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Neutrosophic Simply Soft Open Set in Neutrosophic Soft Topological Space

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Abstract: In this paper, we introduce the notion of Neutrosophic Simply Soft Open (N^{SS}-O) set, Neutrosophic Simply Soft (N^{SS}) compact set in Neutrosophic Soft Topological Spaces (N^{S}-TS) and investigate several properties of it. Also, we furnish the proofs of some theorems associated with N^{SS}-compact spaces. Then, the notion of neutrosophic simply soft continuous (N^{SS}-continuous) mapping, N^{SS}-O mapping on an N^{S}-TS and its properties are developed here.

Keywords: neutrosophic simply soft open, neutrosophic simply soft closed, neutrosophic simply soft compact, neutrosophic simply soft continuous.

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1. Introduction

Maji (2012; 2013) grounded the idea of Neutrosophic Soft Set (N^{S}-S) by combining Neutrosophic Set (NS) (Smarandache, 1998) and Soft Set (Molodtsov, 1999). The impact of NS and N^{S}-S has been reflected in their applicability in decision making (Smarandache & Pramanik, 2016; 2018; Mondal, Pramanik, & Giri, 2018a; 2018b; 2018c; Biswas, Pramanik, & Giri, 2014a; 2014b; 2019; Pramanik, Mallick, & Dasgupta, 2018; Dalapati et al., 2017; Pramanik, Dalapati, Alam, Smarandache, Roy, 2018; Das et al., 2019; Dey, Pramanik, & Giri, 2015; 2016a; 2016b; Karaaslan, 2015; Pramanik & Dalapati, 2016; Pramanik, Dey, & Giri, 2016; Jha et al., 2019). Broumi (2013) further studied N^{S}-S and proposed generalized N^{S}-S by combining generalized neutrosophic set (Salama and Alblowi, 2012a) and soft set (Molodtsov, 1999). Smarandache (2018) generalized the soft set to the hypersoft set and plithogenic hypersoft set.

Bera and Mahapatra (2017) defined the Neutrosophic Soft Topological Space (N^{S}-TS) and introduced separation axioms on N^{S}-TS by extending the Neutrosophic Topological Space (NTS) introduced by Salama and Alblowi (2012b). Aras, Ozturk, and Bayramov (2019) also studied the separation axioms on N^{S}-TS. Bera and Mahapatra (2018) presented connectedness and compactness on N^{S}-TS. Mukherjee, Datta, and Smarandache (2014) presented Interval Valued N^{S}-TS (IVN^{S}-TS).

Das and Pramanik (2020) recently presented neutrosophic b-open sets in NTS. Mehmood et al. (2020) presented neutrosophic soft α−open set in N^S-TS.

El Sayed, & Noaman (2013) presented the simply fuzzy generalized open and closed sets, simply fuzzy continuous mappings, simply fuzzy compactness, simply connectedness. In a neutrosophic soft set environment, these concepts have not been introduced.

Research gap: Investigations on Neutrosophic Simply Soft Open (N^{SS}-O) set in N^S-TS, N^{SS}-continuous mapping, N^{SS}-O mapping, N^{SS}-compactness on an N^S-TS have not been reported in the literature.

Motivation: Since NS generalizes fuzzy set (Zadeh, 1965) and NS is more suitable to deal with uncertainty including inconsistency and indeterminacy, we get the motivation to extend the simply fuzzy set in a neutrosophic environment. To address the research gap, we introduce the N^{SS}-O set, N^{SS}-compactness on an N^S-TS.

The rest of the paper is designed as follows:

Section 2 recalls of some definitions, properties of N^S-S, N^S-T, and N^S-TS. Section 3 introduces N^{SS}-O set, N^{SS}-compactness, and proofs of some theorems, propositions on N^S-TS. Also, in this section, we develop the concept of N^{SS}-continuous mapping, N^{SS}-O mapping. Finally, Section 4 presents concluding remarks.

2. Preliminaries and some properties

Definition 2.1. Assume that W is a non-empty fixed set and P is a collection of parameters. Assume that NS(W) denotes the set of all NSs over W. Then, for any $S\subseteq P$, a pair (N, S) is said to be an N^S-S (Maji, 2012) over W, where N: $S\rightarrow$NS(W) is a mapping.

An N^S-S (N, S) is represented as follows:

$(N, S) = \{(f,\{(u, T_{N(f)}(u), I_{N(f)}(u), F_{N(f)}(u)): u\in W)\}:f\in P\}$, where $T_{N(f)}(u)$, $I_{N(f)}(u)$, $F_{N(f)}(u)$ are the truth, indeterminacy, and falsity membership values of each u w.r.t. the parameter $f\in P$.

Example 2.1. Assume that W= {m_1, m_2, m_3} is a set consisting of three mobiles and P = {f_1(display), f_2(RAM), f_3(cost)} be a set of parameters with respect to which the nature of mobile is described.

Let,

$N(f_1)$ = {(m_1, 0.6, 0.5, 0.5), (m_2, 0.3, 0.8, 0.5), (m_3, 0.5, 0.3, 0.4)},

$N(f_2)$ = {(m_1, 0.7, 0.4, 0.6), (m_2, 0.6, 0.5, 0.4), (m_3, 0.7, 0.3, 0.3)},

$N(f_3)$ = {(m_1, 0.8, 0.5, 0.4), (m_2, 0.7, 0.8, 0.5), (m_3, 0.5, 0.3, 0.6)}.

Then (N, P) = {(f_1, $N(f_1)$), (f_2, $N(f_2)$), (f_3, $N(e_3)$)} is an N^S-S over W w.r.t the set P.

Definition 2.2. The complement of an N^S-S (N, P) (Maji, 2012) is denoted by (N^c, P) and is defined by $(N^c, P) = \{(f, \{(u, 1\text{-}T_{N(f)}(u), 1\text{-}I_{N(f)}(u), 1\text{-}F_{N(f)}(u)): u\in W)\}: f\in P\}$.

Definition 2.3. Assume that (S_1, P) and (S_2, P) are any two N^S-Ss over W. Then (S_1, P) is said to be a neutrosophic soft subset (Maji, 2012) of (S_2, P) if $\forall f\in P$ and $\forall u\in W$, $T_{S_1(f)}(u) \leq T_{S_2(f)}(u)$, $I_{S_1(f)}(u)$

$\geq I_{S_2(f)}(u)$, and $F_{S_1(f)}(u) \geq F_{S_2(f)}(u)$. We write $(S_1, P) \subseteq (S_2, P)$. Then (S_2, P) is called the neutrosophic soft superset of (S_1, P).

Definition 2.4. Assume that (S_1, P) and (S_2, P) be any two N^S-Ss over W. Then their union (Maji, 2012) is denoted by (H, P), where $H = S_1 \cup S_2$ and is defined as:
$(H, P) = \{(f,\{(u, T_{H(f)}(u), I_{H(f)}(u), F_{H(f)}(u)): u \in W)\}: f \in P\}$, where $T_{H(f)}(u) = max\ \{T_{S_1(f)}(u),\ T_{S_2(f)}(u)\}$, $I_{H(f)}(u) = min\ \{I_{S_1(f)}(u)$ and $I_{S_2(f)}(u)\}$, and $F_{H(f)}(u) = min\ \{F_{S_1(f)}(u),\ F_{S_1(f)}(u)\}$.

Definition 2.5. Assume that (S_1, P) and (S_2, P) are any two N^S-Ss over W. Then their intersection (Maji, 2012) is denoted by (H, P), where $H = S_1 \cap S_2$ and is defined as:
$(H, P) = \{(f,\{(u, T_{H(f)}(u), I_{H(f)}(u), F_{H(f)}(u)): u \in W)\}: f \in P\}$, where $T_{H(f)}(u) = min\ \{T_{N_1(f)}(u),\ T_{N_2(f)}(u)\}$, $I_{H(f)}(u) = max\ \{I_{N_1(f)}(u)$ and $I_{N_2(f)}(u)\}$, and $F_{H(f)}(u) = max\ \{F_{N_1(f)}(u),\ F_{N_1(f)}(u)\}$.

Definition 2.6. An N^S-S (S, P) over a non-empty set W is said to be a null N^S-S (Bera, & Mahapatra, 2017) if $T_{S(f)}(u) = 0$, $I_{S(f)}(u) = 1$, $F_{S(f)}(u) = 1\ \forall u \in W$ w.r.t. the parameter $f \in P$. It is denoted by $0_{(S, P)}$.
Definition 2.7. An N^S-S (S, P) over a non-empty set W is called an absolute N^S-S (Bera, & Mahapatra, 2017) if $T_{S(f)}(u) = 1$, $I_{S(f)}(u) = 0$, $F_{S(f)}(u) = 0\ \forall u \in W$ w.r.t. the parameter $f \in P$. It is denoted by $1_{(S, P)}$.
Clearly, $1^c{}_{(S, P)} = 0_{(S, P)}$ and $0^c{}_{(S, P)} = 1_{(S, P)}$.
Definition 2.8 Assume that N^S-S (W, P) be the collection of all N^S-Ss over W via parameters in P and $\tau \subseteq N^S$-S (W, P). Then τ is said to be an N^S-T (Bera, & Mahapatra, 2017) on (W, P) if the following axioms are satisfied.
(i) $0_{(N, P)}, 1_{(N, P)} \in \tau$;
(ii) $(R, P), (Q, P) \in \tau \Rightarrow (R \cap Q, P) \in \tau$
(iii) $\{(Q_i, P): i \in \Delta\} \subseteq \tau \Rightarrow (\cup_{i \in \Delta} Q_i, P) \in \tau$.
The triplet (W, P, τ) is said to be an N^S-TS. Every element of τ is called an N^S-O set. An N^S-S (S, P) is called a neutrosophic soft closed (N^S-C) set iff its complement (S^c, P) is an N^S-O set.
Definition 2.9. Assume that (W, P, τ) be an N^S-TS over (W, P) and (M, P) be an arbitrary element of N^S-S (W, P). Then the neutrosophic soft interior ($N^S{}_{int}$) (Bera, & Mahapatra, 2017) and neutrosophic soft closure ($N^S{}_{cl}$) of (M, P) is defined as follows:
$N^S{}_{int}(M, P) = \cup\{(Q, P): (Q, P)$ is an N^S-O set in W and $(Q, P) \subseteq (M, P)\}$.
$N^S{}_{cl}(M, P) = \cap\{(Q, P): (Q, P)$ is an N^S-C set in W and $(M, P) \subseteq (Q, P)\}$.
Proposition 2.1. Assume that (W, P, τ) be an N^S-TS over (W, P) and $M, N \in N^S$-S (W, P). Then the following results holds:
(i) $M \subseteq N \Rightarrow N^S{}_{cl}(M) \subseteq N^S{}_{cl}(N)$ & $N^S{}_{int}(M) \subseteq N^S{}_{int}(M)$;
(ii) $N^S{}_{int}(M) \subseteq M \subseteq N^S{}_{cl}(M)$;
(iii) $N^S{}_{int}(0_{(N, P)}) = 0_{(N, P)}$ & $N^S{}_{cl}(0_{(N, P)}) = 0_{(N, P)}$;
(iv) $N^S{}_{int}(1_{(N, P)}) = 1_{(N, P)}$ & $N^S{}_{cl}(1_{(N, P)}) = 1_{(N, P)}$;
(v) $N^S{}_{int}N^S{}_{int}(M) = M$ & $N^S{}_{cl}N^S{}_{cl}(M) = M$;
(vi) $N^S{}_{int}(M \cap N) = N^S{}_{int}(M) \cap N^S{}_{int}(M)$;
(vii) $N^S{}_{int}(M \cup N) \supseteq N^S{}_{int}(M) \cup N^S{}_{int}(M)$;

(viii) $N^S{}_{cl}(M \cup N) = N^S{}_{cl}(M) \cup N^S{}_{cl}(N)$;

(ix) $N^S{}_{cl}(M \cap N) \subseteq N^S{}_{cl}(M) \cap N^S{}_{cl}(N)$.

Proof. For proof see (Bera & Mahapatra, 2017).

Proposition 2.2. Assume that (X, E, τ) be an N^S-TS over (X, E) and $M \in$ NSS (X, E). Then the following results hold:

(i) $(N^S{}_{int}(M))^c = N^S{}_{cl}(M^c)$;

(ii) $(N^S{}_{cl}(M))^c = N^S{}_{int}(M^c)$.

Proof. For proof see (Bera & Mahapatra, 2017)

Definition 2.10. Assume that (W, P, τ) be an N^S-TS over (W, P). Then a family $\{(Q_\alpha, P): \alpha \in \Delta\}$ of N^S-O sets in (W, P, τ), is called an N^S-O cover (Bera & Mahapatra, 2018) of an N^S-S (Q, P) if $(Q, P) \subseteq \cup_{\alpha\in\Delta} (Q_\alpha, P)$.

Definition 2.11. An (W, P, τ) over (W, P) is said to be an N^S-compact set (Bera, & Mahapatra, 2018) if every N^S-O cover of W has a finite subcover.

3. Neutrosophic Simply Soft Open Set

Definition 3.1. Assume that (W, P, τ) be an N^S-TS over (W, P). Then (Q, P), a neutrosophic soft subset of (W, P, τ) is said to be a neutrosophic simply soft open (N^{SS}-O) set if $N^S{}_{int}N^S{}_{cl}(Q, P) \subseteq N^S{}_{cl}N^S{}_{int}(Q, P)$.

Definition 3.2. Assume that (W, P, τ) be an N^S-TS over (W, P). Then (Q, P), a neutrosophic soft subset of (W, P, τ) is said to be a neutrosophic simply soft closed (N^{SS}-C) set if its complement is an N^{SS}-O set in (W, P, τ).

Theorem 3.3. In an N^S-TS (W, P, τ), every N^S-O set is an N^{SS}-O set.

Proof. Assume that (Q, P) be an N^S-O set in an N^S-TS (W, P, τ). Therefore $N^S{}_{int}(Q, P) = (Q, P)$.
Now, $(Q, P) \subseteq N^S{}_{cl}(Q, P)$. This implies $(Q, P) \subseteq N^S{}_{cl}N^S{}_{int}(Q, P)$.
Now $(Q, P) \subseteq N^S{}_{cl}N^S{}_{int}(Q, P)$

$\Rightarrow N^S{}_{cl}(Q, P) \subseteq N^S{}_{cl}N^S{}_{cl}N^S{}_{int}(Q, P)$

$= N^S{}_{cl}N^S{}_{int}(Q, P)$ [since $N^S{}_{cl}N^S{}_{int}(Q, P)$ is an N^S-C set in (W, P, τ)]

$\Rightarrow N^S{}_{cl}(Q, P) \subseteq N^S{}_{cl}N^S{}_{int}(Q, P)$ (1)

Again, $N^S{}_{int}N^S{}_{cl}(Q, P) \subseteq N^S{}_{cl}(Q, P)$ (2)

From (1) and (2), we obtain,

$N^S{}_{int}N^S{}_{cl}(Q, P) \subseteq N^S{}_{cl}N^S{}_{int}(Q, P)$.

Hence (Q, P) is an N^{SS}-O set in (W, P, τ).

Definition 3.3. Assume that (W, P, τ) be an N^S-TS. Then the Neutrosophic Simply Soft interior ($N^{SS}{}_{int}$) and Neutrosophic Simply Soft closure ($N^{SS}{}_{cl}$) of a neutrosophic soft subset (Q, P) of (W, P, τ) is defined by

$N^{SS}{}_{int}(M, P) = \cup\{(Q, P): (Q, P)$ is an N^{SS}-O set in W and $(Q, P) \subseteq (M, P)\}$.

$N^{SS}{}_{cl}(M, P) = \cap\{(K, P): (K, P)$ is an N^{SS}-C set in W and $(M, P) \subseteq (K, P)\}$.

Definition 3.4. Assume that (W, P, τ) be an N^S-TS over (W, P). Then a collection $\{(Q_\alpha, P): \alpha \in \Delta\}$ of N^{SS}-O sets in (W, P, τ), is said to be an N^{SS}-O cover of an N^S-S (Q, P) if $(Q, P) \subseteq \cup_{\alpha\in\Delta}(Q_\alpha, P)$.

Definition 3.5. An N^S-TS (W, P, τ) over (W, P) is said to be an N^{SS}-compact space if every N^{SS}-O cover of W has a finite subcover.

Definition 3.6. A neutrosophic soft subset (K, P) of (W, P, τ) is said to be an N^{SS}-Compact set relative to W if every N^{SS}-O cover of (K, P) has a finite subcover.

Definition 3.6. A function ψ:(W, P, τ_1) $\rightarrow$ (G, P, τ_2) is called an N^{SS}-continuous function if for each N^S-O set (Z, P) in G, ψ^{-1}(Z, P) is an N^{SS}-O set in W.

Definition 3.7. A function ψ:(W, P, τ_1) $\rightarrow$ (G, P, τ_2) is said to be an N^{SS}-O function if ψ(K, P) is an N^{SS}-O set in G whenever (K, P) is an N^{SS}-O set in W.

Theorem 3.2. Every N^{SS}-C subset of an N^{SS}-compact space (W, P, τ) is an N^{SS}-compact set relative to W.

Proof. Assume that (W, P, τ) be an N^{SS}-compact space and (K, P) be an N^{SS}-C set in (W, P, τ). Therefore (K^c, P) is an N^{SS}-O set in (W, P, τ). Let U= {(U_i, P): $i\in\Delta$ and (U_i, P)$\in N^{SS}$-O(W)} be an N^{SS}-O cover of (K, P). Then $\mathcal{H}$= {(K^c, P)}$\cup U$ is an N^{SS}-O cover of W. Since W is an N^{SS}-compact space then it has a finite subcover say {(H_1, P), (H_2, P), (H_3, P), ..., (H_n, P), (K^c, P)}. Then {(H_1, P), (H_2, P), (H_3, P), ..., (H_n, P)} is a neutrosophic finite simply soft open cover of (K, P). Hence (K, P) is an N^{SS}-compact set relative to W.

Theorem 3.3. Every N^{SS}-compact space is a neutrosophic soft compact space.

Proof. Assume that (W, P, τ) is an N^{SS}-compact space. Suppose that (W, P, τ) is not an N^S-compact space. Therefore, there exists an N^S-O cover $\mathfrak{R}$ (say) of W, which has no finite subcover. Since every N^S-O set is an N^{SS}-O set, so we have an N^{SS}-O cover $\mathfrak{R}$ of W, which has no finite subcover. This contradicts our assumption. Hence (W, P, τ) must be an N^S-compact space.

Theorem 3.4. If ψ:(W, P, τ_1) $\rightarrow$ (G, P, τ_2) is an N^{SS}-O function and (G, P, τ_2) is an N^{SS}-compact space then (W, P, τ_1) is also an N^S-compact space.

Proof. Assume that ψ:(W, P, τ_1) $\rightarrow$ (G, P, τ_2) be an N^{SS}-O function and (G, P, τ_2) is an N^{SS}-compact space. Let $\mathcal{H}$= {(K_i, P): $i\in\Delta$ and (K_i, P)$\in N^S$-O(W)} be an N^S-O cover of W. This implies that $\psi(\mathcal{H})$ = {ψ(K_i, P): $i\in\Delta$ and ψ(K_i, P)$\in$ N^S-O(G)} is an N^{SS}-O cover of G. Since (G, P, τ_2) is an N^{SS}-compact space, so there exists a finite subcover say {ψ(K_1, P), ψ(K_2, P), … , ψ(K_n, P)} such that $M \subseteq\cup${ψ(K_i, P): i =1, 2, …, n}. This implies that {(K_1, p), (K_2, p), …, (K_n, P)} is a finite subcover for W. Therefore (W, P, τ_1) is an N^S-compact space.

Theorem 3.5. If ψ:(W, P, τ_1) $\rightarrow$ (G, P, τ_2) is an N^S-continuous function then for each N^S-compact set (Q, P) relative to W, ψ(Q, P) is an N^{SS}-compact set in (G, P, τ_2).

Proof. Assume that ψ: (W, P, τ_1) $\rightarrow$ (G, P, τ_2) is an N^S-continuous function and (Q, P) is an N^{SS}-compact set relative to W. Let $\mathcal{H}$= {(H_i, P): $i\in\Delta$ and (H_i, P) be an N^S-O set in G} be an N^S-O cover of ψ(Q, P). Therefore, by hypothesis $\psi^{-1}(\mathcal{H})$={ ψ^{-1}(H_i, P): $i\in\Delta$ and ψ^{-1}(H_i, P) is an N^S-O set in W} is an N^S-O cover of ψ^{-1}(ψ(Q, P)) = (Q, P). Since every N^S-O set is an N^{SS}-O set, so $\psi^{-1}(\mathcal{H})$={ ψ^{-1}(H_i, P): $i\in\Delta$ and ψ^{-1}(H_i, P) is an N^S-O set in W} is an N^{SS}-O cover of (Q, P). Since (Q, P) is an N^{SS}-compact set relative to

W, so there exists a finite subcover of (*Q*, *P*) say $\{\psi^{-1}(H_1, P), \psi^{-1}(H_2, P), ..., \psi^{-1}(H_n, P)\}$ such that $(Q, P) \subseteq \cup_i\{\psi^{-1}(H_1, P): i = 1, 2, ..., n\}$.
Now $(Q, P) \subseteq \cup_i\{\psi^{-1}(H_1, P): i = 1, 2, ..., n\}$.
$\Rightarrow \psi(Q, P) \subseteq \cup_i\{\psi(\psi^{-1}(H_1, P)): i = 1, 2, ..., n\} = \cup_i\{(H_1, P): i = 1, 2, ..., n\}$.

Therefore there exist a finite subcover $\{(H_1, P), (H_2, P), ..., (H_n, P)\}$ of $\psi(Q, P)$ such that $\psi(Q, P) \subseteq \cup_i\{(H_1, P): i = 1, 2, ..., n\}$. Hence $\psi(Q, P)$ is an N^S-compact set relative to *G*.

Theorem 3.6. Every neutrosophic soft continuous function from an N^S-TS (W, P, τ_1) to another N^S-TS (G, P, τ_2) is an N^{SS}-continuous function.

Proof. Assume that $\psi: (W, P, \tau_1) \to (G, P, \tau_2)$ be a neutrosophic soft continuous function. Let (*Q*, P) be an N^S-O set in (G, P, τ_2). Since ψ is a neutrosophic soft continuous function, so $\psi^{-1}(Q, P)$ is an N^S-O set in (W, P, τ_1). Since every N^S-O set is an N^{SS}-O set, so $\psi^{-1}(Q, P)$ is an N^{SS}-O set in (G, P, τ_2). Therefore $\psi^{-1}(Q, P)$ is an N^{SS}-O set in (G, P, τ_2), whenever (*Q*, P) is an N^S-O set in (W, P, τ_1). Hence $\psi:(W, P, \tau_1) \to (G, P, \tau_2)$ is an N^{SS}-continuous function.

Theorem 3.8. If $\psi:(W, P, \tau_1) \to (G, P, \tau_2)$ is an N^{SS}-continuous mapping and $\gamma:(G, P, \tau_2) \to (H, P, \tau_3)$ is a neutrosophic soft continuous mapping, then the composition mapping $\gamma \circ \psi:(W, P, \tau_1) \to (H, P, \tau_3)$ is an N^{SS}-continuous mapping.
Proof. Assume that (*Q*, P) is an N^S-O set in (H, P, τ_3). Since $\gamma:(G, P, \tau_2) \to (H, P, \tau_3)$ is a neutrosophic soft continuous mapping, so $\gamma^{-1}(Q, P)$ is an N^S-O set in (G, P, τ_2). Again since $\psi: (W, P, \tau_1) \to (G, P, \tau_2)$ is an N^{SS}-continuous mapping, so $\psi^{-1}(\gamma^{-1}(Q, P)) = (\gamma \circ \xi)^{-1}(Q, P)$ is an N^{SS}-O set in (W, P, τ_1). Hence $(\gamma \circ \xi)^{-1}(Q, P)$ is an N^{SS}-O set in (W, P, τ_1), whenever (Q, P) is an N^S-O set in (H, P, τ_3). Therefore $\gamma \circ \xi: (W, P, \tau_1) \to (H, P, \tau_3)$ is an N^{SS}-continuous mapping.

4. Conclusions

In this article, we have introduced the N^{SS}-O cover, N^{SS}-compact set, in an N^S-TS. By defining N^{SS}-O cover, N^{SS}-compact set, we have proved some propositions, theorems on N^S-TS. In the future, we hope that based on these notions of neutrosophic simply soft compactness, many new investigations can be carried out. The proposed concepts can be explored in various neutrosophic hybrid sets such as rough neutrosophic set (Broumi, Smarandache, & Dhar, 2014), bipolar neutrosophic set (Deli, Ali, & Smarandache, 2015), etc.

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