Neutrosophic Sets Integrated with Metaheuristic Algorithms: A survey

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Abstract: Neutrosophic set is a branch of neutrosophy concerned with nature, the genesis, and breadth of impartialities, and also their interaction with various mental spectra. Neutrosophic sets constitute relatively new expansions of intuitionistic fuzzy. In a short period of time, numerous researchers have accepted neutrosophic reasoning. Many researchers have linked neutrosophic science and metaheuristics in various ways over the last ten years. Metaheuristic research has attracted a great attention throughout the literature, which covers methodologies, apps, comparative analysis; due to its higher intensities and fruitful implementations. Metaheuristic algorithms are used to introduce the best or the optimum solutions to a lot of optimization problems due to the behavior of these algorithms inspired by Nature and its ability to adapt to problems, as well as the possibility of integrating more than one algorithm to reach the best solutions. Based on the previous reason, many researchers used these algorithms with neutrosophic science to present many platforms in the recent years, which was the motivation to introduce this survey paper. This paper is introduced to cover the publications from 2010 to 2021 in order to draw a comprehensive picture of metaheuristic research integrated with neutrosophic theory.

Keywords: Neutrosophic Set; Neutrosophy; Metaheuristic; Optimization

1. Introduction

Massive amounts of incomplete, vague, fuzzy, and inaccurate data are provided by real-world applications. Errors possession, lack of knowledge, or randomness can all contribute to uncertainty [1]. Several theories and methodologies have been proposed to deal with such ambiguous data, including probability theory[2], Theory of Para-consistent logic[3], Set theory with a fuzziness[4], and Fuzzy set theory with intuition[5]. Furthermore, such theories only can deal through one incorrect problem element at a time rather than the entire problem inside one paradigm; for instance, the fuzzy set theory can just handle imprecise and fuzzy data, not inconstant or unfinished issues in the same data. As a result, in attempt to settle such concerns in a unified framework, the neutrosophic methodology was introduced [6]. As a result, the neutrosophic methodology[6], which really is a philosophical subdivision incorporating philosophic awareness, set theory, intuitions, and probabilistic, can then be used to resolve these issues in a single framework. Neutrosophic methodology is the foundation of neutrosophic logic, which indicates ambiguity and uses a new platform named Neut-A to tackle problems which fuzzy logic can't [7]. Fuzzy logic is typically known as a two-valued logic extension in which statements do not have to be true or untrue, and might have a truth degree in range of 0 and 1. In comparison to all other logics, neutrosophic reasoning and Fuzzy logic with intuition have a higher percentage of "indeterminacy". That's also owing to unexpected criteria which can also be concealed for some unknowingness or proposals, but a neutrosophic logic allows for every item (T, I, F) to be flooded (stirring) over 1, in other words be '1+', or dehydrated, e.g. be '0', in order to distinguish among relative truth and actual truth, along with comparative falseness and ultimate untruth.

Neutrosophic is considered a new area of study which investigates the origin, natural world, and context of impartialities, and also their ability to interact with various mental spectra, according to Smarandache. Traditional logic, probabilistic reasoning, and inaccurate probability are all specified by Neutrosophic, multiple value logic. Neutrosophic is more human-like in that it describes knowledge inaccuracy or linguistic inconsistency as determined by multiple observers. A neutrosophic set is considered a subset in neutrosophic that investigates neutrality's essence, origin, or context of impartialities, as well as its relationships. Each incident within neutrosophic set theory owns a degree of truth, falsehood, and ambiguity that must also be analyzed separately from one another [8].

A neutrosophic set has recently emerged as a general, prominent, and comprehensive strategy. Many researchers have submitted many research papers using neutrosophic science to solve many problems. Looking at the recent years, we find that a link has been made between neutrosophic set theory and metaheuristic science so as to produce the best proposed solutions for many research problems. Integration between the two previous sciences has been based on the importance of metaheuristic.

The concept "metaheuristic" refers to higher-level methodologies that have been proposed for solving a wide range of optimization issues. A number of metaheuristic algorithms have recently proven successful in solving critical situations. The advantage of employing such algorithms to solve tremendous challenges would be that they produce a desired or optimum solution in a short time, even for problem sizes are large scale.

In the last twenty years, new and innovative evolutionary approaches have emerged successfully, despite the progress of classical metaheuristic algorithms. During this period of metaheuristic algorithm research, a large number of new metaheuristic algorithms inspired by evolutionary or behavioral processes are introduced.

Many of metaheuristic algorithms have been used integrated with neutrosophic science to answer a wide range of research issues. For instance, forest fires[9], document-level sentiment analysis[10],image segmentation[11, 12],breast cancer detection[13, 14], time series forecasting[15], Relief distribution and victim evacuation[16],modeling neutrosophic variables[17],CT image segmentation and two[18]… etc.

The goal of this essay is to provide a detailed insight of the major metaheuristic algorithms that have been combined with neutrosophic set theory to introduce a number of efficient solutions or platforms to a variety of problems over the last decade, as well as a clear explanation of NS and metaheuristic concepts.

The following is the structure of the survey on integration between meta- heuristics and neutrosophic. Sect. 2 introduces the concept and model of neutrosophic sets. Sect. 3 introduces the concept meta-heuristic algorithms. Sect. 4 introduces a global review on neutrosophic set incorporated with metaheuristic and its applications and platforms in different models. Finally, Section 5 concludes with a conclusion and recommendations for the future.

2. Theory of Information

In the neutrosophic scientific theory, every proposal is simulated to get the rate of reality $\mu_u(x)$, indeterminacy rate $\sigma_u(x)$, and negation rate $\nu_u(x)$. The theory of neutrosophy is a broadening of fuzziness and intuitionistic fuzzy sets as well as rational thinking. Neutrosophic theory is gaining momentum as a solution to a variety of real-world problems involving ambiguity, imprecision, vagueness, incompleteness, inconsistency, and indeterminacy[19, 20]The neutrosophic logic is used to deal with information that has a lot of uncertainty and irregularity. As a result, the neutrosophic theory is used in a variety of fields to address issues related to indeterminacy. To deal with uncertainty, we need some concepts to define the neutrosophic variable. The triple supports any value of a variable in a neutrosophic universe:

$$u = \{\mu_u(x), \sigma_u(x), \nu_u(x)\} \tag{1}$$

Where $\mu_u(x)$ denotes fact membership, $\sigma_u(x)$ denotes indeterminacy membership, and $\nu_u(x)$ denotes untruth membership. Such three aspects are self-contained and quantifiable. According to the neutrosophic set description[21] ,every element $x \in X$ inside set u represented in Eq. 1 is falling under the upcoming constraints:

$$0^- \le \mu_u(x), \sigma_u(x), \nu_u(x) \le 1^+ \tag{2}$$

$$0^- \le \mu_u(x) + \sigma_u(x) + \nu_u(x) \le 3^+ \tag{3}$$

The following equations limit a type 1 neutrosophic fuzzy set:

$$0^- \le \mu_u(x), \sigma_u(x), \nu_u(x) \le 1^+ \tag{4}$$

$$\mu_u(x) \wedge \sigma_u(x) \wedge \nu_u(x) \le 0.5 \tag{5}$$

$$0^- \le \mu_u(x) + \sigma_u(x) + \nu_u(x) \le 3^+ \tag{6}$$

The third classification, a neutrosophic intuitionistic set with type 2, is compelled with the upcoming formula:

$$0.5 \le \mu_u(x), \sigma_u(x), \nu_u(x) \tag{7}$$

$$\mu_u(x) \wedge \sigma_u(x) \le 0.5, \mu_u(x) \wedge \nu_u(x) \le 0.5, \sigma_u(x) \wedge \nu_u(x) \le 0.5 \tag{8}$$

$$0^- \le \mu_u(x) + \sigma_u(x) + \nu_u(x) \le 2^+ \tag{9}$$

In order to make certainty science an open field for working in environments of degree of truth, uncertainty, and error, a set of definitions of neutrosophic science is provided in the literature.

Figure 1[9] depicts a typical neutrosophic decision-making aid. The system starts with a prepping process that converts traditional data from various repositories into rough set theory data that is then transferred via the neutrosophic platform. Aim of providing neutrosophic data 'B,' the neutrosophic system applies system formula 'U o R= B' toward a data of neutrosophic 'U,' during which R considers the group of neutrosophic laws pertaining that apply to the framework so as to provide the data 'B.'. In addition, o represents the intermediate representation. The wisdom of neutrosophic is obtained by extracting knowledge from neutrosophic data. As a result of applying the decision support system procedure to neutrosophic data, the neutrosophic decision seems to be the ultimate destination.

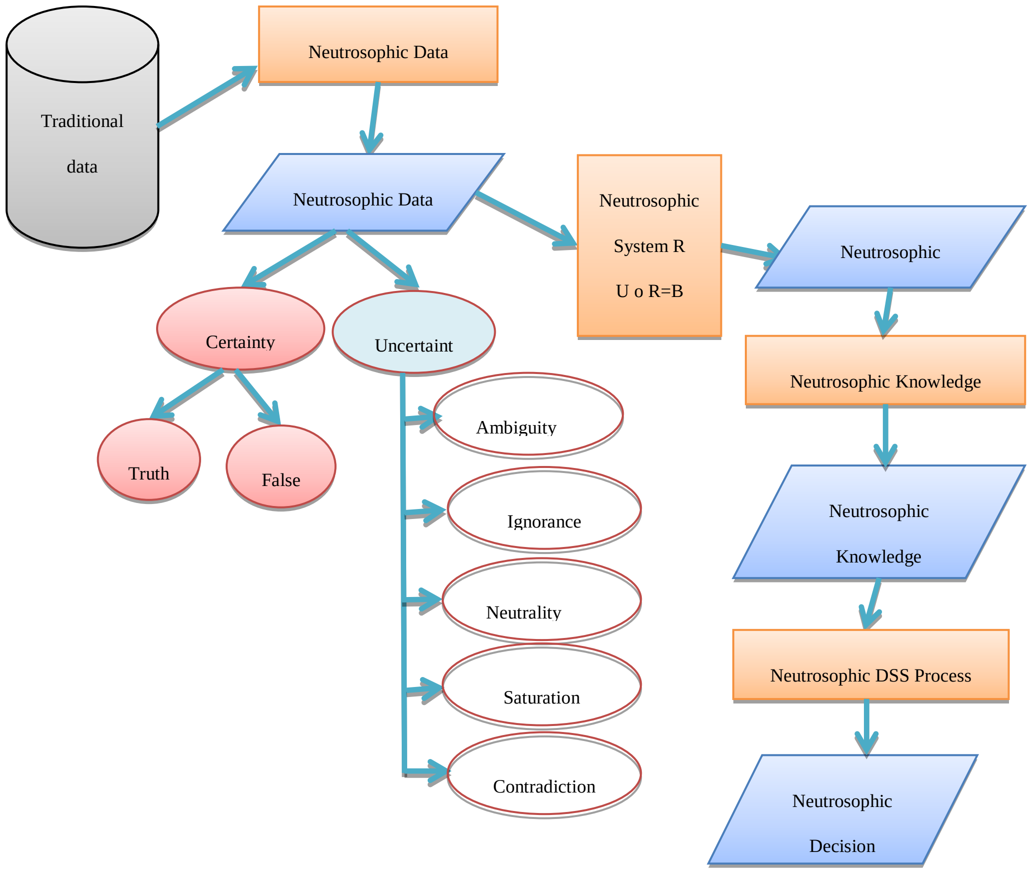

Figure 1. a typical neutrosophic decision-making aid

3. Overview on Meta-heuristic Algorithms

A metaheuristic is an algorithmic structure that covers a lot of optimization issues with only a few tweaks to adapt to the specific problem. By studying the nature of the work of any metaheuristic algorithm, we find that, the harmonization of two search archetypes: the exploration and the exploitation is the reason for metaheuristics robust searching mechanism. Metaheuristics can be used with a variety of classification criteria. Consider how metaheuristics are classified according to the path they take, whether they use memory, what form of neighborhood exploration they use, or how many existing solutions they carry from one iteration to the next. A lot of researchers introduced various metaheuristic categories.

4. Integration of Neutrosophic Set and Met-heuristic Algorithms

According to F Smarandache [6], neutrosophic set is basic paradigm which extrapolates with neutrosophic set and its variants, such as simplistic neutrosophic sets, single valued neutrosophic sets, fuzzy intuitionistic fuzzy sets, Interval-valued neutrosophic set, ragged neutrosophic set, intuitionistic neutrosophic set, interval neutrosophic set, neutrosophic soft set, neutrosophic hesitant fuzzy set. These variants have recently been integrated with meta-heuristic optimization algorithms and employed in a broad variety of topics, including computer applications, medical applications, image segmentation, clustering, text analysis, time series forecasting and more.

4.1. Neutrosophic Set and Met-heuristic Integration on Image Segmentation

Throughout the fields of photo processing and computer vision, accurately and efficiently segmenting images has always been critical. Biomedical image segmentation is a critical step in picture processing and style recognition that distinguishes objects from the background, determining the analysis' quality. The image is frequently segmented to non-overlapping pieces during this process. Fuzzy theory, when applied to image segmentation, retains more information than strict segmentation techniques. Segmenting the data can potentially be a part of different clusters using FCM. The indeterminacy of every object in the series, however, cannot be described or assessed using the traditional set techniques. As a result, fuzzy sight has been used to deal with uncertainty. Neutrosophic integrated with meta-heuristic has recently been a popular tool for dealing with this problem.

Image segmentation algorithms can also be divided into three categories according to the resemblance and incompleteness of gray levels: Integrating region-based segmenting, border segmenting, and segmentation approaches with specialized theoretical tools algorithms. The innate fuzziness of images, as well as the ambiguity during segmentation, is added to the complexity of image segmentation. Classical segmentation methods have a hard time keeping up with modern demands. For example, when a single monolithic sill is also utilized to segregate the objective from the surroundings in the limit picture segmentation approach, the impact cannot be optimal. In picture segmentation of region-based, it is generally more-segmented and babble-sensitive. If the image segmentation method is ineffective, the segmentation process will be of poor quality. In-depth image segmentation research is beneficial to enhance image processing follow-up performance. In recent decades, numerous researchers have conducted considerable picture segmentation research; however there isn’t presently absolutely clear a segmentation technique which is adequate over all images. Numerous image segmentation methodologies have been introduced that incorporate some particular theories and methods, like the FCM algorithm relies on cluster analysis, as a result of the emergence of several concepts and approaches in numerous sectors. The initial parameters of the FCM algorithm are extremely sensitive, and it may be necessary to manually adjust them to estimate the global optimum and strengthen segmentation speed. Furthermore, the conventional FCM methodology is vulnerable to noise or gray - scale discontinuities because it ignores spatial information. The region based segmentation method only considers information such as pixel intensities, image boundary, and so on, and ignores the image's inherent indeterminacy, which can lead to erroneous picture segmentation findings. Although, because turbulence is unavoidable throughout images acquired, transportation, and storage, de-noising is emerged as a key research for image processing. A lot of academics have suggested many de-noising techniques.

Benaichouche et al [22] boosted fuzzy c-means in 3 stages for solving image segmentation problems. First, particle swarm optimization algorithm (PSO) was incorporated to improve the initialization steps of fuzzy c-means method. Second, during cluster segmentation, the Mahalanobis space was also employed to limit the impact of geometric pattern upon the locative gray information incorporation of pictures. Ultimately, the clustered mistake had been rectified via redistributing potentially misclassified pixels, allowing the segmentation results to be refined. Canayaz et al [11] presented a segmentation method which could be applied to image processing. Image segmentation algorithms such as the Neutrosophic Set (NS), which is used to evaluate indeterminacy information, and metaheuristic algorithms have become popular. Both of these methods were used in this research. After transforming a picture into the neutrosophic domains, that has 3 subsets (Truth, indeterminacy, and Falsehood), after that, image pixels' indeterminacy is removed, and meaningful features of the image are acquired. Then, using T, I subset, the coefficient matrix is found, and the thresholds which coincide to the values optimizing the entropy objective function are dictated using coefficient matrices. This is accomplished using the Cricket Algorithm. The picture will be represented by these thresholds, and indeed the picture will be segregated as a result.

A new bandwidth image retrieval scheme is proposed by Rashno et al [23]. RGB images are first turned into two subgroups in the NS sector and then segmented for this job. Color features such as the dominant color descriptor (DCD), distribution, and statistical components are retrieved for each segment of an image. Wavelet characteristics are also retrieved from the entire image as texture features. A feature vector is created by combining all retrieved characteristics either from a fragmented or entire image. Feature vectors are offered for feature selection in ant colony optimization, which picks its most important features. For the final retrieval process, only a few features are used.

Gehad et al [24] presented a composite segmentation strategy depending on a variant of watershed algorithm and Neutrosophic reasoning. Pre - processing stage, CT image translation to the Neutrosophic space, and post-processing are the three aspects of the proposed technique. Normalization and the median filter are employed in the preprocessing step so as to improve the clarity and brightness ratios of the hepatic CT picture while also reducing noise. Three membership sets transform and depict the improved CT liver picture in the Neutrosophic set domain. Finally, in the last phase, morphology with mathematical formula and a variant of watershed method are utilized to improve the generated truthful image out from the previous step and recover the liver of the CT image.

Image segmentation of ultrasound breast cancer is a critical point; different studies were introduced to cover this area. For example, Zhang article [7] demonstrated segmenting of ultrasonography breast cancer imaging by defining a neutrosophic range, that is split into 3 subsets: T, I, and F, neutrosophic may be applied to image processing. The image is then segmented in the neutrosophic domain with the watershed technique. M Zhang et al [25]also introduced an approach for segmenting breast ultrasound pictures (BUS) using a neutrosophic approach and watershed algorithm. According to M Zhang, First, a BUS picture is tied with the domain of neutrosophic. The image is then converted into a binary one using neutrosophic logic, and the resultant image is segmented using the watershed technique. The tumor is finally found in the segmental area. TS Umamaheswari et al [14] addressed the problem of simultaneously gene selection and robust breast cancer (BC) test categorization by displaying two crossbred algorithms, namely the enhanced firefly algorithm (EFA) and the adaptive neuro neutrosophic inference system (ANNIS), both of which have chosen attributes for CTC detection. It is divided into 3 distinct phases: The main phase is to eliminate fineness markers associated with paired cell composition separation. The second step proposes a new meta-heuristic method based on EFA to discern prescient features for BC prediction. FAs have been changed in the EFA algorithm by using the discontinuous domain as a continuous domain. The EFA flexibly balances research and abuse to swiftly identify the optimum solution EFA is a new calculation method based on the blazing lighting technique used by fireflies. In the gene space, the EFA can quickly determine the best or relatively close gene subset amplifying a given fitness work.

Moving to histopathology, GI Sayed et al [13] presented an approach to histopathology slide imaging that uses neutrosophic sets (NS) and metaheuristic optimization algorithm called moth-flame (MFO) to detect mitosis automatically. The suggested method is divided into two primary phases: candidate extraction and candidate categorization. A Gaussian filtering is applied to the histopathology slide image during the candidate extraction stage, and the enhanced picture was transferred into the NS domain. The truth subset image was then subjected to morphological treatments in order to improve the image and focus on mitotic cells. Several statistical, form, textural, and echoes were retrieved from each candidate during the candidate categorization step. The greatest distinguishing properties of mitotic cells were then chosen using a meta-heuristic MFO algorithm principle. Finally, the characteristics that were chosen were supplied into the classification and regression trees (CART).

In the field of image segmentation, Nondestructive testing (NDT) is a method of detecting a flaw in metal without destroying it. To detect the flaw from an NDT image by using an image segmentation-based technique, it is a difficult task. The problem arises as a result of uncertainties in the NDT image pattern. The uncertainty should be addressed effectively when segmenting an NDT picture. S Dhar [26] described a novel technique for segmenting an NDT picture while dealing with uncertainties using a neutrosophic set in this paper. The NS handles the uncertainty by dividing the image to three subsets: truth, falsehood, and indeterminacy. Two procedures - mean and augmentation - are required for appropriate NS value representation. The bat algorithm is integrated to identify the right values of and based on statistics of the image (BA). The method determines the best values for and in order to adequately manage the uncertainty. In comparison to the most recent methods, we found the proposed method to be pretty satisfactory in terms of performance.

4.2. Neutrosophic Set and Meta-heuristic Integration on Time –Series-Forecasting

Recent years, various time series forecasting models were introduced based on neutrosophic integrated with meta-heuristic. For example, P Singh research paper [27] introduced a new method for forecasting time series datasets that uses a neutrosophic-quantum optimization strategy. The inherited uncertainty of a time series set of data was represented in this paper using neutrosophic set (NS) theory, which has three memberships: truthful, ambiguity, and falsehood. The term "neutrosophic time series" refers to these kinds of forms of time series datasets (NTS). NTS has also been used to model and forecast time series dataset. The success of the NTS molding technique is strongly reliant on the ideal picking of the discourse space and its related periods, according to the findings. The paper uses the quantitative optimization algorithm called QOA and aggregates, as well as the NTS molding technique to tackle this problem. By picking the global optimum universe of speech and its accompanying periods from a collection of local optimum solution, the NTS molding approach performs better with QOA. A new time - series model was suggested by P Singh et al [15] based on neutrosophic theory and the PSO algorithm. This suggested framework started with a time series set of data being represented in NS utilizing three separate NS subscriptions: truth, indeterminacy, and falsity. This NS representation of time series was given the label neutrosophic time - series data (NTS). The suggested model's predicting performance was discovered to be strongly dependent on the optimal universe of discussion of the time series set of data selection. In this work, the image segmentation problem was solved using the PSO method.

P Singh et al [28]also presented another research that focused on three primary issues with time series datasets: depiction of time series datasets using NS, a number of three membership degrees of NS combined, and predicting outcomes production. This study recommended using a neutrosophic-neuro-gradient technique to overcome these three domain-specific issues. The uncertainty associated with time series datasets was represented using NS theory. Numerous decision rules with the style of IF-THEN principles were generated in NTS and dubbed neutrosophic entropy decision rules (NEDRs). The forecasting findings were evolved using an ANN-based structure with NEDRs as an input. This study also used the gradient descent approach to reduce the disparities among of computed and targeted outcomes values in during experiment in order to enhance the effectiveness of the ANN and create optimal prediction performance.

For forest fires forecasting, M Gamal et al [9] introduced a platform that combines the measures of information theory with PSO to predict a neutrosophic parameter using empirical data. PSO is a meta-heuristic methodology for determining the best partitions for truth membership, indeterminacy, and falsity. For the wildfire temperature variable, the suggested methodology produced relatively similar function subsets, whereas the Fuzzy C-Mean obviously altered the function subsets. Estimating actual temperature vagueness in wildfire data will help to accurately forecast these fires.

4.3. Classifying MANET's Attacks Based on Neutrosophic and Meta-heuristic Integration

A mobile ad hoc network (MANET) is an ad hoc system made up of mobile wireless servers with no permanent telecommunications infrastructure. This platform's evolution may be more rapid and unpredictable.. Because of MANETs' unique characteristics, an adversary can launch several attacks on ad hoc networks. The most pressing concern with MANETs is security, which is critical to the system's overall utility. Accessibility of system administrations, privacy, and data integrity can all be achieved by ensuring that security concerns are addressed. MANETs are vulnerable to security attacks on accounts due to their characteristics such as open medium, powerful topology change, lack of central monitoring and management, pleasant computations, and no obvious protection mechanism. The battleground for MANETs vs. the security threat has altered as a result of these causes. Because of such traits, MANETs are more vulnerable to attacks from within the network. Remote connections also render MANETs more vulnerable to attacks, making it easier for an attacker to break into the system and gain access to the ongoing conversation.

Routing table overflows, flooding assault, wormhole attack, Mitm attacks, and greedy node misbehaving are some of the risks that MANET can face. Nodes in MANETs are vulnerable to intrusion and assault because they lack specified architecture and mobility. Intruder Detection Learning Technology is used by designers to protect a computer system from unauthorized access such as hackers. It is a learning challenge to use an intrusion detector to generate a classifier. The detectors should really have the ability to tell the difference between "abnormal" connections, also known as invasions or threats, and "normal" contacts.

Elwahsh et al [29] proposed an Intelligent System for Categorizing MANETs Attacks based on Neutrosophic and Genetic Algorithm (GA), which is a challenging step for categorizing MANETs threats. This framework is relying on two phases: the first is pre-processing and the second is classification for network invasions. In the preprocessing step, network characteristics are formatted in a classifying format. The data from the KDD network [30] is transformed to take the format of neutrosophic (Membership, Indeterminacy, Non-membership). The genetic algorithms (GA) searching technique is used to find a series of neutrosophic constraints to categorize MANETs assaults after transforming traditional KDD data to a neutrosophic data form. The GA starting population is made up of individuals who were chosen at random. A neutrosophic (if-then) categorization rule is represented by each individual.

H Elwahsh et al [31]proposed another method for classifying MANET’s threats using a composite neutrosophic intelligent system with genetic algorithm. This study presents a hybrid framework of Self-Organized Features Maps (SOFM) and evolutionary algorithms for MANETs attack inference (GA). To construct the MANET's neutrosophic conditioned parameters, the hybrid uses the SOFM's unsupervised learning capabilities. The neutrosophic variables, as well as the training set of data, are given to the GA, which uses the fitness function to discover the most suitable neutrosophic set of rules from a series of original sub threats. This approach is intended to identify unknown MANET assaults.

4.4. Job Shop Scheduling Based on Neutrosophic and Meta-heuristic Integration.

Scheduling module schedules machines work for reducing the maximum completion time (make span) or meeting other criteria. The flexible job-shop scheduling problem (FJSP) with routing flexibility seems to be more challenging, and can be thought of it as an integrated making plans and job shop scheduling (IPPS) problem, in which the two significant roles of process planning and task shop scheduling are regarded as a whole and streamlined simultaneously in order to take advantage of versatility in a production system. Because of their intricacy, meta-heuristic methods are frequently used to tackle scheduling difficulties. L Jin et al [32] presented a study on the modeling and optimization strategy for the problem of IPPS with unpredictable process time. To describe unknown processing times, NS is initially presented. They created an enhanced teaching-learning-based optimizing (TLBO) methodology to handle more resilient scheduling strategies owing to the complicated of the math modelThe scoring values of the unknown execution per each device are assessed and enhanced in the proposed optimization approach to achieve the most effective alternative. In [33] L Jin et al proposed a research focused the problem of IPPS with unpredictable process time in order to mitigate the inconsistency in make span in [36]. To simulate the unknown processing times, the innovative neutrosophic numbers are first presented. A mixed-integer linear programming (MILP) framework based on neutrosophic numbers is evolved; regarding the NP hardness and difficulty of estimating the model, the variable neighborhood search (VNS) embedded mimetic algorithm (MA) is formed to expedite extra efficient systems. The nominal make span criteria and the robustness requirement has been weighted summed in the suggested algorithm.

4.5. Image Clustering Based on Neutrosophic Set and Meta-heuristic Integration

Clustering is the division of a group of samples or items into a number of clusters with comparable common components. The fuzzy c-means (FCM) method is one of the most often used fuzzy clustering approaches. To acquire the data membership degrees in FCM, an iterative reduction of a cost function is done. This objective functions are subjected to a constraint for each data set, namely that combination of degrees of membership across bunches must equal one. The FCM approach, on the other hand, has some downsides, including the fact that, firstly its sensitivity to noise, secondly, it strives to reduce intra-cluster variance, thirdly, having a local minima, and fourth the outcomes are dependent on the beginning values. A group's number of noise points could be rather large. As a result, academics are interested in finding new approaches to address these issues. The NS was introduced to handle the uncertainties connected with the clustering based methodologies' parameters since it is a formidable strategy to cope with indeterminacy.

Based on NS, PSO, and the fast fuzzy c-means (FFCM) approach, Anter et al [18] suggested an upgraded segmentation method for abdominal CT liver tumors. To reduce the noise and modify the image, the median filter method was used first. The abdominal CT image was then processed using the neutrosophic domain. The PSO algorithm developed to enhance the FFCM algorithm before utilizing the approach to fragment the neutrosophic image. Subsequently, using the abdominal CT, a segmentation image of the liver was acquired.

Relying on PSO and FCM, Watershed image segmentation method was proposed by Yu et al [34], who used a new variant of PSO algorithm to obtain the accurate clustering core. They also segmented a tiny section of the original image with an accurate clustering core and enhanced fitness function, and acquired a segmentation results for the full image.

To tackle the drawbacks of FCM, J Zhao et al [35] introduced a technique called an Innovative Neutrosophic Image Segmentation Improved Fuzzy C-Means Methodology (NIS-IFCM), in which they first de-noise the image by transforming it into a neutrosophic image. Then the study proposed a new method that combines the PSO and FCM algorithms to decrease the FCM algorithm's reliance on the initial value introduced an innovative methodology for tackling the problem of image segmentation. Another study presented by F Zhao et al [36], he provided an innovative solution for this problem of poor image border segmenting. The proposed study combined FCM with PSO algorithm to enhance the capability of global search to tackle the issue of neutrosophic image clustering. Hanuman et al [37]presented a hybrid FCM-PSO approach. FCM-PSO is a hybrid method that combines the best aspects of FCM and PSO algorithms to solve the problem of local minima in FCM.

4.6. Image Thresholding Based on Neutrosophic Set and Meta-heuristic Integration

Image thresholding is a crucial step in segmenting and extracting objects from photos. In this area, a set of techniques have been offered. Typically, the indetermination every element in a crisp set, cannot usually be specified and assessed. The membership of fuzzy set N specified on universe A is traditionally represented by an actual number inside the traditional fuzzy set. The fuzzy sets methods, on the other hand, only evaluate the truthful membership that is substantiated and ignore the falsehood membership that is contradictory to the proof that is problematic in various situations. On the other hand, the NS combines the concepts of a variety of sets like the classic, interval valued fuzzy, fuzzy, interval valued intuitionistic fuzzy, and intuitionistic fuzzy into a single idea. In the NS, indeterminism is clearly measured, and truth (T), indeterminacy (I), and falsity (F) memberships are all independent. As a result, many experiments were conducted to increase the thresholding efficiency of NS.

Based on NS and improved artificial bee colony (I-ABC) algorithms, K Hanbay et al [38] introduced a new synthetic aperture radar (SAR) algorithm for picture segmentation. Threshold value estimation is viewed in this approach as a search technique for a suitable value within a gray scale period. For getting the best threshold value, the I-ABC optimized procedure is provided. To develop an efficient and powerful fitness function for the I-ABC approach, the input SAR picture is translated into the domain of NS. After that, images of the neutrosophic T and I subsets are obtained. A co-occurrence matrices relying on neutrosophic T and I subset pictures is created, and the objective functions of the I-ABC algorithm is represented using a two-dimensional gray entropy function. Consequently, in the I-ABC algorithm, the occupied, bystanders, and scouting bees rapidly explore the best threshold value.

M Nasef et al [39] introduced a study that is provided a multi-criteria adaptive strategy for brightening the dark parts of musculoskeletal scintigraphy images (NS) using the algorithm of Salp Swarm and the NS. Firstly, the task of improving the dark areas is turned into an optimization issue. The SSA is then used to identify the optimal enhancement for any image independently, and the neutrosophic algorithm is then used to calculate the similarity score for each image using adaptive weight coefficients produced by the SSA algorithm.

On the other hand, because conventional image segmentation techniques for side scan sonar (SSS) images are typically inefficient or inaccurate, Jianhu et al [40]work proposes a new image thresholding segmentation approach called SSS relying on the NS and quantitate-behaved particle swarm optimization (QPSO) algorithms. To begin, the image grayscale co-occurrence matrix is built with respect to the NS space, expressing the precise texture of the SSS picture, which can increase the accuracy of SSS image segmentation. The optimal two-dimensional segmentation threshold vector is then rapidly and precisely generated using the QPSO method, based on the two-dimensional maximum entropy theory, which can increases the effectiveness and reliability of SSS picture segmentation. Ultimately, target segmentation of SSS images with high noise levels is accomplished with precision and efficiency. The algorithm's efficiency is demonstrated by segmenting SSS images including various objectives.

4.7. COVID-19 Diagnosing Based on Neutrosophic set integration with metaheuristic

COVID-19, a rapidly spreading virus, created a tremendous demand for an accurate and quick testing approach. The well-known RT-PCR test is expensive and unavailable throughout many suspect instances. SH Basha et al [41] suggests a neutrosophic framework for diagnosing COVID-19 patients. The suggested framework consists of five phases. The speeded up robust features called SURF methodology is first performed for every X-ray image in order to obtain resilient invariance in features. Secondly, three selecting sampling techniques are used to deal with the dataset's imbalance. Thirdly, a neutrosophic rule-based categorization scheme is presented, which generates a set of rules depending on three neutrosophic quantities <T; I; F>, which represent the truthful, indeterminism, and falsehood degrees. Fourth, improve the classification's performance, a genetic algorithm is used to pick the best neutrosophic set of rules. The classification-based neutrosophic logic is proposed in the fifth step.

4.8. Integration of Neutrosophic Set and Meta-heuristic in other fields

Document, sentence, and aspect level sentiment analysis are the three layers of sentiment analysis. The text gives polarity at the document and sentence levels, respectively, on the basis of the entire document and sentence. The text gives positive polarity for some aspects but negative polarity for others at the aspect level. A Jain et al [10] proposed a composite framework, which is concerned with document level analysis called "Senti-NSetPSO" to evaluate large text document. Senti-NSetPSO consists of two binary and ternary classifiers based on PSO and Neutrosophic Set hybridization. This approach is appropriate for classifying large text document with a file size of more than 25 kilobytes. The size of the swarm is created from large text can valuable metric for implementing PSO convergence.

Another topic of study is the cloud environment. A feast of research papers was just given. Because the cloud environment is made up of distributed resources that are used in a dynamic manner, it is necessary to design optimal scheduling in the cloud environment to ensure that cloud consumers get the quality of service they want while cloud providers make the most money. However, the occurrence of inefficiencies when scheduling cloud resources poses a challenge to typical scheduling rules. The major goal of K Gurumurthy et al [42] research was to address ambiguity in cloud resource scheduling by developing a neutrosophic inference system for prioritizing incoming tasks and optimizing resource utilization using quantum cuckoo search cache management. The suggested study used neutrosophic representation to express the parameters involved in resource scheduling with the goal of reducing response and execution time while increasing throughput, which benefits the cloud service provider's profitability.

6. Conclusion and Future Work

Because many real-life decision-making problems entail imprecision, imprecision, ambiguity, inconsistencies, incomplete data, and indeterminacy, NS, meta-heuristics, as well as logic are becoming more prominent as answers. The research and applications of the neutrosophic- set, logic, measure, and probability are referred to as neutrosophic. The neutrosophic logic (NL) has traditionally been used to denote a mathematical formula of ambiguity, inconsistency, ambiguity, incompleteness, and redundancy inconsistency based on non-standard analysis. It is regarded as a framework for assessing indeterminacy, truth, and falsity. In contrast, the NS quantifies indeterminacy directly, while T, I, and F memberships are all independent. This property is critical in a variety of applications, including data fusion to merge data from many sensors and other biomedical diagnosis scenarios. The NS concept is an innovative mathematical technique to dealing with uncertainty that has a lot of potential in a lot of different ways. Recently, NS has been combined with meta-heuristics to create decision schemes for a variety of applications such as processes on images as thresholding, clustering, segmentation and classification, medical image processing, cloud computing, job-shop scheduling, time series forecasting, forest fires forecasting, document level sentiment analysis, modeling neutrosophic variables, breast cancer detection, and other uses. Because no study has been done on the use of the NS and meta-heuristic integration in picture registration, compression, or restoration, this will be the future direction. As a result, it is recommended to use NS techniques in such activities rather than existing procedures. Furthermore, the FCM is the most clustering technique that can be coupled with the NS and meta-heuristic to reduce uncertainty. As a result, it is recommended that the NS and meta-heuristic be combined with other clustering algorithms.

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