ON Neutrosophic Crisp Supra Bi-Topological Spaces

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Abstract

In this paper, neutrosophic crisp supra bi-topological structure, which is a more general structure than neutrosophic crisp supra topological spaces, is built on neutrosophic crisp sets. The necessary arguments which are pairwise neutrosophic crisp supra open set, pairwise neutrosophic crisp supra closed set, pairwise neutrosophic crisp supra closure, pairwise neutrosophic crisp supra interior is defined, and their basic properties are presented. Finally, many examples are presented.

Keywords: Neutrosophic crisp supra bi-topological spaces, neutrosophic crisp supra pairwise open (closed) sets, neutrosophic crisp supra bi-open (closed) sets.

1. Introduction

The concept of neutrosophy is a new branch of Philosophy introduced by Smarandache [1,2], and has many applications in different fields of sciences such as topology. As a generalization of the concept of topological spaces, Salama and Smarandache [3] defined neutrosophic crisp topological spaces in 2014. The crisp supra topological space was introduced by Mashhour et al. [4] In 1983, as a generalization of the concept of topological space. Jayaparthasarathy et al.[5] generalized this concept and introduced the concept of neutrosophic supra topological space in 2019, by using the neutrosophic fuzzy sets. Also, Al-Hamido presented a more general study, where he created the concept of neutrosophic crisp supra topological spaces [6] in 2020. In 2018 AL-Nafee et al. [7] introduced the notion of new neutrosophic crisp points and neutrosophic crisp separation axioms in neutrosophic crisp topological space. The concept of supra bi-topological spaces was introduced by Gowri, and Rajayal [8] as an extension of supra topological spaces in 2017. On the other hand, the concept of bi-topological spaces was introduced by Kelly [9] as an extension of topological spaces in 1963. He did define bi-topological space as a set endowed with two topologies. The concept of neutrosophic bi-topological spaces was introduced by Al-Hamido [10] as an extension of neutrosophic topological spaces in 2019. This concept has been studied in [11]. Also, the concept of neutrosophic crisp bi-

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topological spaces was introduced by Al-Hamido [12] as an extension of neutrosophic crisp topological spaces in 2018. Since the discovery of neutrosophic topological space and neutrosophic crisp topological space, there has been a concerted research efforts to find new neutrosophic open sets and neutrosophic crisp open sets, for more detail see [13-31].

In this paper, we use the neutrosophic crisp sets to introduce neutrosophic crisp supra bi-topological space. Also, we introduce new class of neutrosophic crisp supra open (closed) sets in this space, as pairwise neutrosophic crisp supra open set, pairwise neutrosophic crisp supra closed set, pairwise neutrosophic crisp supra closure, and we study some basic properties of this new neutrosophic crisp supra open (closed) sets.

2. Preliminaries

In this part, we recall some basic definitions and properties which are useful in this paper.

Definition 2.1. [3]

Let $X \neq \emptyset$ be a fixed set. A neutrosophic crisp set (NCS) U is an object having the form $U =< U_1, U_2, U_3 >$; U_1, U_2 *and* U_3 are subsets of X, satisfying $U_1 \cap U_2 = \emptyset, U_1 \cap U_3 = \emptyset$ *and* $U_2 \cap U_3 = \emptyset$.

Definition 2.2. [3]

$\emptyset_N$ maybe defined in four ways as a neutrosophic crisp set, as follows :

1. $\emptyset_N$=<$\emptyset$, $\emptyset$, X>.
2. $\emptyset_N$=<$\emptyset$, X, $\emptyset$ >.
3. $\emptyset_N$=<$\emptyset$, X, X >.
4. $\emptyset_N$=<$\emptyset$, $\emptyset$, $\emptyset$ >.

X_N may be defined in four ways as a neutrosophic crisp set, as follows :

1. X_N=<X, $\emptyset$, $\emptyset$>.
2. X_N=<X, X, $\emptyset$ >.
3. X_N=<X, $\emptyset$, X >.
4. X_N=<X, X, X >.

Definition 2.3. [3]

Let $X \neq \emptyset$ be a fixed set, and $U =< U_1, U_2, U_3 >, V =< V_1, V_2, V_3 >$ are two neutrosophic crisp sets, then:

U∪V may be defined as two ways, as follows :

1. $U \cup V =< U_1 \cup V_1, U_2 \cup V_2, U_3 \cap V_3 >$.
2. $U \cup V =< U_1 \cup V_1, U_2 \cap V_2, U_3 \cap V_3 >$.

$U \cap V$ may be defined as two ways, as follows :

3. $U \cap V =< U_1 \cap V_1, U_2 \cap V_2, U_3 \cup V_3 >$.

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4. $U \cap V = < U_1 \cap V_1, U_2 \cup V_2, U_3 \cup V_3 >$.

Definition 2.4. [3]

A neutrosophic crisp topology (NCT) on a non-empty set X is a family T of neutrosophic crisp subsets in X may be satisfying the following axioms:

1. X_N and $\emptyset_N$ belong to T.
2. T is closed under finite intersection.
3. T is closed under arbitrary union.

The pair (X, T) is a neutrosophic crisp topological space (NCTS) in X. Moreover, the elements in T are said to be neutrosophic crisp open sets (NCOS). A neutrosophic crisp set F is closed (NCCS) if and only if its complement F^c is a neutrosophic crisp open set.

Definition 2.5. [6]

A neutrosophic crisp supra topology (NCST) on a non-empty set X is a family S of neutrosophic crisp subsets in X may be satisfying the following axioms:

1. X_N and $\emptyset_N$ belong to S.
2. S is closed under arbitrary union.

The pair(X, S) is said to be a neutrosophic crisp supra topological space (NCSTS) in X. Moreover, the elements in S are said to be neutrosophic crisp supra open sets (NCSOS). A neutrosophic crisp set F is neutrosophic crisp supra closed (NCSCS) if and only if its complement F^c is neutrosophic crisp supra open.

3. Neutrosophic crisp supra bi-topological space

In this section, we introduce the neutrosophic crisp supra bi-topological space. Moreover, we introduce new types of neutrosophic crisp supra open (closed) sets in this space and study their properties.

Definition 3.1.

Let Γ_1, Γ_2 is two neutrosophic crisp supra topologies on a nonempty set X then (X, Γ_1, Γ_2) is a neutrosophic crisp supra bi-topological space (SBi-NCTS for short).

Example 3.2.

Let X={a,b}, Γ_1={$\emptyset_N$, X_N, A, B, E}, Γ_2={$\emptyset_N$, X_N, B, G}; A={<{a},∅,∅>}, B={<∅,{b},∅>}, E={<{a},{b},∅>}, G={<∅,∅,{a}>}.

Then $(X, \Gamma_1), (X, \Gamma_2)$ are neutrosophic crisp supra spaces. Therefore (X, Γ_1, Γ_2) is a neutrosophic crisp supra bi-topological space.

Definition 3.3.

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Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space. Elements in $\Gamma_1 \cup \Gamma_2$ are said to be neutrosophic crisp supra bi-open sets (SBi-NCOS for short). A neutrosophic crisp set F is neutrosophic crisp supra closed (SBi-NCCS for short) if and only if its complement F^c is a neutrosophic crisp supra bi-open set.

- The family of all neutrosophic crisp supra bi-open sets is denoted by (SBi-NCOS(X)).
- The family of all neutrosophic crisp supra bi-closed sets is denoted by (SBi-NCCS(X)).

Example 3.4.

In Example 3.2, the neutrosophic crisp supra bi-open sets (SBi-NCOS) are :

SBi-NCOS(X) ={$\emptyset_N$, X_N, A, B, E , G}.

Remark 3.5.

1. Every neutrosophic crisp supra open sets in (X, Γ_1) or (X, Γ_2) is a neutrosophic crisp supra bi-open set.
2. Every neutrosophic crisp supra closed sets in (X, Γ_1) or (X, Γ_2) is a neutrosophic crisp supra bi-closed set.

Remark 3.6.

Every neutrosophic crisp supra bi-topological space (X, Γ_1, Γ_2) induces two neutrosophic crisp supra topological spaces as (X, Γ_1), (X, Γ_2) .

Remark 3.7.

If (X, Γ) is neutrosophic crisp supra topological space. Then (X, Γ, Γ) is a neutrosophic crisp supra bi-topological space.

Remark 3.8.

Let (X, Γ_1, Γ_2) is a neutrosophic crisp supra bi-topological space (SBi-NCTS). Then the union of two neutrosophic crisp supra bi-open (bi-closed) sets is not necessary a neutrosophic crisp supra bi-open (bi-closed) set as the following example shows that.

Example 3.9.

Let X={a,b}, Γ_1={$\emptyset_N$, X_N, A }, Γ_2={$\emptyset_N$, X_N, B }; A={<{a},∅,∅>}, B={<∅,{b},{a}>}. Then (X, Γ_1, Γ_2) is a neutrosophic crisp supra bi-topological space.

A, B are two neutrosophic crisp supra bi-open sets but A∪B={<{a},{b},∅>} is not a neutrosophic crisp supra bi-open set.

Also, A^c, B^c are two neutrosophic crisp supra bi-closed sets but $A^c \cup B^c$ ={<X, X, {b}>} is not a neutrosophic crisp supra bi-closed set.

Remark 3.10.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space (SBi-NCTS). Then the intersection of two neutrosophic crisp supra bi-open (bi-closed) sets is not necessary a neutrosophic crisp supra bi-open (bi-closed) set as the following example shows that.

Example 3.11.

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In Example 3.9, A, B are two neutrosophic crisp supra bi-open sets, but A∩B={<∅, ∅,{a}>} is not neutrosophic crisp supra bi-open set.

Also, A^c, B^c are two neutrosophic crisp supra bi-closed sets, but $A^c \cap B^c$ ={<{b},{a},X>} is not neutrosophic crisp supra bi-closed set.

4. The interior and the closure via neutrosophic Supra bi-open (closed) sets

In this section we define the closure and interior neutrosophic crisp supra set based on these new varieties of neutrosophic crisp supra open and closed sets. Also, we introduce the basic properties of closure and the interior.

Definition 4.1.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space, and A be a neutrosophic crisp supra set then :

The union of any neutrosophic crisp supra bi-open sets contained in A is called a neutrosophic crisp supra bi-interior of A (NCSint(A)).

NCSint(A) =∪{B ;B⊆A; B∈SBi-NCOS(X)}.

Theorem 4.2.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space. If A, B are neutrosophic crisp supra sets then :

1. NCSint(A) ⊆ A.
2. NCSint(A) is not necessary a neutrosophic crisp supra bi-open set.
3. A⊆B ⇒ NCSint(A) ⊆ NCSint(B)·

Proof :

1. The proof follows from the definition of NCSint(A) as a union of any neutrosophic crisp supra bi-open sets contained in A.
2. The proof follows from Remark 3.8.
3. Obvious.

Definition 4.3.

Let (X, Γ_1, Γ_2) bea neutrosophic crisp supra bi-topological space. If A is neutrosophic crisp supra set then :

The intersection of any a neutrosophic crisp supra bi-closed sets containing A is called neutrosophic crisp supra

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bi-closure of A ((NCScl(A)).

NCScl(A)=∩{B ;B⊇A; B∈SBi-NCCS(X)}.

Theorem 4.4.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space and A be a neutrosophic crisp supra set then:

1. A⊆ NCScl(A).
2. NCScl(A) is not necessary a neutrosophic crisp supra bi-closed set.

Proof :

1. The proof follows from the definition of NCScl(A) as an intersection of any neutrosophic crisp supra bi-closed set contained A.
2. The proof follows from Remark 3.10.

5. Pairwise neutrosophic crisp supra open (closed) sets

In this section, we introduce new concept of open and closed sets in neutrosophic crisp supra bi-topological space, as a pairwise neutrosophic crisp supra open(closed) sets. Also, we investigate the basic properties of this new concept of open and closed sets in SBi-NCTS .

Definition 5.1

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space. A neutrosophic crisp supra set A over X is said to be a pairwise neutrosophic crisp supra open set in (X, Γ_1, Γ_2) if there exists a neutrosophic crisp supra open set B in Γ_1 and a neutrosophic crisp supra open set C in Γ_2 such that A=B∪C .

Definition 5.2

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space. A neutrosophic crisp supra set A over X is said to be a pairwise neutrosophic crisp supra closed set in (X, Γ_1, Γ_2) if its crisp neutrosophic complement is a pairwise neutrosophic crisp supra open set in (X, Γ_1, Γ_2). Obviously, a neutrosophic crisp set A over X is a pairwise neutrosophic crisp supra closed set in (X, Γ_1, Γ_2) if there exists a neutrosophic crisp supra closed set B in $(\Gamma_1)^c$ and a neutrosophic crisp supra closed set C in $(\Gamma_2)^c$ such that A=B∩C .

The family of all pairwise neutrosophic crisp supra open (closed) sets in (X, Γ_1, Γ_2) s denoted by PNCSO(X, Γ_1, Γ_2) [PNCSC(X, Γ_1, Γ_2)].

Example 5.3

In Example 3.9, the family of all pairwise neutrosophic crisp supra open (closed) sets in (X, Γ_1, Γ_2)

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PNCSO(X, Γ_1, Γ_2)={ $\emptyset_N$, X_N, A, B, A∪B };
A∪B={<{a},{b},∅>}.

Theorem 5.4

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space. Then the family of all pairwise neutrosophic crisp supra open set is a neutrosophic crisp supra topology on X. This neutrosophic crisp supra topology is denoted by Γ_{12} .

Proof:

Since $\emptyset_N \cup \emptyset_N = \emptyset_N$, hence $\emptyset_N \in \Gamma_1, \Gamma_2$ Therefore $\emptyset_N \in$ PNCSO(X, Γ_1, Γ_2). Similarly, $X_N \in$ PNCSO(X, Γ_1, Γ_2).
Let $\{(N_i): i \in I\} \subseteq PNCSO(X, \Gamma_1, \Gamma_2)$. Ni is a pairwise neutrosophic crisp supra open set, $\forall\ i \in I$.
There exist $N_{i1} \in \Gamma_1$ and $N_{i2} \in \Gamma_2$ such that $= N_{i1} \cup N_{i2}\ \forall\ i \in I$, which implies that:

$$\bigcup_{i\in I} N_i = \bigcup_{i\in I}(N_{i1} \cup N_{i2}) = (\bigcup_{i\in I}[N_{i1}]) \cup (\bigcup_{i\in I}[N_{i2}]).$$

Since Γ_1, Γ_2 are neutrosophic crisp supra topologies, $\bigcup_{i\in I}[N_{i1}] \in \Gamma_1$ and $\bigcup_{i\in I}[N_{i2}] \in \Gamma_2$.
Therefore $\bigcup_{i\in I} Ni$ is a pairwise neutrosophic crisp supra open set.

Remark 5.5

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space. Then an arbitrary intersection of pairwise neutrosophic crisp supra closed sets is a pairwise neutrosophic crisp closed set.

Proof:

Let $\{(N_i): i \in I\} \subseteq PNSC(X, \Gamma_1, \Gamma_2)$. Then Ni is a pairwise neutrosophic crisp supra closed set $\forall i \in I$, therefore there exist $N_{i1} \in (\Gamma_1)^c$ and $N_{i2} \in (\Gamma_2)^c$ such that $N_i = N_{i1} \cap N_{i2}\ \forall i \in I$ which implies that:

$$\bigcap_{i\in I} N_i = \bigcap_{i\in I}(N_{i1} \cap N_{i2}) = (\bigcap_{i\in I}[N_{i1}]) \cap (\bigcap_{i\in I}[N_{i2}]).$$

Now, since Γ_1, Γ_2 are neutrosophic crisp supra topologies, $\bigcap_{i\in I}[N_{i1}] \in (\Gamma_1)^c$ and $\bigcap_{i\in I}[N_{i2}] \in (\Gamma_2)^c$. Therefore, $\bigcap_{i\in I} N_i$ is a pairwise neutrosophic crisp supra closed set.

Remark 5.6.

1) Every neutrosophic crisp supra open sets in (X, Γ_1) or (X, Γ_2) is a pairwise neutrosophic crisp supra open set.
2) Every neutrosophic crisp supra closed sets in (X, Γ_1) or (X, Γ_2) is a pairwise neutrosophic crisp supra closed set.

Proof. Straightforward.

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Remark 5.7.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space then :

1) Every neutrosophic crisp supra bi-open sets is a pairwise neutrosophic crisp supra open set, but the converse is not true.
2) Every neutrosophic crisp supra bi-closed sets is a pairwise neutrosophic crisp supra closed set, but the converse is not true.

Proof. Straightforward.

Example 5.8.

In Example 3.9 A∪B is pairwise neutrosophic crisp supra open sets in (X, Γ_1, Γ_2) ,but it is not a neutrosophic crisp supra bi-open set .

Definition 5.9.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space (SBi-NCTS) and let A be a neutrosophic crisp set. then the union of any neutrosophic crisp a pairwise supra open sets , contained in A is called pairwise neutrosophic crisp supra interior of A ($\text{PNS}^{Bi}\text{int}(\text{A})$). and let A be a neutrosophic crisp set.

$$\text{PNS}^{Bi}\text{int}(\text{A}) = \cup \{B : B \subseteq A \,; B \in \text{PNCSO}(\text{X}, \Gamma_1, \Gamma_2)\}.$$

Theorem 5.10.

Let (X, Γ_1, Γ_2) be a neutrosophic crisp supra bi-topological space, and let A be a neutrosophic crisp set. then :

1. $\text{PNS}^{Bi}\text{int}(\text{A}) \subseteq \text{A}$.
2. $\text{PNS}^{Bi}\text{int}(\text{A})$is pairwise neutrosophic crisp supra open set .

Proof :

1. The proof follows from the definition of $\text{PNS}^{Bi}\text{int}(\text{A})$ as a union of any pairwise neutrosophic crisp supra open sets ,contained in A.
2. The proof follows from Theorem 5.4.

Definition 5.11.

Let (X, Γ_1, Γ_2) be neutrosophic crisp supra bi-topological space (SBi-NCTS) and let A be a neutrosophic crisp set. Then the intersection of any neutrosophic crisp a pairwise supra closed sets , containing A is called pairwise neutrosophic crisp supra closer of A ($\text{PNS}^{Bi}\text{cl}(\text{A})$).

$$\text{PNS}^{Bi}\text{cl}(\text{A}) = \cup \{B : B \supseteq A \,; B \in \text{PNCSC}(\text{X}, \Gamma_1, \Gamma_2)\}.$$

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Theorem 5.12.

Let (X, Γ_1, Γ_2) be neutrosophic crisp supra bi-topological space , A be a neutrosophic crisp set then :

1. $A \subseteq PNS^{Bi}cl(A)$.

2. $PNS^{Bi}cl(A)$ is a pairwise neutrosophic crisp supra closed set.

Proof :

1. The proof follows from the definition of $PNS^{Bi}cl(A)$ as a intersection of any pairwise neutrosophic crisp supra closed set containing in A.

2. The proof follows from remark 5.5.

Remark 5.13.

The following diagram shows the relationship between different types of neutrosophic crisp open sets that were studied in section 3 and section 5.

NCSOS(X,Γ_1) or NCSOS(X,Γ_2) $\Rightarrow$ $\nLeftarrow$ SBi-NCOS(X) $\Rightarrow$ $\nLeftarrow$ PNCOS(X,Γ_1,Γ_2)

6. Conclusion

In this paper, we have defined a new topological space by using neutrosophic crisp sets due to Salama [3]. This new space called neutrosophic crisp supra bi-topological space .Then we have introduced new neutrosophic crisp open(closed) sets in neutrosophic crisp supra bi-topological space Also we studied some of their basic properties and their relationship with each other. We introduced pairwise neutrosophic crisp supra closure, pairwise neutrosophic crisp supra interior, we also have provided examples where such properties fail to be preserved. In addition, Many results have been established. This paper is just the beginning of a new structure, and we have studied a few ideas only, it will be necessary to carry out more theoretical research to establish a general framework for the practical application. In the future, using these notions, various classes of mappings on neutrosophic crisp supra bi-topological space, separation axioms on the neutrosophic crisp supra bi-topological spaces, neutrosophic crisp supra bi-α-open sets, neutrosophic crisp supra bi-β-open sets , neutrosophic crisp supra bi-pre-open sets , Neutrosophic crisp supra bi-semi-open sets and many researchers can be studied.

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References

[1] F. Smarandache, "Neutrosophy / Neutrosophic probability, set, and logic", American Research Press, 1998. See also: http://gallup.unm.edu/~smarandache/NeutLog.txt.

[2] F. Smarandache, "Neutrosophy and Neutrosophic Logic, First International Conference on Neutrosophy, Neutrosophic Logic, Set, Probability, and Statistics" University of New Mexico, Gallup, NM 87301, USA 2002.

[3] A. A Salama, F.Smarandache and Kroumov, "Neutrosophic crisp Sets and Neutrosophic crisp Topological Spaces" Neutrosophic Sets and Systems Vlo.2, pp.25-30, (2014).

[4] S. Mashhour, A. A. Allam, F. S. Mahmoud, and F.H. Khedr, "On Supra topological spaces", Indian Jr.Pure and Appl.Math.No.4, 14, pp.502-510, 1983.

[5] G. Jayaparthasarathy, V. F. Little Flower, M. Arockia Dasan, "Neutrosophic Supra Topological Applications in Data Mining Process", Neutrosophic Sets and Systems,vol. 27, pp.80-97, 2019.

[6] R. K. Al-Hamido, "Neutrosophic Crisp Supra Topological Spaces", Neutrosophic Sets and Systems, Communicated, 2020.

[7] A. B.AL-Nafee, R.K. Al-Hamido, F.Smarandache, "Separation Axioms In Neutrosophic Crisp Topological Spaces", Neutrosophic Sets and Systems, vol. 25, pp.25-32, 2019.

[8] R. Gowri, A. K. R. Rajayal, "On Supra Bi-topological spaces", IOSR Journal of Mathematics (IOSR-JM), Vol 113 .No.5,pp. 55-58, 2017.

[9] J. C. Kelly, "Bi-topological spaces", Proceedings of the London Mathematical Society, vol. No.31,pp. 71-89, 1963.

[10] R. K. Al-Hamido, "A study of multi-Topological Spaces", PhD Theses, AlBaath university , Syria, 2019.

[11] T. Y, Ozturk, A. Ozkan "Neutrosophic Bi-topological Spaces", Neutrosophic Sets and Systems, vol. 30, pp.88-97, 2019.

[12] R.K. Al-Hamido, "Neutrosophic Crisp Bi-Topological Spaces", Neutrosophic Sets and Systems, vol. 21,pp. 66-73, 2018.

[13] W. F. Al- Omeri, "Neutrosophic crisp sets via neutrosophic crisp topological spaces", Neutrosophic Sets and Systems, vol. 13, pp.96–104, 2016.

[14] W. F. Al- Omeri, S. Jafari, "On Generalized Closed Sets and Generalized Pre-Closed Sets in Neutrosophic Topological Spaces", Mathematics,vol. 7, pp.1-12, 2019. doi:doi.org/10.3390/math7010001.

[15] R.K. Al-Hamido, Q. H. Imran, K. A. Alghurabi, T. Gharibah, "On Neutrosophic Crisp Semi Alpha Closed Sets", Neutrosophic Sets and Systems", vol. 21, pp.28-35, 2018.

[16] R.K. Al-Hamido, T. Gharibah, S. Jafari F.Smarandache, "On Neutrosophic Crisp Topology via N-Topology", Neutrosophic Sets and Systems, vol. 21, 96-109, 2018.

[17] Q. H. Imran, F. Smarandache, R.K. Al-Hamido, R. Dhavasselan, "On Neutrosophic Semi Alpha open Sets", Neutrosophic Sets and Systems, vol. 18, pp.37-42, 2017.

DOI: 10.5281/zenodo.3758401

[18] M. Parimala , M. Karthika , F. Smarandache , S. Broumi, "On $\alpha\omega$-closed sets and its connectedness in terms of neutrosophic topological spaces", International Journal of Neutrosophic Science, Vol. 2 ,pp. 82-88 , 2020.

[19] A.A. Salama, S.A. Alblowi, "Neutrosophic Set and Neutrosophic Topological Spaces", IOSR Journal of Mathematics,vol. 3, no. 4, pp.31-35, 2012.

[20] A. A. Salama, "Basic Structure of Some Classes of Neutrosophic Crisp Nearly Open Sets & Possible Application to GIS Topology", Neutrosophic Sets and Systems, vol. 7, pp.18-22, 2015.

[21] S. A. Alblowi, A. A. Salama, M. Eisa, "New concepts of neutrosophic sets", International Journal of Mathematics and Computer Applications Research (IJMCAR),vol 4, pp.59-66, 2014.

[22] I. Hanafy, A. A. Salama, K. Mahfouz, "Correlation of neutrosophic data", International Refereed Journal of Engineering and Science (IRJES), vol. 1, pp.39-43, 2012.

[23] I. M. Hanafy, A. A. Salama and K. M. Mahfouz, "Neutrosophic crisp events and its probability", International Journal of Mathematics and Computer Applications Research (IJMCAR), vol. 3,pp. 171-178, 2013.

[24] A. Salama, "Neutrosophic Crisp Points and Neutrosophic Crisp Ideals", Neutrosophic Sets and Systems, vol. 1, pp.50-54, 2013.

[25] V. Christianto, F. Smarandache , M. Aslam, "How we can extend the standard deviation notion with neutrosophic interval and quadruple neutrosophic numbers", International Journal of Neutrosophic Science, vol. 2, No. 2, pp.72-76 , 2020.

[26] E. O. Adeleke, A. A. A. Agboola , F. Smarandache, "Refined Neutrosophic Rings I ", International Journal of Neutrosophic Science, vol. 2 , No. 2, pp.77-81 , 2020.

[27] E. O. Adeleke , A. A. A. Agboola , F. Smarandache, "Refined Neutrosophic Rings II", International Journal of Neutrosophic Science, vol 2. , No. 2, pp.89-94 , 2020.

[28] M. A. Ibrahim, A. A. A. Agboola , E. O. Adeleke, S. A. Akinleye, "Introduction to Neutrosophic Subtraction Algebra and Neutrosophic Subtraction Semigroup", International Journal of Neutrosophic Science, vol. 2 , No. 1, pp.47-62 , 2020.

[29] S. Broumi, D. Nagarajan, A. Bakali, M. Talea, F. Smarandache, M. Lathamaheswari and J. Kavikumar, "Implementation of Neutrosophic Function Memberships Using MATLAB Program", Neutrosophic Sets and Systems, vol. 27, pp.44-52, 2019. DOI: 10.5281/zenodo.3275355

[30] S. Broumi, M. Talea, A. Bakali, F. Smarandache, D. Nagarajan, M. Lathamaheswari and M. Parimala, "Shortest path problem in fuzzy, intuitionistic fuzzy and neutrosophic environment: an overview", Complex & Intelligent Systems, vol. 5, pp.371–378, 2019.https://doi.org/10.1007/s40747-019-0098-z

[31] S. Broumi, D. Nagarajan, A. Bakali, M. Talea, F. Smarandache, M. Lathamaheswari", The shortest path problem in interval valued trapezoidal and triangular neutrosophic environment", Complex & Intelligent Systems, 5, pp.391–402, 2019. https://doi.org/10.1007/s40747-019-0092-5.

DOI: 10.5281/zenodo.3758401