On NeutroBitopological Space

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Abstract

The current study shows the study of NeutroBitopological Space. In this work, the properties of NeutroBitopological Space are discussed. It is seen that many properties do not coincide with the properties of general Bitopological space. The terms NeutroInterior, NeutroClosure, and NeutroBoundary are defined with examples also their properties are observed.

Keywords: NeutroInterior, NeutroClosure, NeutroBoundary, NeutroBitopological Space.

1.Introduction

Smarandache [1, 2] proposed the neutrosophic set (NS), and after that many researchers applied it in science & technology. In recent years, there has been a surge in academic interest in neutrosophic set theory. Florentin Smarandache first defined the idea of neutro-structures and anti-structures [3, 4]. Neutrosophication of an axiom on a given set X means dividing the set X into three regions, one in which the axiom is true (we call this the degree of truth T of the axiom), one in which the axiom is indeterminate (we call this the degree of indeterminacy I of the axiom), and one in which the axiom is false (we call this the degree of indeterminacy I of the axiom (we say the degree of falsehood F of the axiom). On, the other hand Antisophication of an axiom on a given set X means to have the axiom false on the whole set X. Without using neutrosophic sets and neutrosophic numbers, the structure of neutrosophic logic has been transferred to the structure of classical algebras. MemetŞahin et al. [8] studied NeutroTopological Space (NTS) and Anti-Topological Space. Smarandache [7] studied neutroAlgebra as a generalization of partial algebra. Many researchers [11-15] studied neutroAlgebra. Basumataryet al. [21] studied some properties of NTS.

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In this paper, NeutroBitopological Space is studied based on NeutroInterior, NeutroClosure, and NeutroBoundary, also its properties are learned with examples.

2. Preliminaires

Definition 2.1: [7]

TheNeutro-sophication of the Law

(i) Let X be a non-empty set and $*$ be binary operation. For some elements $(a, b) \in (X, X)$, $(a * b) \in X$ (degree of well defined (T)) and for other elements $(x, y), (p, q) \in (X, X)$; $[x * y$ is indeterminate (degree of indeterminacy (I)), or $p * q \notin X$ (degree of outer-defined (F)], where (T,I,F) is different from (1,0,0) that represents the Classical Law, and from (0,0,1) that represents the AntiLaw.

(ii) In NeutroAlgebra, the classical well-defined for $*$ binary operation is divided into three regions: degree of well-defined (T), degree of indeterminacy (I) and degree of outer-defined (F) similar to neutrosophic set and neutrosophic logic

Definition 2.2: [8]

Let X be a non-empty set, $\mathfrak{I}$ be a collection of subsets of X. If at least one of the following conditions {i, ii, iii} is satisfied, then $\mathfrak{I}$ is called a NeutroTopology on X and (X, $\mathfrak{I}$) is called a **NTS**.

(i) $[\emptyset \in \mathfrak{I}, X \notin \mathfrak{I}$ or $X \in \mathfrak{I}, \emptyset \notin \mathfrak{I}]$ or $[\emptyset, X \in_1 \mathfrak{I}]$

(ii) For at least n elements $p_1, p_2, \ldots, p_n \in \mathfrak{I}$, $\cap_{i=1}^{n} p_i \in \mathfrak{I}$ and for at least n elements $q_1, q_2, \ldots, q_n \in \mathfrak{I}$, $r_1, r_2, \ldots, r_n \in \mathfrak{I}$; $[\cap_{i=1}^{n} q_i \notin \mathfrak{I}$ or $\cap_{i=1}^{n} r_i \in_1 \mathfrak{I}]$. Where n is finite.

(iii) For at least n elements $p_1, p_2, \ldots, p_n \in \mathfrak{I}$, $\cup_{i \in I} p_i \in \mathfrak{I}$ and for at least n elements$q_1, q_2, \ldots, q_n \in \mathfrak{I}$, $r_1, r_2, \ldots, r_n \in \mathfrak{I}$; $[\cup_{i \in I} q_i \notin \mathfrak{I}$ or $\cup_{i \in I} r_i \in_1 \mathfrak{I}]$.

Definition 2.3: [21]

Let (X, τ) be a NTS over X and A is subset on X. Then, the NeutroInterior of A is the union of all NeutroOpen subsets of A. Clearly, NeutroInterior of A is the biggest NeutroOpen set over X which is contained in A.

Definition 2.4:[21]

Let (X, τ) be a NTS over X and A is subset on X. Then, the NeutroClosure of A is the intersection of all NeutroClosed super sets of A. Clearly, NeutroClosure of A is the smallest NeutroClosed set over X conatining A.

3. Results

Definition 3.1.

Let X be a non-empty set endowed with two NeutroTopologies T_1andT_2. Then (X, T_1, T_2) is called a NeutroBitopological space (NBS). In this entire paper, we expressed (X, T_1, T_2) with $\mathfrak{I}$.

Example 3.1.

Let $X = \{1,2,3,4\}, T_1 = \{\emptyset, \{3\}, \{1,4\}, \{1,2,3\}\}$ and $T_2 = \{\emptyset, \{4\}, \{1,2\}, \{2,3\}, \{1,2,3\}\}$

For T_1: $i)$ $\emptyset \in T_1, X \notin T_1$

$ii)$ $\{3\} \cap \{1,2,3\} = \{3\} \in T_1; \{3\} \cap \{1,4\} = \emptyset \in T_1but\{1,4\} \cap \{1,2,3\} = \{1\} \notin T_1$

$iii)$ $\{3\} \cup \{1,2,3\} = \{1,2,3\} \in T_1$but $\{3\} \cup \{1,4\} = \{1,3,4\} \notin T_1$

For T_2: $i)$ $\emptyset \in T_2, X \notin T_2$

$ii)$ $\{4\} \cap \{1,2\} = \emptyset \in T_2;$ but$\{1,2\} \cap \{2,3\} = \{2\} \notin T_2$

$iii)$ $\{1,2\} \cup \{2,3\} = \{1,2,3\} \in T_2$ but $\{4\} \cup \{1,2\} = \{1,2,4\} \notin T_2$.

Thus, it can be observed that $T_1$and T_2 are both NeutroTopologies on X. Therefore, (X, T_1, T_2) is a NeutroBitopological space. It may be noted that a NeutroBitopological (X, T_1, T_2) is not a general bitopological

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space (GBS) because T_1andT_2 are not topologies on X. Thus, a NBS is a different thing altogether and it will be seen that a NBS can be derived from any GBS. It can be seen from the following two theorems.

Proposition3.1.
If $\mathfrak{I}$ be a GBS then $(X, T_1 - \emptyset, T_2 - \emptyset)$ be a NBS.
Proof: Since the empty set is excluded from the two topologies, they are no longer general topologies but NTSs.

Proposition 3.2.
If $\mathfrak{I}$ be a GBS then $(X, T_1 - X, T_2 - X)$ be a NBS.
Proof: Since the whole set is excluded from the two topologies, they are no longer general topologies but NTSs and hence the proved.

Definition 3.2.
Let $\mathfrak{I}$ be a NBS, then the NeutroInterior of a subset A of X is defined as:

$$T_1T_2 - \text{Neu}Int(A) = T_1 - \text{Neu}Int\big(T_2 - \text{Neu}Int(A)\big).$$

Example 3.2.
Let $X = \{a, b, c, d\}$, $T_1 = \big\{\emptyset, \{a, b\}, \{c, d\}\big\}andT_2 = \big\{\emptyset, \{b\}, \{a, b\}, \{b, c\}, \{c, d\}\big\}$. Then, clearly $T_1$and T_2 are NTSs on X. So, (X, T_1, T_2) is a NBS.
Let $A = \{b, c, d\}$. Then we have, $T_1T_2 - \text{Neu}Int(A) = T_1 - \text{Neu}Int\big(T_2 - \text{Neu}Int(A)\big)$

$$= T_1 - \text{Neu}Int\big(T_2 - \text{Neu}Int(\{b, c, d\})\big)$$
$$= T_1 - \text{Neu}Int(\{b\} \cup \{b, c\} \cup \{c, d\})$$
$$= T_1 - \text{Neu}Int\{b, c, d\}$$
$$= \{c, d\}.$$

Proposition 3.3.
Let $\mathfrak{I}$ be a NBS, then $T_1T_2 - \text{Neu}Int(A) \subseteq A$.
Proof: Let $x \in T_1T_2 - \text{Neu}Int(A)$
$\Longrightarrow x \in T_1 - \text{Neu}Int(T_2 - \text{Neu}Int(A))$
$\Longrightarrow x \in T_1 - \text{Neu}Int(B)$ where, $B = T_2 - \text{Neu}Int(A) \subseteq A$
$\Longrightarrow x \in B \subseteq A$
$\Longrightarrow x \in A$
Hence, $T_1T_2 - \text{Neu}Int(A) \subseteq A$.
But the converse is not true as shown in the example below:
Example 3.3.
Let $X = \{1,2,3\}$, $T_1 = \{\emptyset, \{2\}, \{1,2\}, \{1,3\}\}$and $T_2 = \big\{\emptyset, \{1\}, \{1,3\}, \{2,3\}\big\}$. Then, (X, T_1, T_2) is aNBS. Let, $A = \{2,3\}$.
Then, we have $T_1T_2 - \text{Neu}Int(A) = T_1 - \text{Neu}Int\big(T_2 - \text{Neu}Int(\{2,3\})\big) = T_1 - \text{Neu}Int(\{2,3\}) = \{2\}$
This shows that $T_1T_2 - \text{Neu}Int(A) \subseteq A$ but $A \nsubseteq T_1T_2 - \text{Neu}Int(A)$.
So, $T_1T_2 - \text{Neu}Int(A) \neq A$.

Proposition3.4.
Let $\mathfrak{I}$ be a NBS, and $A \subseteq B$, then $T_1T_2 - \text{Neu}Int(A) \subseteq T_1T_2 - \text{Neu}Int(B)$.
Proof: Let $x \in T_1T_2 - \text{Neu}Int(A)$
$\Longrightarrow x \in T_1 - \text{Neu}Int(T_2 - \text{Neu}Int(A))$
$\Longrightarrow x \in T_1 - \text{Neu}Int(T_2 - \text{Neu}Int(B))$ since $A \subseteq B$
$\Longrightarrow x \in T_1T_2 - \text{Neu}Int(B)$
Hence, $x \in T_1T_2 - \text{Neu}Int(A) \Rightarrow x \in T_1T_2 - \text{Neu}Int(B)$.

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Proposition3.5.
Let $\Im$ be a NBS, then $T_1T_2-\text{Neu}Int(A\cap B)\subseteq T_1T_2-\text{Neu}Int(A)\cap T_1T_2-\text{Neu}Int(B)$.

Proposition3.6.
Let $\Im$ be a NBS, then $T_1T_2-\text{Neu}Int(A)\cup T_1T_2-\text{Neu}Int(B)\subseteq T_1T_2-\text{Neu}Int(A\cup B)$
Proof: We have $A\subseteq A\cup B\Longrightarrow T_1T_2-\text{Neu}Int(A)\subseteq T_1T_2-\text{Neu}Int(A\cup B)$.
Also, $B\subseteq A\cup B\Longrightarrow T_1T_2-\text{Neu}Int(B)\subseteq T_1T_2-\text{Neu}Int(A\cup B)$
Therefore, $T_1T_2-\text{Neu}Int(A)\cup T_1T_2-\text{Neu}Int(B)\subseteq T_1T_2-\text{Neu}Int(A\cup B)$.

Remark 3.1.
Let $\Im$ be a NBS, then $T_1T_2-\text{Neu}Int(A)\neq T_2T_1-\text{Neu}Int(A)$.

Example 3.4.
Let $X=\{1,2,3,4\}$, $T_1=\{\emptyset,\{1\},\{1,2\},\{2,3\},\{1,2,4\}\}$ and $T_2=\{\emptyset,\{2\},\{1,3\},\{2,3\},\{2,4\},\{1,2,3\}\}$. Let $A=\{1,2\}$.
Then, $T_1T_2-\text{Neu}Int(A)=T_1-\text{Neu}Int(T_2-\text{Neu}Int(A))$
$=T_1-\text{Neu}Int(T_2-\text{Neu}Int(\{1,2\})=T_1-\text{Neu}Int(\{2\})\ =\emptyset$.
And,$T_2T_1-Int(A)=T_2-\text{Neu}Int(T_1-\text{Neu}Int(A))=T_2-\text{Neu}Int(T_1-\text{Neu}Int(\{1,2\})$
$=T_2-\text{Neu}Int(\{1,2\})\ =\{2\}$
Therefore, $T_1T_2-\text{Neu}Int(A)\neq T_2T_1-\text{Neu}Int(A)$.

Remark 3.2.
Let $\Im$ be a NBS, then $T_1T_2-\text{Neu}Int(A)=T_2T_1-\text{Neu}Int(A)$if $T_1=T_2$.

Remark3.3.
Let $\Im$ be a NBS, then$T_1T_2-\text{Neu}Int\big(T_1T_2-\text{Neu}Int(A)\big)\neq T_1T_1-\text{Neu}Int(A)$.

Example 3.5.
Let $X=\{1,2,3,4\}$, $T_1=\{\emptyset,\{2\},\{1,3\},\{2,3\},\{2,4\},\{1,2,3\}\}$and $T_2=\{\emptyset,\{1\},\{1,2\},\{2,3\},\{1,2,4\}\}$.
Let $A=\{1,2\}$.
Then, $T_1T_2-\text{Neu}Int(A)=T_1-\text{Neu}Int(T_2-\text{Neu}Int(A))$
$=T_1-\text{Neu}Int(T_2-\text{Neu}Int(\{1,2\})=T_1-\text{Neu}Int(\{1,2\})\ =\{2\}$
Now, $T_1T_2-\text{Neu}Int\big(T_1T_2-\text{Neu}Int(A)\big)=T_1T_2-\text{Neu}Int(\{2\})$
$=T_1-\text{Neu}Int(T_2-\text{Neu}Int(\{2\})=T_1-\text{Neu}Int(\emptyset)=\emptyset$.

Remark 3.4.
Let $\Im$ be a NBS, then $T_1T_2-\text{Neu}Int\big(T_1T_2-\text{Neu}Int(A)\big)=T_1T_2-\text{Neu}Int(A)$if $T_1=T_2$.

Definition 3.3.
Let $\Im$ be a NBS and $A\subset X$. The intersection of all $T_1T_2-Neutro$Closed supersets of A is called the $T_1T_2-Neutro$Closure of A and denoted by $T_1T_2-\text{Neu}Cl(A)$ and will be evaluated as $T_1-\text{Neu}Cl\big(T_2-\text{Neu}Cl(A)\big)$.

Remark 3.5.
Let $\Im$ be a NBSand $A\subset X$. Then, $T_1T_2-\text{Neu}Cl(A)\neq T_2T_1-\text{Neu}Cl(A)$.

Example 3.6.
Let $X=\{1,2,3,4\}$, $T_1=\{\emptyset,\{1\},\{1,2\},\{1,3\},\{1,2,4\}\}$ and $T_2=\{\emptyset,\{2\},\{2,3\},\{3,4\},\{1,2,3\}\}$.
The $T_1-Neutro$Closed sets are: $X,\{2,3,4\},\{3,4\},\{2,4\},\{3\}$
And, the $T_2-Neutro$Closed sets are: $X,\{1,3,4\},\{1,4\},\{1,2\},\{4\}\}$

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Let $A = \{3,4\}$.
Then, $T_1T_2 - \text{Neu}Cl(A) = T_1 - \text{Neu}Cl\big(T_2 - \text{Neu}Cl(A)\big) = T_1 - \text{Neu}Cl\big(T_2 - \text{Neu}Cl(\{3,4\})\big) = T_1 - \text{Neu}Cl(\{1,3,4\}) = X$
And, $T_2T_1 - \text{Neu}Cl(A) = T_2 - \text{Neu}Cl\big(T_1 - \text{Neu}Cl(\{3,4\})\big) = T_2 - \text{Neu}Cl(\{2,3,4\} \cap \{3,4\}) = T_2 - \text{Neu}Cl(\{3,4\}) = \{1,3,4\} \neq X$
Therefore, $T_1T_2 - \text{Neu}Cl(A) \neq T_2T_1 - \text{Neu}Cl(A)$.

Proposition 3.7.
Let $\Im$ be a NBS and $A \subset X$. If A is $T_1T_2 - NeutroC$losed set, then $A \subset T_1T_2 - \text{Neu}Cl(A)$.
Proof: From the definition of $T_1T_2 - \text{Neu}Cl(A)$ it is clear that $A \subset T_1T_2 - \text{Neu}Cl(A)$ since $T_1T_2 - \text{Neu}Cl(A)$ is the intersection of all supersets of A, which will obviously contain A.

Proposition 3.8.
If $A \subset B$, then $T_1T_2 - \text{Neu}Cl(A) \subset T_1T_2 - \text{Neu}Cl(B)$.
Proof: By Proposition 3.7, $B \subset T_1T_2 - \text{Neu}Cl(B)$ and $A \subset B$, so $A \subset T_1T_2 - \text{Neu}Cl(B)$ which gives $T_1T_2 - \text{Neu}Cl(A) \subset T_1T_2 - \text{Neu}Cl(B)$.

Proposition 3.9.
Let $\Im$ be a NBS and $A, B \subset X$. Then $T_1T_2 - \text{Neu}Cl(A \cup B) \subset T_1T_2 - \text{Neu}Cl(A) \cup T_1T_2 - \text{Neu}Cl(B)$.

Proposition 3.10.
Let $\Im$ be a NBS and $A, B \subset X$. Then $T_1T_2 - \text{Neu}Cl(A \cap B) \subset T_1T_2 - \text{Neu}Cl(A) \cap T_1T_2 - \text{Neu}Cl(B)$.
Proof: We have: $A \cap B \subset A \text{ and } A \cap B \subset B$
Therefore, $T_1T_2 - \text{Neu}Cl(A \cap B) \subset T_1T_2 - \text{Neu}Cl(A)$ and $T_1T_2 - \text{Neu}Cl(A \cap B) \subset T_1T_2 - \text{Neu}Cl(B)$
Hence, $T_1T_2 - \text{Neu}Cl(A \cap B) \subset T_1T_2 - \text{Neu}Cl(A) \cap T_1T_2 - \text{Neu}Cl(B)$.

Proposition 3.11.
Let $\Im$ be a NBS and $A \subset X$. Then $T_1T_2 - \text{Neu}Cl\big(T_1T_2 - \text{Neu}Cl(A)\big) = T_1T_2 - \text{Neu}Cl(A)$ if A is $T_1T_2 - NeutroC$losed.
Proof: If A is $T_1T_2 - NeutroC$losed, then A is the smallest $NeutroC$losed set containing A, so $T_1T_2 - \text{NeuCl(A)} = \text{A}$.
Therefore, $T_1T_2 - \text{Neu}Cl\big(T_1T_2 - \text{Neu}Cl(A)\big) = T_1T_2 - \text{Neu}Cl(A)$.

Proposition 3.12.
Let $\Im$ be a NBS and $A \subset X$, then the NeutoInterior of A is equal to the complement of the NeutroClosureof the complement of A.

Proposition 3.13.
Let $\Im$ be a NBSand $A \subset X$, then the NeutroClosure of the complement of A is not equal to the complement of the NeutroInterior of A.

Proposition 3.14.
Let $\Im$ be a NBS and $A \subset X$, then the NeutroClosure of A is equal to the complement of the NeutroInterior of the complement of A.

Definition 3.4.
Let $\Im$ be a NBS and $A \subset X$. A point and $x \in X$ is said to be $T_1T_2 - NeutotroExterior$ of Aif $x \in T_1T_2 - \text{Neu}Int(A^c)$.

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Definition 3.5.

Let $\Im$ be a NBS and $A \subset X$. A point and $x \in X$ is said to be a $T_1T_2 - NeutroBoundary$ point if it is neither an $T_1T_2 - NeutroInterior$ nor $T_1T_2 - NeutroExterior$ point of A.

We define $T_1T_2 - \text{Neu}Bd(A) = T_1T_2 - \text{Neu}Cl(A) \cap T_1T_2 - \text{Neu}Cl(A^c)$.

Proposition 3.15.

Let $\Im$ be a NBS with $T_1 = T_2$and $A, B \subset X$. Then the following results are found:

(i) $T_1T_2 - \text{Neu}Bd\left(T_1T_2 - \text{Neu}Int(A)\right) \subseteq T_1T_2 - \text{Neu}Bd(A)$

(ii) $T_1T_2 - \text{Neu}Bd\left(T_1T_2 - \text{Neu}Cl(A)\right) \subseteq T_1T_2 - \text{Neu}Bd(A)$

(iii) $T_1T_2 - \text{Neu}Bd(A \cup B) \subseteq T_1T_2 - \text{Neu}Bd(A) \cup T_1T_2 - \text{Neu}Bd(B)$

(iv) $T_1T_2 - \text{Neu}Bd(A \cap B) \subseteq T_1T_2 - \text{Neu}Bd(A) \cup T_1T_2 - \text{Neu}Bd(B)$.

Remark 3.6.

If $T_1 \neq T_2$,then the **proposition 3.15** is not true that is for $A, B \subset X$, the following results are found:

(i) $T_1T_2 - \text{Neu}Bd\left(T_1T_2 - \text{Neu}Int(A)\right) \nsubseteq T_1T_2 - \text{Neu}Bd(A)$

(ii) $T_1T_2 - \text{Neu}Bd\left(T_1T_2 - \text{Neu}Cl(A)\right) \nsubseteq T_1T_2 - \text{Neu}Bd(A)$

(iii) $T_1T_2 - \text{Neu}Bd(A \cup B) \nsubseteq T_1T_2 - \text{Neu}Bd(A) \cup T_1T_2 - \text{Neu}Bd(B)$

(iv) $T_1T_2 - \text{Neu}Bd(A \cap B) \nsubseteq T_1T_2 - \text{Neu}Bd(A) \cup T_1T_2 - \text{Neu}Bd(B)$

For this we cite the following examples

(i) **Example 3.7.**

Let $X = \{a, b, c, d\}$, $T_1 = \{\emptyset, \{a\}, \{c\}, \{a, b\}, \{b, c\}, \{a, b, d\}\}$and $T_2 = \{\emptyset, \{b\}, \{d\}, \{c, d\}, \{a, d\}, \{a, b, c\}\}$

$T_1 - NeutroClosed$ sets are: $X, \{b, c, d\}, \{a, b, d\}, \{c, d\}, \{a, d\}, \{c\}$ and

$T_2 - NeutroClosed$ sets are are: $X, \{a, c, d\}, \{a, b, c\}, \{a, b\}, \{b, c\}, \{d\}$

Let $A = \{a, d\}$, $A^C = \{b, c\}$.

Now $T_1T_2 - \text{Neu}Int(A) = \{a\} = B(say)$.

Now $T_1T_2 - \text{Neu}Cl(B) = \{a, d\}$and $T_1T_2 - \text{Neu}Cl(B^C) = X$. Therefore, $T_1T_2 - \text{Neu}Bd(B) = \{a, d\}$.

Again $T_1T_2 - \text{Neu}Cl(A) = X$ and $T_1T_2 - \text{Neu}Cl(A^C) = \{b, c, d\}$, and $T_1T_2 - \text{Neu}Bd(B) = \{b, c, d\}$

Hence $T_1T_2 - \text{Neu}Bd\left(T_1T_2 - \text{Neu}Int(A)\right) \nsubseteq T_1T_2 - \text{Neu}Bd(A)$.

Similarly, other properties of Remark 3.6 can be shown.

5. Conclusions

In this work, NeutroBitological space is studied. The terms NeutroInterior, NeutroClosureand NeutroBoundary are defined. It is seen that some properties of NBS are not the same as the properties of GBS. For this, we have cited examples. We hope, this work can lead towards the development of many properties of NeutroBitological space.

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