Neutrosophic Sets and Metaheuristic Optimization: A Survey

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Abstract

Smarandache presents neutrosophic sets and provides a domain area that is made up of three separate subsets to reflect the various kinds of uncertainty. Neutrosophic sets are defined as the sets where every other element of the universe possesses a degree of truthiness, indeterminacy, and falsity, which range from 0 to 1, and where these degrees are subsets of the neutrosophic sets that are independent of each other. Neutrosophic sets are also known as neutrosophical subsets. In the neutrosophic sets, impreciseness is represented as truth and falsity functions, but the indeterminacy function represents degrees of belongingness and non-belongingness and differentiates between absoluteness and relativeness. Neutrosophic sets can deal with the unpredictability of the system and cut down on the paralysis brought on by conflicting information thanks to this notation. As a result, one might argue that this capacity is the single most significant benefit offered by neutrosophic sets in comparison to the many other forms of fuzzy extensions. By making use of these three functions, neutrosophic sets are able to create a domain area. This area makes it possible for various kinds of mathematical operations to be carried out separately despite the presence of uncertainty. Due to the fact that the behavior of these methodologies is inspired by Nature and its capacity for adapting to issues, in addition to the potential for combining more than one method to reach the best alternatives, metaheuristic algorithms are employed to initiate the finest or the best possible alternatives to a lot of optimization techniques. This is possible because metaheuristic algorithms have the ability to adapt to problems. The fact that numerous academics have utilized these techniques with neutrosophic science to offer several systems in recent years was the impetus for writing this overview study in the first place, which was based on the above rationale.

Keywords: Intelligent Model; MCDM; Neutrosophic Sets; Metaheuristic optimization

1. Introduction

A variety of novel ideas that manage with imprecision and ambiguity have been presented in the fuzzy area since Zadeh established the Fuzzy Set (FS) in 1965. Smarandache's Neutrosophic Sets (NSs) provide the basis for an extension of both Fundamentalist Sets and Intuitionistic Fundamental Sets (IFS). whilst the FS provides the level of Truth value of an aspect in a prescribed group, the IFS provides both an extent of truth and an extent of false value, and the NS provides an extent of truth, an extent of Indeterminacy value, and an extent of false value. While the NS provides the extent of truth, indeterminacy and falsity values [1]. In IFS, the false function is not reliant on the true function; however, this is not the case with FS, where the false function is based on the true function. The truth, indeterminacy and falsity are each separate and distinct in NS. Smarandache discussed the distinctions among NSs and the numerous modifications of FSs that are available. An example of NS known as Single-Valued NS (SVNS) may be traced back to the research conducted by Smarandache. The SVNS was introduced by the initial author, Haibin Wang, during the international symposium that was held in Salt Lake City, Utah, in the United States. In order to get a great deal of attention from the academics, NSs and SVNSs have been discussed at a variety of conferences and published in a variety of conferences and publications [2], [3].

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Both multi-attribute individual decision-making (MADM) and multi-attribute group decision-making (MAGDM) have found widespread application for the usage of NSs and SVNSs. An instance of the Neutrosophic Set (NS) known as the Interval Neutrosophic Set (INS) has been suggested. The only sub unitary intervals that are taken into consideration by the INS subclass of the NS are those that fall between 0 and 1 [4], [5].

Scientists have shown a considerable amount of interest in NSs. NS-based systems have been implemented in a variety of applications, including the index options, the capital sector, image denoising, clustering algorithms, information extraction, love dynamics, camera tracking, fault diagnostics, air monitoring, and many more. Following the year 2010, a flurry of new suggestions for NS expansions appeared in the scholarly papers. Ye gave the definition of the Simple NS (SNS) using the three integers ranging from 0 to 1. The NS class has a subclass called SNS. An SVNS and an INS are both components of an SNS. SNSs have been employed in a variety of contexts, including judgement, medical diagnosis, and others [6]–[8].

The rest of this paper is organized as follow: section 2 presented the neutrosophic sets. Section 3 presented the metaheuristic. Section 4 presented the combination of NS and metaheuristic. Finally, section 5 presented the conclusions.

2. Neutrosophic Sets

Applications that simulate the real world produce a vast amount of information that is insufficient, inaccurate, ambiguous, and inconsistent. It's possible that the uncertainty stems from things like insufficient information, mistakes made during data collecting, or random chance. Many current theories and approaches, such as the probability and statistics, fuzzy set (FS) theory, intuitionistic fuzzy set (IFS), and para-consistent logic theory, were presented in order to handle such nebulous data. Even so, these hypotheses are only able to address a single inexact aspect of an issue rather than the entire issue within a single framework [9], [10]. For instance, the FS is only able to manage hazy and unclear data without addressing any inconsistencies or gaps in the information that it is analyzing. The use of the neutrosophy method, which is a branch of philosophy that combines the knowledge of philosophy, set theories, logics, and probabilities and statistics, is thus recommended to settle such questions in a single framework. Neutrosophy serves as the foundation for neutrosophic logic, which expresses indeterminacy by using a novel model referred to as "Neut-A" to resolve certain issues that cannot be resolved by fuzzy logic. In most cases, fuzzy logic may be characterized as an application of two-valued logic, in which the assertions do not need to be true or false, but rather, they can have a truth degree that ranges from 0 to 1. In comparison to all other logics, neutrosophic logic and IF logic often display a greater degree of "uncertainty [11], [12]". This is because of unintended variables that can be hidden in certain unknownness or proposals; even so, the neutrosophic logic permits every element (T, I, F) to be equally overflooded (simmering) over 1, i.e., to be "1+," or underdried under 0 (freezing), i.e., to be "0," in order to be to differentiate among relative truth and actual truth in addition to among relative falsity and absolute false [13], [14].

According to Smarandache, "neutrosophy is a new field of philosophy that explores the genesis, nature, and extent of neutralities, in addition to their connections with other ideational spectra." Classical logic, fuzzy logic, and imperfect likelihood are all accounted for within the framework of neutrosophy, which is an example of various value logic. Due to the fact that it explains the vagueness of information, or the linguistic error proven by several witnesses, neutrosophy is more closely aligned with human rationality. Neutrosophy, in general, refers to the study of the nature, origin, and extent of neutralities together with their interactions. One aspect of neutrosophy is the neutrosophic set. Each event described by the neutrosophy theory has a specific degree of truth, a degree of falsehood, and a degree of indeterminacy; these three degrees should be evaluated separately from one another. Neutrosophic set has emerged in recent years as a broad, preeminent, and appropriate structure[15], [16].

3. Metaheuristic algorithms

The act of looking for optimum solutions to a specific issue of interest is what is meant by the term "metaheuristics," and it is this process that is employed to solve optimization challenges. It is possible to conduct the process of searching by using many agents, which, in essence, build a system of developing solutions by employing a collection of guidelines or mathematical equations throughout several iterations. These cycles will continue until the answer that is identified satisfies some previously established criteria. It is argued that this final solution, which is a near optimum solution, is an ideal answer, and a structure is said to have achieved a converged state when it has arrived at this solution [17], [18].

In contrast to precise approaches, which locate an optimum solution at the price of a significant amount of computing effort, heuristic methods locate a result that is close to ideal in a truly short amount of time. Yet, the majority of these approaches are problem-tailored. As the prefix "meta" in the word "metaheuristics" indicates,

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these methods are one step above from heuristic techniques. Techniques based on metaheuristics have seen a significant deal of success due to the high probability that they will offer answers at a level of computational expense that is acceptable. When applied to a wide variety of real-world issues, the hybridization of solid heuristics with time-tested metaheuristics may provide very high-quality answers [19]–[21].
A reasoning process in problem solving that permits a solution to an issue to be led by trial-and-error experimentation is referred to as a heuristic. When it comes to finding solutions to problems, a metaheuristic is a generic or higher-level heuristic that is broader [22], [23].
The term "metaheuristic computing" refers to an adaptive kind of computing that employs broad heuristic guidelines in the process of finding solutions to a category of computational issues [24], [25].
Metaheuristic can be explained as:

$$MetaH = (O, A, R^c, R^i, R^o)$$

where O is a collection of several types of metaheuristic techniques (such as adaptive, automotive, cognition, trial-and-error, etc.); A is a collection of generic algorithms (such as genetic algorithm, particle swarm optimization, evolutionary algorithm, ant colony optimization, and so on); Rc = OA is a set of internal relations; R^i is a set of input relations; where C′ is a collection of external notions and c is the concept area; and so on.
In addition to the ideas described in the previous paragraphs, it is essential to understand the following additional important aspects: neighborhood search, diversifying or exploration, rapid expansion or subjugation, local minima versus global minima, escaping local minima, local search versus global search, evolutionary algorithms, swarm intelligence, and so on. In addition to these terms, there are also some fundamental methods that are used in metaheuristics. These techniques include maintaining an equilibrium between exploration and exploitation searching for the neighbors with the most potential or promise, avoiding neighbors who are inappropriate or inefficient, limiting the search from trying to enter into neighbors who do not promise anything, and so on [26], [27].
Exploration vs. exploitation Both exploration and exploitation, which may also be called to as diversity and intensity, dispersion, and converging, correspondingly, are two characteristics that are universal to all optimization methods and are essential to their operation. Yet, it is very dependent on the particular search philosophy used by each metaheuristic. When it comes to properly resolving an optimization issue, these two characteristics are regarded to be the pillars[28], [29]. Exploration is the capability to broaden search in a widespread domain to discover uninhabited areas, whereas exploitation, via cumulative search experience, enables one to focus on attractive opportunities (top quality solutions) to utilize and combine optimally. Exploration and exploitation are both aspects of the same process. For the purpose of mastering the two characteristics, an effective algorithm distributes new solutions far out from the present area of search by using randomization methods and random walks. This is done so that exploratory moves may make it to all of the areas inside the search space at least once. On the other hand, the algorithm works to converge as rapidly as possible while minimizing the amount of time wasted on unnecessary steps by using extensive local search knowledge about the terrain and historical search data[30], [31].

4. Combination of Neutrosophic Sets and Metaheuristic

In order to improve the dark portions of the skeletal scintigraphy picture in an effective manner, Nasef et al. [32]developed an adaptive method that was based on the Salp Swarm algorithm (SSA) and a neutrosophic set (NS) under several criteria. To begin, the process of enhancing the dark areas is transformed into an optimization issue. When the SSA method has determined the greatest potential improvement for each picture on its own, the neutrosophic technique is used to calculate a similarity score for every image using the adaptive weight coefficients that were determined by the SSA method. An Egyptian medical dataset obtained from Menoufia University Hospital was used in the application of the suggested technique. The dataset included one picture with no references. The NS method, and the local enhance method are compared to the findings. The findings indicate that the proposed method achieves high results in all of the requirements that were tested, including the fitness function, entropy, number of edges, nNaturalness image quality Evaluator, sharpness, sharpness index, and contrast-distorted images that were enhanced with contrast. The findings shown that the concept of incorporation among the falsity membership of the neutrosophic set and the Salp swarm method may be used for the advancement of skeletal scintigraphy.
For the purpose of segmentation, Palanisamy et al. [33]spoke about using the neutrosophic set (NS) in conjunction with the fuzzy c-means clustering (FCM) and the altered particle swarm optimization (PSO). The nonlocal mean filtered MR image is used to obtain the NS image, which is then subjected to additional clustering using FCM, which is steered by an altered PSO. This allows for optimized clustering, which in turn allows for fragmenting the brain tumour with lesser time consumption and increased accurateness. The findings shown

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that the suggested technique is superior to both FCM alone and FCM combined with NS when applied to a total of one hundred magnetic resonance images (MR).

Ashour and Guo [34]came up with an original approach for denoising medical images that was based on an NS indeterminacy filter (IF) that had an optimized kernel. After that, the filter that was suggested, which is referred to as the optimum indeterminacy filter (OIF), is used for the process of denoising dermoscopy pictures. The outcomes of the experiments included investigations that compared the filter that was suggested to more conventional types of denoising filters. In addition, a variety of performance assessment measures were assessed, demonstrating that the suggested denoising approach was superior to the others.

An better segmentation strategy for abdominal CT liver tumors relying on NS, PSO, and fast fuzzy C-mean algorithm (FFCM) is proposed by Anter and Hassenian[35]. To get a higher level of contrast in the CT picture of the liver, the high frequency and intensity values of the actual pictures were masked out and replaced with a median filter in the first step of the adjustment process. After that, the abdominal CT image is converted to the NS domain, which is characterized by utilizing three subsets: the proportion of truth T, the percentage of falsehood F, and the proportion of indeterminacy I. This step concludes the process. For assessing indeterminacy in the NS domain, entropy is the metric of choice. After that, the NS image is sent to an improved FFCM employing PSO to enhance, optimize, and segment the liver from the abdominal CT scan. After that, these livers underwent the PSOFCM procedure, which clustered and segmented the tumors that were present.

Because it spreads so quickly, the COVID-19 virus has created a significant demand for a diagnosis method that is both accurate and quick. The well-known RT-PCR test is expensive and is therefore not accessible for many diagnoses. Basha and colleagues [36] came up with the idea of using a neutrosophic model to diagnose COVID-19 patients using the chest X-ray images they provided. The model that has been suggested includes five primary stages. The speeded up robust features (SURF) technique is used to extract robust invariance from every X-ray image first. Second, to treat the unequal dataset, three different sampling methods are used. Third, the neutrosophic regulation categorization is suggested to create a set of rules utilizing the three neutrosophic values known as T, I, and F, which represent the grades of truth, indeterminacy, and falsity, respectively. In the fourth step, an application of a genetic algorithm is used to choose the most effective neutrosophic rules in order to enhance the performance of the classification. The categorization neutrosophic logic is suggested as the fifth step in this phase of the process. The checking rule matrix is formed without a class label; the purpose of this step is to figure out what the class label should be for every testing rule by calculating the percentage of overlap between both the diagnostics rules and the strength and conditioning rules.

Using NS and moth-flame optimization, Sayed and Hassanien [37]introduced an automated mitotic detection strategy for histopathology slide imaging. The strategy that has been developed may be broken down into two main steps: the stage of candidate extraction, and the stage of candidate categorization. During the phase that included the extraction of candidates, a Gaussian filter was used on the image of the histopathology slide, and then the improved picture was mapped into the NS domain. After that, morphological treatments have been applied to the truth subset picture to provide further upgrades and put the emphasis on mitotic cells. During the phase of candidate classification, many characteristics such as statistical, shape, texture, and energy features were retrieved from every candidate. These features were used to classify the candidates. Subsequently, in order to choose the characteristics of mitotic cells that are most useful for discrimination, a concept from the meta-heuristic MFO algorithm was used. In conclusion, the chosen characteristics were used in order to provide input for the categorization and regression tree (CART). To examine how well the suggested method works, a benchmark dataset made up of fifty histopathology pictures was used. The dataset that was ultimately selected included breast tissue samples on five separate slides. These H&E-stained slides were scanned using Aperio XT scanners at a magnification of 40 times. When tried to compare to other well enough and other meta-heuristic proposed algorithms, the experimental results show that the MFO feature selection algorithm is capable of finding the optimal feature subset that maximizes performance of the classifier. This ability was revealed by the MFO feature extraction method.

In order to analyses enormous amounts of text, Jain et al. [38]created a hybrid framework that they called "PSO and NS." Both binary and ternary classifiers are included in NS and PSO, both of which are derived from a combination of PSO and NS. This approach is appropriate for classifying big amounts of text that are more than 25 kilobytes in size. The size of the swarm that is created from a huge text may provide a measurement that is acceptable for the execution of PSO convergence. The technique that has been suggested has been taught and tested with enormous amounts of text. The suggested technique creates a correlation between Neutrosophic Set and sentiment analysis in order to achieve its goals.

To model a neutrosophic variable using empirical data, Gafar et al. [39]provided a platform that integrates information theory measurements with PSO as a meta-heuristic method. An effective population-based method called PSO has been introduced for the purpose of finding optimum membership, indeterminacy, and non-

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membership divisions. A presentation will be given on the combined composite model of information theory measurements and PSO. The experimental comparisons are done between the suggested method and the Fuzzy C-Mean tool that may be generated in MATLAB. This tool is used for constructing fuzzy membership functions. In order to illustrate how successful the suggested paradigm is, comprehensive generation method of the temperature variables of the forest fires data set as well as the conversion rates are supplied. The suggested method's conversion rates indicate that the optimum membership and non-membership functions may be determined after 10 and 17 cycles, correspondingly, which is a reasonably quick pace. This is shown by the fact that the optimal participation and non-membership values have been found.

5. Conclusions

Since many real-life judgment issues include inaccuracy, uncertainty, inconsistency, missing data, and uncertainty, NS, meta-heuristics, and logic are increasingly popular as potential solutions. The word "neutrosophic theory" relates to the branch of philosophy known as neutrosophy, which has been used in a variety of contexts to find solutions to issues including indeterminacy and ambiguity. Neutrosophy is a new branch of mathematics that generalizes both traditional mathematical techniques and fuzzy logic. Neutrosophic likelihood, neutrosophic set theory, neutrosophic logic, and neutrosophic statistics are all examples of such methods to neutrosophy. Lately, NS has been merged with meta-heuristics to produce decision schemes for a range of tasks. These judgment schemes have been used for procedures on images including such median filter, grouping, fragmentation, and categorization; medical image analysis; cloud services, and other.

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