N-SOFT SETS: LITERATURE REVIEW AND RESEARCH POTENTIAL

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Abstract

N-soft sets have attracted many researchers rapidly. This paper presents a systematic literature review to provide the state of the art of N-soft sets. Scope for further research potential using N-soft sets and their extensions in decision-making problems is also explained.
Keywords: N-Soft Sets, Literature Review, Research Potential, Decision-Making

1 INTRODUCTION

Real-world problems are complex. Therefore, these problems need to consider uncertainties whose handling is vital for obtaining fairish solutions. Uncertainty can be incomplete data, indistinguishability situations, randomness, fuzziness, and soft sets.

We focus on soft sets theory [1] that allows all parameters such as numbers, words, sentences, and functions. Thus, a soft set relates the parameters or attributes with information about the elements in the universe. This theory has been extensively applied in many different areas to manage uncertainty. Some of the recent soft set applications are as follows: in coding theory [2], smartphone selection [3], artificial neural network [4], credit scoring [5], context-aware video recommender systems using soft-rough set [6], social network analysis [7], movie selection [8].

Nowadays, we often face ratings in real-world situations, and decision-making based on that becomes significant. Nevertheless, soft set presents limitations to dealing with ranking or rating systems in non-binary evaluations. Fatimah et al. [9] introduced the concept of

N-soft set as the novel idea of a parameterized description of the universe of objects that depends on a finite number of ordered grades.

This paper aims to provide an outline of the N-soft set, its various extensions, its operations and to give a perspective to the research community about the potential of N-soft set theory in different fields. The rest of this paper is systematized: Section 2 introduces the concept of N-soft set, some basic operators, and extensions of N-soft set. Section 3 points out the trends and directions of the N-soft set context, and finally, the paper is concluded in Section 4.

2 *N*-SOFT SETS: LITERATURE REVIEW

Fatimah et al. [9] have illustrated N-soft set main features with real examples, and they have investigated its essential properties and fundamental operations, plus its relationships with existing models.

2.1 *N*-Soft Sets: Concepts and Basic Operations

This subsection wraps up the concept and basic operations of the N-soft set. The formal definitions are as follows:

Definition 1 [9]. Let U imply the universe of objects under consideration and E the set of attributes, $A \subseteq E$. Let $R = \{0, 1, 2, \ldots, N-1\}$ be the set of ordered grades where $N \in \{2, 3, \ldots\}$. A triple (F, A, N) is called an N-soft set on U if F is mapping from A to $2^{U \times R}$, with the characteristic that for each $a \in A$ and $u \in U$ there exists a particular $(u, r_a) \in U \times R$ such that $(u, r_a) \in F(a)$, $r_a \in R$.

The interpretation of the pair $(u, r_a) \in F(a)$, is that the element u belongs to the set of a-approximations of the set U with the grade r_a. The N-soft set tabular representation is recalled in Table 1.

Table 1. N-Soft Set.

(F, A, N)	a_1	a_2	…	a_q
u_1	$\{r_{11}\}$	$\{r_{12}\}$	…	$\{r_{1q}\}$
u_2	$\{r_{21}\}$	$\{r_{22}\}$	…	$\{r_{2q}\}$
…	…	…	…	…
u_p	$\{r_{p1}\}$	$\{r_{p2}\}$	…	$\{r_{pq}\}$

Incredibly, this definition of N-soft set (Definition 1) is suitable and flexible to decision making, when experts must assess a set of alternatives based on various types of uncertainty attributes. In the first paper of N-soft set, Fatimah et al. [9] initially introduced several basic definitions and operations to deal with N-soft set. We mention some of them in this paper.

Definition 2 [9]. Define (F^0, Q, N) the normalized N-soft set from (F, A, N), by the expression: for all $a_i \in A$, $u_i \in U$, $F^0(a_j)(u_i) = F(a_j)(u_i) - m$, where $m = min\, r_{ij}$ in the tabular representation of the original (F, A, N) and $Q = \{1,2, \ldots, q\}$.

Definition 3 [9]. Two N-soft sets (F_1, A_1, N_1) and (F_2, A_2, N_2) are equal over the same universal U, (F_1, A_1, N_1)=(F_2, A_2, N_2), if and only if $F_1 = F_2$, A_1=A_2 , and N_1=N_2.

Definition 4 [9]. Two N-soft sets (F, A_1, N) and (G, A_2 , N) on U are equivalent under normalization if $(F^0, Q_1, N) = (G^0, Q_2 , N)$.

Definition 5 [9]. A weak complement of the N-soft set (F, A, N) is any N-soft set, (F^c, A, N), where $F^c(a) \cap$

$F(a) = \emptyset$, for each $a \in A$.

In tabular form, the weak complement acquires from any table with the same universe and set of attributes, where the number in each cell is always distinct from the number in the suitable cell of the genuine tabular representation.

2.2 Extensions of N-Soft Sets

In the last few years, the development of hybrid models of uncertain knowledge has been snowballing. Table 2 confirms the interest of many researchers in hybridization N-soft sets (NSS). They are fuzzy N-soft sets [10], hesitant N-soft sets [11], hesitant fuzzy N-soft sets [12], interval-valued hesitant fuzzy N-soft sets [13], N-soft set approach to rough sets [14], intuitionistic fuzzy N-soft rough sets [15], N-soft topology [16], multi hesitant N-soft sets [17], neutrosophic N-soft sets [18], generalized vague N-soft sets [19], neutrosophic vague N-soft sets [20], Pythagorean fuzzy N-soft sets [21], complex fuzzy N-soft sets [22], complex Pythagorean fuzzy N-soft sets [23], complex spherical fuzzy N-soft sets [24], complex single-valued neutrosophic N-soft set [25], picture fuzzy N-soft sets [26], M-parameterized N-soft topology based on Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) approach [27], N-soft rough sets [28], Multi (Q, N)-soft multi granulation rough sets [29], and multi-fuzzy N-soft set [30].

Let us dwell on that N-soft sets advances. Fuzzy N-soft sets [10] is a hybrid model that combines fuzzy set theory with N-soft sets. Hesitant N-soft sets are a fusion of N-soft sets and hesitancy [11]. Hesitant fuzzy N-soft sets are a mix of hesitant fuzzy set theory with N-soft sets [12]. Interval-valued hesitant fuzzy N-soft sets blend of N-soft sets and interval-valued hesitant fuzzy sets [13]. The corresponding structures between N-soft sets and rough structures of various types N-soft sets are proposed by Alcantud et al. [14]. Akram et al. [15] introduced intuitionistic fuzzy N-soft sets, N-soft rough intuitionistic fuzzy sets, and also intuitionistic fuzzy N-soft rough sets. The N-soft topology consists of N-soft interior, N-soft exterior, N-soft closure, N-soft basis, N-soft frontier, and their related results [16].

N-soft set research development in 2020 as follows. Fatimah proposed multi hesitant N-soft sets [17] as a form of expansion of N-soft sets needed to represent multiple opinions from various respondents for multiple criteria and decisions. Neutrosophic N-soft sets as a hybrid model of neutrosophic sets and N-soft sets [18]. Generalized vague N-soft sets is a suitable combination of generalized vague soft sets with N-soft sets [19]. Neutrosophic vague N-soft sets are composed of neutrosophic vague sets and N-soft sets [20]. Pythagorean fuzzy N-soft sets as an integrating Pythagorean fuzzy set with N-soft set [21].

In 2021, N-soft set research is still growing. Complex fuzzy N-soft sets combine CFSs with N-SSs to handle the complex data in decision-making [22]. Complex Pythagorean fuzzy N-soft sets are the fusion of complex PFS theory with N-soft sets [23]. Complex spherical fuzzy N-soft sets describe parameterized information and ordinal ranking systems [24]. Complex single-valued neutrosophic N-soft set combines the 2-dimensional single-valued neutrosophic nature of the attributes with parameterized ordered grades [25]. Picture fuzzy N-soft set is a generalization of picture fuzzy sets (PFSs) and N-soft sets (N-SS) by observing that one of the essential concepts of neutral grade is missing in intuitionistic fuzzy N-SS (IFN-SS) theory [26]. M-parameterized N-soft topology based on the TOPSIS approach is proposed to deal with the actual situation in life when the grading/rating of both parameters and alternatives [27]. N-soft rough sets as a combination of rough sets and N-soft sets [28]. Multi (Q, N)-soft sets, multi (Q, N)-soft rough sets, and multi (Q, N)-soft multi-granulation rough sets [29]. Fatimah and Alcantud [30] proposed a new model that enhances multi-fuzzy set theory with the N-soft sets called multi-fuzzy N-soft set.

Table 2. Extensions of N-Soft Sets.

Year	Proposed model	Conclusion/Algorithm	Authors
2018	FNSS	1. The algorithm of choice values of (F, N)-soft sets. 2. The algorithm of R-choice values of (F, N)-soft sets. 3. The algorithm comparison table of (F, N)-soft sets.	[10]
2019	HNSS	1. The algorithm of choice values of HNSSs. 2. The algorithm of weighted choice values of HNSSs.	[11]

Year	Proposed model	Conclusion/Algorithm	Authors
		3. The algorithm of choice values for arithmetic scores of HNSSs. 4. The algorithm of weighted choice values for arithmetic scores of HNSSs.	
	HFNSS	1. The algorithm of TOPSIS method based on HFNSS 2. The algorithm of the choice value of HFNSS 3. The algorithm of the L-choice value of HFNSS	[12]
	IVHFNSS	The algorithm of the proposed approach for MAGDM	[13]
	NSS to RS	1. The corresponding structures of Pawlak's rough sets, tolerance rough sets, and multigranulation rough sets can be derived from a given N-soft set 2. Integrated use of combinatorial and graph-theoretic techniques to represent tolerance rough structures by N-soft sets	[14]
	IFNSRS	1. The algorithm of selection of an alternative in an IFNSS. 2. The algorithm of selection of an alternative in an IFNSRS	[15]

Year	Proposed model	Conclusion/Algorithm	Authors
	N-Soft Topology	Two algorithms for modeling uncertainties in the multi-criteria group decision-making	[16]
2020	MHNSS	The algorithm of the choice value of MHNSS	[17]
	NNSS	Algorithm 1. Neutrosophic N-soft set Algorithm 2. Neutrosophic N-soft set TOPSIS Method	[18]
	GVNSS	The decision-maker uses the two-terminal values α and β of the interval to make the decision	[19]
	NVNSS	It is presented method of priority relation ranking based on neutrosophic vague N-soft sets	[20]
	PFNSS	1. The algorithm of choice values of PFNSS. 2. The algorithm of D-choice values of PFNSS	[21]
2021	CFNSS	1. The algorithm of choice values of CFN-SSs. 2. The algorithm of l-choice values of CFN-SSs 3. The algorithm of the comparison table of CFN-SSs	[22]
	CPFNSS	1. The algorithm of choice values of CPFNSS 2. The algorithm of T-choice values of CPFNSS	[23]

Year	Proposed model	Conclusion/Algorithm	Authors
		3. The algorithm of the comparison table of CPFNSS	
	CSFNSS	1. The algorithm of $CSFNS_f$-TOPSIS method 2. The algorithm of choice values of $CSFNS_f$Ss. 3. The algorithm of weighted choice values of $CSFNS_f$Ss.	[24]
	CSVNSS	Steps to deal MAGDM problem by $CSVNN_f$-TOPSIS method	[25]
	PFNSS	An algorithm to cope with PFN-SS	[26]
	MPNSS	Algorithm 1: (MPNS topology-based method 1). Algorithm 2: (MPNS topology-based method 2)	[27]
	NSRS	The algorithm addresses some limitations of the extended rough sets models in dealing with inconsistent decision problems	[28]
	Multi (Q, N)-soft MGRS	1. The algorithm of multi (Q, N)-soft sets. 2. The algorithm of multi (Q, N)-soft rough sets. 3. The algorithm of multi (Q, N)-soft multi-granulation rough sets	[29]
	MFNSS	Decision-making by weighted choice values of induced HNSSs	[30]

N-soft sets have inspired many researchers in a short period. N-soft sets are not only concerned with theoretical concepts but also include decision-making algorithms and applications.

3 N-SOFT SETS RESEARCH POTENTIAL

It is crucial to uniting the notation to define concepts, extensions, and procedures for N-soft sets. New concepts can be defined clearly to be understood and used effectively in actual data. Some promising further research are M-polar N-soft sets, expanded dual hesitant fuzzy N-soft sets that combine expanded dual hesitant fuzzy [31] with N-soft sets, hesitant N-soft graphs, negative parameters in N-soft sets that inspired from [32], and probabilistic N-soft sets. The researchers can confirm that the new hybrid models are more accurate than those obtained by traditional ones.

Grading non-binary evaluations has become necessary in diverse fields. Thus, future studies in N-soft sets should consider more data sources to reach more relevant research. Researchers can further investigate the applications of N-soft sets hybrid models for data science, forecasting, medical diagnosis, game theory, and social sciences.

On the other side, future research should explore using merge algorithms to select input alternatives and optimal parameters to provide the system's best decision. Future research may also focus on using artificial intelligence analysis to perform N-Soft sets to diverse life challenges better. In web mining, future research can use hybrid model N-soft sets from visitor access patterns to analyze web access logs and find groups of pages that often occur together. Those visits may be used for the prediction of user preferences. Development of decision-making procedures for evaluating the model in terms of the capture of the main parameters. The coding programs for each algorithm in R software.

4 CONCLUSIONS

We have discussed the scope of non-binary values using the N-soft set. This paper recalled an overview about N-soft set paying attention to theoretical concepts including extensions, computational tools, or applications in which N-soft set have provided satisfactory results and fixed a consistent notation.

Forthcoming, we hope novel hybrid models that can improve the performance of N-soft sets with the additional advantages of other uncertainty theories. Some of that ideas can be M-polar N-soft sets, dual hesitant fuzzy N-soft sets, hesitant N-soft graphs, negative parameters in N-soft sets, probabilistic N-soft sets. We can also apply the N-soft set in medical diagnosis, data science, game theory, social sciences, and forecasting in the future. These promising hybridizations will allow us to design more flexible decision-making procedures that fit various people's needs.

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