper [28] considers a new neutrosophic rough set model, multi-granulation neutrosophic rough set (MGNRS). First, the concept of MGNRS on a single domain and dual domains was proposed. Then, their properties and operators were considered. The authors obtained that MGNRS on dual domains will degenerate into MGNRS on a single domain when the two domains are the same. Finally, a kind of special multi-criteria group decision making (MCGDM) problem was solved based on MGNRS on dual domains, and an example was given to show its feasibility.

As a new generalization of the notion of the standard group, the notion of the NTG is derived from the basic idea of the neutrosophic set and can be regarded as a mathematical structure describing generalized symmetry. In the next paper [29], the properties and structural features of NTG are studied in depth by using theoretical analysis and software calculations (in fact, some important examples in the paper are calculated and verified by mathematics software, but the related programs are omitted). The main results are obtained as follows: (1) by constructing counterexamples, some mistakes in the some literatures are pointed out; (2) some new properties of NTGs are obtained, and it is proved that every element has a unique neutral element in any neutrosophic triplet group; (3) the notions of NT-subgroups, strong NT-subgroups, and weak commutative neutrosophic triplet groups (WCNTGs) are introduced, the quotient structures are constructed by strong NT-subgroups, and a homomorphism theorem is proved in weak commutative neutrosophic triplet groups.

The aim of the following paper [30] is to introduce some new operators for aggregating single-valued neutrosophic (SVN) information and to apply them to solve the multi-criteria decision-making (MCDM) problems. The single-valued neutrosophic set, as an extension and generalization of an intuitionistic fuzzy set, is a powerful tool to describe the fuzziness and uncertainty [60], and MM is a well-known aggregation operator which can consider interrelationships among any number of arguments assigned by a variable vector. In order to make full use of the advantages of both, the authors introduce two new prioritized MM aggregation operators, such as the SVN prioritized MM (SVNPMM) and SVN prioritized dual MM (SVNPDMM) under an SVN set environment. In addition, some properties of these new aggregation operators are investigated and some special cases are discussed. Furthermore, the authors propose a new method based on these operators for solving the MCDM problems. Finally, an illustrative example is presented to testify the efficiency and superiority of the proposed method by comparing it with the existing method.

Making predictions according to historical values has long been regarded as common practice by many researchers. However, forecasting solely based on historical values could lead to inevitable over-complexity and uncertainty due to the uncertainties inside, and the random influence outside, of the data. Consequently, finding the inherent rules and patterns of a time series by eliminating disturbances without losing important details has long been a research hotspot. In the following paper [31], the authors propose a novel forecasting model based on multi-valued neutrosophic sets to find fluctuation rules and patterns of a time series. The contributions of the proposed model are: (1) using a multi-valued neutrosophic set (MVNS) to describe the fluctuation patterns of a time series, the model could represent the fluctuation trend of up, equal, and down with degrees of truth, indeterminacy, and falsity which significantly preserve details of the historical values; (2) measuring the similarities of different fluctuation patterns by the Hamming distance could avoid the confusion caused by incomplete information from limited samples; and (3) introducing another related time series as a secondary factor to avoid warp and deviation in inferring inherent rules of historical values, which could lead to more comprehensive rules for further forecasting. To evaluate the performance of the model, the authors explore the Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX) as the major factor, and the Dow Jones Index as the secondary factor to facilitate the predicting of the TAIEX. To show the universality of the model, they apply the proposed model to forecast the Shanghai Stock Exchange Composite Index (SHSECI) as well.

The new notion of a neutrosophic triplet group (NTG) proposed by Smarandache is a new algebraic structure different from the classical group. The aim of the next paper [32] is to further expand this new concept and to study its application in related logic algebra systems. Some new notions of left (right)-quasi neutrosophic triplet loops and left (right)-quasi neutrosophic triplet groups are introduced, and some properties are presented. As a corollary of these properties, the following important result are proved: for any commutative neutrosophic triplet group, its every element has a unique neutral element. Moreover, some left (right)-quasi neutrosophic triplet structures in BE-algebras and generalized BE-algebras (including CI-algebras and pseudo CI-algebras) are established, and the adjoint semigroups of the BE-algebras and generalized BE-algebras are investigated for the first time.

In a neutrosophic triplet set, there is a neutral element and antielement for each element. In the following study [33], the concept of neutrosophic triplet partial metric space (NTPMS) is given and the properties of NTPMS are studied. The authors show that both classical metric and neutrosophic triplet metric (NTM) are different from NTPM. Also, they show that NTPMS can be defined with each NTMS. Furthermore, the authors define a contraction for NTPMS and give a fixed point theory (FPT) for NTPMS. The FPT has been revealed as a very powerful tool in the study of nonlinear phenomena.

Another paper [34] of this book presents a modified Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) with maximizing deviation method based on the SVNS model [60]. A SVNS is a special case of a neutrosophic set which is characterized by a truth, indeterminacy, and falsity membership function, each of which lies in the standard interval of [0,1]. An integrated weight measure approach that takes into consideration both the objective and subjective weights of the attributes is used. The maximizing deviation method is used to compute the objective weight of the attributes, and the non-linear weighted comprehensive method is used to determine the combined weights for each attributes. The use of the maximizing deviation method allows our proposed method to handle situations in which information pertaining to the weight coefficients of the attributes are completely unknown or only partially known. The proposed method is then applied to a multi-attribute decision-making (MADM) problem. Lastly, a comprehensive comparative studies is presented, in which the performance of our proposed algorithm is compared and contrasted with other recent approaches involving SVNSs in literature.

One of the most significant competitive strategies for organizations is sustainable supply chain management (SSCM). The vital part in the administration of a sustainable supply chain is the sustainable supplier selection, which is a multi-criteria decision-making issue, including many conflicting criteria. The valuation and selection of sustainable suppliers are difficult problems due to vague, inconsistent, and imprecise knowledge of decision makers. In the literature on supply chain management for measuring green performance, the requirement for methodological analysis of how sustainable variables affect each other, and how to consider vague, imprecise and inconsistent knowledge, is still unresolved. The next research [35] provides an incorporated multi-criteria decision-making procedure for sustainable supplier selection problems (SSSPs). An integrated framework is presented via interval-valued neutrosophic sets to deal with vague, imprecise and inconsistent information that exists usually in real world. The analytic network process (ANP) is employed to calculate weights of selected criteria by considering their interdependencies. For ranking alternatives and avoiding additional comparisons of analytic network processes, the TOPSIS is used. The proposed framework is turned to account for analyzing and selecting the optimal supplier. An actual case study of a dairy company in Egypt is examined within the proposed framework. Comparison with other existing methods is implemented to confirm the effectiveness and efficiency of the proposed approach.

The concept of interval neutrosophic sets has been studied [63] and the introduction of a new kind of set in topological spaces called the interval valued neutrosophic support soft set is suggested in the next paper [36]. The authors also study some of its basic properties. The main purpose of the paper is to give the optimum solution to decision-making in real life problems the using interval valued neutrosophic support soft set.

In inconsistent and indeterminate settings, as a usual tool, the NCS containing single-valued neutrosophic numbers [60] and interval neutrosophic numbers [64] can be applied in decision-making to present its partial indeterminate and partial determinate information. However, a few researchers have studied neutrosophic cubic decision-making problems, where the similarity measure of NCSs is one of the useful measure methods. For the following work [37] in this book, the authors propose the Dice, cotangent, and Jaccard measures between NCSs, and indicate their properties. Then, under an NCS environment, the similarity measures-based decision-making method of multiple attributes is developed. In the decision-making process, all the alternatives are ranked by the similarity measure of each alternative and the ideal solution to obtain the best one. Finally, two practical examples are applied to indicate the feasibility and effectiveness of the developed method.

In real-world diagnostic procedures, due to the limitation of human cognitive competence, a medical expert may not conveniently use some crisp numbers to express the diagnostic information, and plenty of research has indicated that generalized fuzzy numbers play a significant role in describing complex diagnostic information. To deal with medical diagnosis problems based on generalized fuzzy sets (FSs), the notion of single-valued neutrosophic multisets (SVNMs) [60] is firstly used to express the diagnostic information [38]. Then the model of probabilistic rough sets (PRSs) over two universes is applied to analyze SVNMs, and the concepts of single-valued neutrosophic rough multisets (SVNRMs) over two universes and probabilistic rough single-valued neutrosophic multisets (PRSVNMs) over two universes are introduced. Based on SVNRMs over two universes and PRSVNMs over two universes, single-valued neutrosophic probabilistic rough multisets (SVNPRMs) over two universes are further established. Next, a three-way decision model by virtue of SVNPRMs over two universes in the context of medical diagnosis is constructed. Finally, a practical case study along with a comparative study are carried out to reveal the accuracy and reliability of the constructed three-way decisions model.

The next article [39] is based on new developments on a NTG and applications earlier introduced in 2016 by Smarandache and Ali. NTG sprang up from neutrosophic triplet set X: a collection of triplets (b,neut(b),anti(b)) for an b∈X that obeys certain axioms (existence of neutral(s) and opposite(s)). Some results that are true in classical groups are investigated in NTG and shown to be either universally true in NTG or true in some peculiar types of NTG. Distinguishing features between an NTG and some other algebraic structures such as: generalized group (GG), quasigroup, loop, and group are investigated. Some neutrosophic triplet subgroups (NTSGs) of a neutrosophic triplet group are studied. Applications of the neutrosophic triplet set, and our results on NTG in relation to management and sports, are highlighted and discussed.

Neutrosophic cubic sets [64] are the more generalized tool by which one can handle imprecise information in a more effective way as compared to fuzzy sets and all other versions of fuzzy sets. Neutrosophic cubic sets have the more flexibility, precision and compatibility to the system as compared to previous existing fuzzy models. On the other hand, the graphs represent a problem physically in the form of diagrams and matrices, etc., which is very easy to understand and handle. Therefore, the authors of the subsequent paper [40] apply the neutrosophic cubic sets to graph theory in order to develop a more general approach where they can model imprecise information through graphs. One of very important futures of two neutrosophic cubic sets is the R-union that R-union of two neutrosophic cubic sets is again a neutrosophic cubic set. Since the purpose of this new model is to capture the uncertainty, the authors provide applications in industries to test the applicability of the defined model based on present time and future prediction which is the main advantage of neutrosophic cubic sets.

Thereafter, another paper [41] presents a deciding technique for robotic dexterous hand configurations. This algorithm can be used to decide on how to configure a robotic hand so it can grasp objects in different scenarios. Receiving as input from several sensor signals that provide information on the object's shape, the DSmT decision-making algorithm passes the information through several steps before deciding what hand configuration should be used for a certain object and task. The proposed decision-making method for real time control will decrease the feedback time between the command and grasped object, and can be successfully applied on robot dexterous hands. For this, the authors have used the Dezert–Smarandache theory which can provide information even on contradictory or uncertain systems.

The study [42] that follows introduces simplified neutrosophic linguistic numbers (SNLNs) to describe online consumer reviews in an appropriate manner. Considering the defects of studies on SNLNs in handling linguistic information, the cloud model is used to convert linguistic terms in SNLNs to three numerical characteristics. Then, a novel simplified neutrosophic cloud (SNC) concept is presented, and its operations and distance are defined. Next, a series of simplified neutrosophic cloud aggregation operators are investigated, including the simplified neutrosophic clouds Maclaurin symmetric mean (SNCMSM) operator, weighted SNCMSM operator, and generalized weighted SNCMSM operator. Subsequently, a MCDM model is constructed based on the proposed aggregation operators. Finally, a hotel selection problem is presented to verify the effectiveness and validity of our developed approach.

In recent years, typhoon disasters have occurred frequently and the economic losses caused by them have received increasing attention. The next study [43] focuses on the evaluation of typhoon disasters based on the interval neutrosophic set theory. An interval neutrosophic set (INS) [63] is a subclass of a NS [57]. However, the existing exponential operations and their aggregation methods are primarily for the intuitionistic fuzzy set. So, this paper mainly focus on the research of the exponential operational laws of INNs in which the bases are positive real numbers and the exponents are interval neutrosophic numbers. Several properties based on the exponential operational law are discussed in detail. Then, the interval neutrosophic weighted exponential aggregation (INWEA) operator is used to aggregate assessment information to obtain the comprehensive risk assessment. Finally, a multiple attribute decision making (MADM) approach based on the INWEA operator is introduced and applied to the evaluation of typhoon disasters in Fujian Province, China. Results show that the proposed new approach is feasible and effective in practical applications.

In the coming paper [44] of this book, the authors study the neutrosophic triplet groups for a∈Z2p and prove this collection of triplets (a,neut(a),anti(a)) if trivial forms a semigroup under product, and semi-neutrosophic triplets are included in that collection. Otherwise, they form a group under product, and it is of order (p−1), with (p+1,p+1,p+1) as the multiplicative identity. The new notion of pseudo primitive element is introduced in Z2p analogous to primitive elements in Zp, where p is a prime. Open problems based on the pseudo primitive elements are proposed. The study is restricted to Z2p and take only the usual product modulo 2p.

Fuzzy graph theory plays an important role in the study of the symmetry and asymmetry properties of fuzzy graphs. With this in mind, in the next paper [45], the authors introduce new neutrosophic graphs called complex neutrosophic graphs of type 1 (abbr. CNG1). They then present a matrix representation for it and study some properties of this new concept. The concept of CNG1 is an extension of the generalized fuzzy graphs of type 1 (GFG1) and generalized single-valued neutrosophic graphs of type 1 (GSVNG1). The utility of the CNG1 introduced here is applied to a multi-attribute decision making problem related to Internet server selection.

The purpose of the subsequent paper [46] is to study new algebraic operations and fundamental properties of totally dependent-neutrosophic sets and totally dependent-neutrosophic soft sets. Firstly, the in-coordination relationships among the original inclusion relations of totally dependent-neutrosophic sets (called type-1 and typ-2 inclusion relations in this paper) and union (intersection) operations are analyzed, and then type-3 inclusion relation of totally dependent-neutrosophic sets and corresponding type-3 union, type-3 intersection, and complement operations are introduced. Secondly, the following theorem is proved: all totally dependent-neutrosophic sets (based on a certain universe) determined a generalized De Morgan algebra with respect to type-3 union, type-3 intersection, and complement operations. Thirdly, the relationships among the type-3 order relation, score function, and accuracy function of totally dependent-neutrosophic sets are discussed. Finally, some new operations and properties of totally dependent-neutrosophic soft sets are investigated, and another generalized De Morgan algebra induced by totally dependent-neutrosophic soft sets is obtained.

In the recent years, school administrators often come across various problems while teaching, counseling, and promoting and providing other services which engender disagreements and interpersonal conflicts between students, the administrative staff, and others. Action learning is an effective way to train school administrators in order to improve their conflict-handling styles. In the next paper [47], a novel approach is used to determine the effectiveness of training in school administrators who attended an action learning course based on their conflict-handling styles. To this end, a Rahim Organization Conflict Inventory II (ROCI-II) instrument is used that consists of both the demographic information and the conflict-handling styles of the school administrators. The proposed method uses the neutrosophic set (NS) and support vector machines (SVMs) to construct an efficient classification scheme neutrosophic support vector machine (NS-SVM). The neutrosophic c-means (NCM) clustering algorithm is used to determine the neutrosophic memberships and then a weighting parameter is calculated from the neutrosophic memberships. The calculated weight value is then used in SVM as handled in the fuzzy SVM (FSVM) approach. Various experimental works are carried in a computer environment out to validate the proposed idea. All experimental works are simulated in a MATLAB environment with a five-fold cross-validation technique. The classification performance is measured by accuracy criteria. The prediction experiments are conducted based on two scenarios. In the first one, all statements are used to predict if a school administrator is trained or not after attending an action learning program. In the second scenario, five independent dimensions are used individually to predict if a school administrator is trained or not after attending an action learning program. According to the obtained results, the proposed NS-SVM outperforms for all experimental works.

The notions of the neutrosophic hesitant fuzzy subalgebra and neutrosophic hesitant fuzzy filter in pseudo-BCI algebras are introduced, and some properties and equivalent conditions are investigated in the next paper [48]. The relationships between neutrosophic hesitant fuzzy subalgebras (filters) and hesitant fuzzy subalgebras (filters) are discussed. Five kinds of special sets are constructed by a neutrosophic hesitant fuzzy set, and the conditions for the two kinds of sets to be filters are given. Moreover, the conditions for two kinds of special neutrosophic hesitant fuzzy sets to be neutrosophic hesitant fuzzy filters are proved.

To solve the problems related to inhomogeneous connections among the attributes, the authors of the following paper [49] introduce a novel multiple attribute group decision-making (MAGDM) method based on the introduced linguistic neutrosophic generalized weighted partitioned Bonferroni mean operator (LNGWPBM) for linguistic neutrosophic numbers (LNNs). First of all, inspired by the merits of the generalized partitioned Bonferroni mean (GPBM) operator and LNNs, they combine the GPBM operator and LNNs to propose the linguistic neutrosophic GPBM (LNGPBM) operator, which supposes that the relationships are heterogeneous among the attributes in MAGDM. In addition, aimed at the different importance of each attribute, the weighted form of the LNGPBM operator is investigated. Then, the authors discuss some of its desirable properties and special examples accordingly. Finally, they propose a novel MAGDM method on the basis of the introduced LNGWPBM operator, and illustrate its validity and merit by comparing it with the existing methods.

Based on the multiplicity evaluation in some real situations, the next paper [50] firstly introduces a single-valued neutrosophic multiset (SVNM) as a subclass of neutrosophic multiset (NM) to express the multiplicity information and the operational relations of SVNMs. Then, a cosine measure between SVNMs and weighted cosine measure between SVNMs are presented to measure the cosine degree between SVNMs, and their properties are investigated. Based on the weighted cosine measure of SVNMs, a multiple attribute decision-making method under a SVNM environment is proposed, in which the evaluated values of alternatives are taken in the form of SVNMs. The ranking order of all alternatives and the best one can be determined by the weighted cosine measure between every alternative and the ideal alternative. Finally, an actual application on the selecting problem illustrates the effectiveness and application of the proposed method.

Rooftop distributed photovoltaic projects have been quickly proposed in China because of policy promotion. Before, the rooftops of the shopping mall had not been occupied, and it was urged to have a decision-making framework to select suitable shopping mall photovoltaic plans. However, a traditional MCDM method failed to solve this issue at the same time, due to the following three defects: the interactions problems between the criteria, the loss of evaluation information in the conversion process, and the compensation problems between diverse criteria. In the subsequent paper [51], an integrated MCDM framework is proposed to address these problems. First of all, the compositive evaluation index is constructed, and the application of DEMATEL method helped analyze the internal influence and connection behind each criterion. Then, the interval-valued neutrosophic set is utilized to express the imperfect knowledge of experts group and avoid the information loss. Next, an extended elimination et choice translation reality (ELECTRE) III method is applied, and it succeed in avoiding the compensation problem and obtaining the scientific result. The integrated method used maintained symmetry in the solar photovoltaic (PV) investment. Last but not least, a comparative analysis using Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method and VIKOR method is carried out, and alternative plan X1 ranks first at the same. The outcome certified the correctness and rationality of the results obtained in this study.

In the next paper [52], by utilizing the concept of a neutrosophic extended triplet (NET), the authors define the neutrosophic image, neutrosophic inverse-image, neutrosophic kernel, and the NET subgroup. The notion of the neutrosophic triplet coset and its relation with the classical coset are defined and the properties of the neutrosophic triplet cosets are given. Furthermore, the neutrosophic triplet normal subgroups, and neutrosophic triplet quotient groups are studied.

The following paper [53] in the book proposes novel skin lesion detection based on neutrosophic clustering and adaptive region growing algorithms applied to dermoscopic images, called NCARG. First, the dermoscopic images are mapped into a neutrosophic set domain using the shearlet transform results for the images. The images are described via three memberships: true, indeterminate, and false memberships. An indeterminate filter is then defined in the neutrosophic set for reducing the indeterminacy of the images. A neutrosophic c-means clustering algorithm is applied to segment the dermoscopic images. With the clustering results, skin lesions are identified precisely using an adaptive region growing method. To evaluate the performance of this algorithm, a public data set (ISIC 2017) is employed to train and test the proposed method. Fifty images are randomly selected for training and 500 images for testing. Several metrics are measured for quantitatively evaluating the performance of NCARG. The results establish that the proposed approach has the ability to detect a lesion with high accuracy, 95.3% average value, compared to the obtained average accuracy, 80.6%, found when employing the neutrosophic similarity score and level set (NSSLS) segmentation approach.

Every organization seeks to set strategies for its development and growth and to do this, it must take into account the factors that affect its success or failure. The most widely used technique in strategic planning is SWOT analysis. SWOT examines strengths (S), weaknesses (W), opportunities (O), and threats (T), to select and implement the best strategy to achieve organizational goals. The chosen strategy should harness the advantages of strengths and opportunities, handle weaknesses, and avoid or mitigate threats. SWOT analysis does not quantify factors (i.e., strengths, weaknesses, opportunities, and threats) and it fails to rank available alternatives. To overcome this drawback, the authors of the next paper [54] integrate it with the analytic hierarchy process (AHP). The AHP is able to determine both quantitative and the qualitative elements by weighting and ranking them via comparison matrices. Due to the vague and inconsistent information that exists in the real world, they apply the proposed model in a neutrosophic environment. A real case study of Starbucks Company is presented to validate the model.

Big Data is a large-sized and complex dataset, which cannot be managed using traditional data processing tools. The mining process of big data is the ability to extract valuable information from these large datasets. Association rule mining is a type of data mining process, which is intended to determine interesting associations between items and to establish a set of association rules whose support is greater than a specific threshold. The classical association rules can only be extracted from binary data where an item exists in a transaction, but it fails to deal effectively with quantitative attributes, through decreasing the quality of generated association rules due to sharp boundary problems. In order to overcome the drawbacks of classical association rule mining, the authors of the following research [55] propose a new neutrosophic association rule algorithm. The algorithm uses a new approach for generating association rules by dealing with membership, indeterminacy, and non-membership functions of items, conducting to an efficient decision-making system by considering all vague association rules. To prove the validity of the method, they compare the fuzzy mining and the neutrosophic mining [65]. The results show that the proposed approach increases the number of generated association rules.

The INS is a subclass of the NS and a generalization of the interval-valued intuitionistic fuzzy set (IVIFS), which can be used in real engineering and scientific applications. The last paper [56] in the book aims at developing new generalized Choquet aggregation operators for INSs, including the generalized interval neutrosophic Choquet ordered averaging (G-INCOA) operator and generalized interval neutrosophic Choquet ordered geometric (G-INCOG) operator. The main advantages of the proposed operators can be described as follows: (i) during decision-making or analyzing process, the positive interaction, negative interaction or non-interaction among attributes can be considered by the G-INCOA and G-INCOG operators; (ii) each generalized Choquet aggregation operator presents a unique comprehensive framework for INSs, which comprises a bunch of existing interval neutrosophic aggregation operators; (iii) new multi-attribute decision making (MADM) approaches for INSs are established based on these operators, and decision makers may determine the value of λ by different MADM problems or their preferences, which makes the decision-making process more flexible; (iv) a new clustering algorithm for INSs are introduced based on the G-INCOA and G-INCOG operators, which proves that they have the potential to be applied to many new fields in the future.

The individual articles of this book can be downloaded from here:

https://www.mdpi.com/journal/symmetry/special_issues/Algebraic_Structure_Neutrosophic_Triplet_Neutrosophic_Duplet_Neutrosophic_Multiset.

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