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On Neutrosophic Semi-Supra Open Set and Neutrosophic Semi-Supra Continuous Functions

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Abstract: In this paper, we introduce and investigate a new class of sets and functions between topological space called neutrosophic semi-supra open set and neutrosophic semi-supra open continuous functions respectively.

Keywords: Supra topological spaces; neutrosophic supra-topological spaces; neutrosophic semi-supra open set.

1 Introduction and Preliminaries

Intuitionistic fuzzy set is defined by Atanassov [2] as a generalization of the concept of fuzzy set given by Zadesh [14]. Using the notation of intuitionistic fuzzy sets, Coker [3] introduced the notion of an intuitionistic fuzzy topological space. The supra topological spaces and studied s-continuous functions and s^*-continuous functions were introduced by A. S. Mashhour [6] in 1993. In 1987, M. E. Abd El-Monsef et al. [1] introduced the fuzzy supra topological spaces and studied fuzzy supra continuous functions and obtained some properties and characterizations. In 1996, Keun Min [13] introduced fuzzy s-continuous, fuzzy s-open and fuzzy s-closed maps and established a number of characterizations. In 2008, R. Devi et al. [4] introduced the concept of supra α-open set, and in 1983, A. S. Mashhour et al. introduced the notion of supra-semi open set, supra semi-continuous functions and studied some of the basic properties for this class of functions. In 1999, Necla Turan [11] introduced the concept of intuitionistic fuzzy supra topological space. The concept of intuitionistic fuzzy semi-supra open set was introduced by Parimala and Indirani [7]. After the introduction of the concepts of neutrosophy and a neutrosophic se by F. Smarandache [[9], [10]], A. A. Salama and S. A. Alblowi[8] introduced the concepts of neutrosophic crisp set and neutrosophic topological spaces.

The purpose of this paper is to introduce and investigate a new class of sets and functions between topological space called neutrosophic semi-supra open set and neutrosophic semi-supra open continuous functions, respectively.

Definition 1.1. Let T, I, F be real standard or non standard subsets of $]0^-, 1^+[$, with $sup_T = t_{sup}, inf_T = t_{inf}$
$sup_I = i_{sup}, inf_I = i_{inf}$
$sup_F = f_{sup}, inf_F = f_{inf}$
$n-sup = t_{sup} + i_{sup} + f_{sup}$
$n-inf = t_{inf} + i_{inf} + f_{inf}$. T, I, F are neutrosophic components.

Definition 1.2. Let X be a nonempty fixed set. A neutrosophic set [briefly NS] A is an object having the form $A = \{\langle x, \mu_A(x), \sigma_A(x), \gamma_A(x)\rangle : x \in X\}$, where $\mu_A(x), \sigma_A(x)$ and $\gamma_A(x)$ represent the degree of membership function (namely $\mu_A(x)$), the degree of indeterminacy (namely $\sigma_A(x)$) and the degree of nonmembership (namely $\gamma_A(x)$) respectively of each element $x \in X$ to the set A.

Remark 1.1. (1) A neutrosophic set $A = \{\langle x, \mu_A(x), \sigma_A(x), \gamma_A(x)\rangle : x \in X\}$ can be identified to an ordered triple $\langle \mu_A, \sigma_A, \gamma_A\rangle$ in $]0^-, 1^+[$ on X.

(2) For the sake of simplicity, we shall use the symbol $A = \langle \mu_A, \sigma_A, \gamma_A\rangle$ for the neutrosophic set $A = \{\langle x, \mu_A(x), \sigma_A(x), \gamma_A(x)\rangle : x \in X\}$.

Definition 1.3. Let X be a nonempty set and the neutrosophic sets A and B in the form
$A = \{\langle x, \mu_A(x), \sigma_A(x), \gamma_A(x)\rangle : x \in X\}$, $B = \{\langle x, \mu_B(x), \sigma_B(x), \gamma_B(x)\rangle : x \in X\}$. Then

(a) $A \subseteq B$ iff $\mu_A(x) \leq \mu_B(x)$, $\sigma_A(x) \leq \sigma_B(x)$ and $\gamma_A(x) \geq \gamma_B(x)$ for all $x \in X$;

(b) $A = B$ iff $A \subseteq B$ and $B \subseteq A$;

(c) $\bar{A} = \{\langle x, \gamma_A(x), \sigma_A(x), \mu_A(x)\rangle : x \in X\}$; [Complement of A]

(d) $A \cap B = \{\langle x, \mu_A(x) \wedge \mu_B(x), \sigma_A(x) \wedge \sigma_B(x), \gamma_A(x) \vee \gamma_B(x)\rangle : x \in X\}$;

(e) $A \cup B = \{\langle x, \mu_A(x) \vee \mu_B(x), \sigma_A(x) \vee \sigma_B(x), \gamma_A(x) \wedge \gamma_B(x)\rangle : x \in X\}$;

(f) $[\,]A = \{\langle x, \mu_A(x), \sigma_A(x), 1 - \mu_A(x)\rangle : x \in X\}$;

(g) $\langle\rangle A = \{\langle x, 1 - \gamma_A(x), \sigma_A(x), \gamma_A(x)\rangle : x \in X\}$.

Definition 1.4. Let $\{A_i : i \in J\}$ be an arbitrary family of neutrosophic sets in X. Then

(a) $\bigcap A_i = \{\langle x, \wedge\mu_{A_i}(x), \wedge\sigma_{A_i}(x), \vee\gamma_{A_i}(x)\rangle : x \in X\}$;

(b) $\bigcup A_i = \{\langle x, \vee\mu_{A_i}(x), \vee\sigma_{A_i}(x), \wedge\gamma_{A_i}(x)\rangle : x \in X\}$.

Since our main purpose is to construct the tools for developing neutrosophic topological spaces, we must introduce the neutrosophic sets 0_N and 1_N in X as follows:

Definition 1.5. $0_N = \{\langle x, 0, 0, 1\rangle : x \in X\}$ and $1_N = \{\langle x, 1, 1, 0\rangle : x \in X\}$.

Definition 1.6. [5] A neutrosophic topology (NT) on a nonempty set X is a family T of neutrosophic sets in X satisfying the following axioms:

(i) $0_N, 1_N \in T$,

(ii) $G_1 \cap G_2 \in T$ for any $G_1, G_2 \in T$,

(iii) $\cup G_i \in T$ for arbitrary family $\{G_i \mid i \in \Lambda\} \subseteq T$.

In this case the ordered pair (X, T) or simply X is called a neutrosophic topological space (NTS) and each neutrosophic set in T is called a neutrosophic open set (NOS). The complement $\overline{A}$ of a NOS A in X is called a neutrosophic closed set (NCS) in X.

Definition 1.7. [5] Let A be a neutrosophic set in a neutrosophic topological space X. Then

$Nint(A) = \bigcup\{G \mid G$ is a neutrosophic open set in X and $G \subseteq A\}$ is called the neutrosophic interior of A;

$Ncl(A) = \bigcap\{G \mid G$ is a neutrosophic closed set in X and $G \supseteq A\}$ is called the neutrosophic closure of A.

Definition 1.8. Let X be a nonempty set. If r, t, s be real standard or non standard subsets of $]0^-, 1^+[$, then the neutrosophic set $x_{r,t,s}$ is called a neutrosophic point(in short NP)in X given by

$$x_{r,t,s}(x_p) = \begin{cases} (r, t, s), & \text{if } x = x_p \\ (0, 0, 1), & \text{if } x \neq x_p \end{cases}$$

for $x_p \in X$ is called the support of $x_{r,t,s}$, where r denotes the degree of membership value ,t denotes the degree of indeterminacy and s is the degree of non-membership value of $x_{r,t,s}$.

Now we shall define the image and preimage of neutrosophic sets. Let X and Y be two nonempty sets and $f : X \to Y$ be a function.

Definition 1.9. [5]

(a) If $B = \{\langle y, \mu_B(y), \sigma_B(y), \gamma_B(y)\rangle : y \in Y\}$ is a neutrosophic set in Y, then the preimage of B under f, denoted by $f^{-1}(B)$, is the neutrosophic set in X defined by
$f^{-1}(B) = \{\langle x, f^{-1}(\mu_B)(x), f^{-1}(\sigma_B)(x), f^{-1}(\gamma_B)(x)\rangle : x \in X\}$.

(b) If $A = \{\langle x, \mu_A(x), \sigma_A(x), \gamma_A(x)\rangle : x \in X\}$ is a neutrosophic set in X, then the image of A under f, denoted by $f(A)$, is the neutrosophic set in Y defined by
$f(A) = \{\langle y, f(\mu_A)(y), f(\sigma_A)(y), (1 - f(1 - \gamma_A))(y)\rangle : y \in Y\}$. where

$$f(\mu_A)(y) = \begin{cases} \sup_{x \in f^{-1}(y)} \mu_A(x), & \text{if } f^{-1}(y) \neq \emptyset, \\ 0, & \text{otherwise,} \end{cases}$$

$$f(\sigma_A)(y) = \begin{cases} \sup_{x \in f^{-1}(y)} \sigma_A(x), & \text{if } f^{-1}(y) \neq \emptyset, \\ 0, & \text{otherwise,} \end{cases}$$

$$(1 - f(1 - \gamma_A))(y) = \begin{cases} \inf_{x \in f^{-1}(y)} \gamma_A(x), & \text{if } f^{-1}(y) \neq \emptyset, \\ 1, & \text{otherwise,} \end{cases}$$

For the sake of simplicity, let us use the symbol $f_-(\gamma_A)$ for $1 - f(1 - \gamma_A)$.

Corollary 1.1. [5] Let A , $A_i (i \in J)$ be neutrosophic sets in X, B, $B_i (i \in K)$ be neutrosophic sets in Y and $f : X \to Y$ a function. Then

(a) $A_1 \subseteq A_2 \Rightarrow f(A_1) \subseteq f(A_2)$,

(b) $B_1 \subseteq B_2 \Rightarrow f^{-1}(B_1) \subseteq f^{-1}(B_2)$,

(c) $A \subseteq f^{-1}(f(A))$ { If f is injective,then $A = f^{-1}(f(A))$ } ,

(d) $f(f^{-1}(B)) \subseteq B$ { If f is surjective,then $f(f^{-1}(B)) = B$ },

(e) $f^{-1}(\bigcup B_j) = \bigcup f^{-1}(B_j)$,

(f) $f^{-1}(\bigcap B_j) = \bigcap f^{-1}(B_j)$,

(g) $f(\bigcup A_i) = \bigcup f(A_i)$,

(h) $f(\bigcap A_i) \subseteq \bigcap f(A_i)$ { If f is injective,then $f(\bigcap A_i) = \bigcap f(A_i)$},

(i) $f^{-1}(1_N) = 1_N$,

(j) $f^{-1}(0_N) = 0_N$,

(k) $f(1_N) = 1_N$, if f is surjective

(l) $f(0_N) = 0_N$,

(m) $\overline{f(A)} \subseteq f(\overline{A})$, if f is surjective,

(n) $f^{-1}(\overline{B}) = \overline{f^{-1}(B)}$.

2 Main Results

Definition 2.1. A neutrosophic set A in a neutrosophic topological space (X, T) is called

1) a neutrosophic semiopen set (NSOS) if $A \subseteq Ncl(Nint(A))$.

2) a neutrosophic α open set $(N\alpha OS)$ if $A \subseteq Nint(Ncl(Nint(A)))$.

3) a neutrosophic preopen set (NPOS) if $A \subseteq Nint(Ncl(A))$.

4) a neutrosophic regular open set (NROS) if $A = Nint(Ncl(A))$.

5) a neutrosophic semipre open or β open set $(N\beta OS)$ if $A \subseteq Ncl(Nint(Ncl(A)))$.

A neutrosophic set A is called a neutrosophic semiclosed set, neutrosophic α closed set, neutrosophic preclosed set, neutrosophic regular closed set and neutrosophic β closed set, respectively (NSCS, NαCS, NPCS, NRCS and NβCS, resp), if the complement of A is a neutrosophic semiopen set, neutrosophic α-open set, neutrosophic preopen set, neutrosophic regular open set, and neutrosophic β-open set, respectively.

Definition 2.2. Let (X, T) ba a neutrosophic topological space. A neutrosophic set A is called a neutrosophic semi-supra open set (briefly NSSOS) if $A \subseteq s\text{-}Ncl(s\text{-}Nint(A))$. The complement of a neutrosophic semi-supra open set is called a neutrosophic semi-supra closed set.

Proposition 2.1. Every neutrosophic supra open set is neutrosophic semi-supra open set.

Proof. Let A be a neutrosophic supra open set in (X, T). Since $A \subseteq s\text{-}Ncl(A)$, we get $A \subseteq s\text{-}Ncl(s\text{-}Nint(A))$. Then $s\text{-}Nint(A) \subseteq s\text{-}Ncl(s\text{-}Nint(A))$. Hence $A \subseteq s\text{-}Ncl(s\text{-}Nint(A))$. □

The converse of Proposition 2.1., need not be true as shown in Example 2.1.

Example 2.1. Let $X = \{a, b\}$. Define the neutrosophic sets A, B and C in X as follows:
$A = \langle x, (\frac{a}{0.2}, \frac{b}{0.4}), (\frac{a}{0.2}, \frac{b}{0.4}), (\frac{a}{0.5}, \frac{b}{0.6}) \rangle$, $B = \langle x, (\frac{a}{0.6}, \frac{b}{0.2}), (\frac{a}{0.6}, \frac{b}{0.2}), (\frac{a}{0.3}, \frac{b}{0.4}) \rangle$
and $C = \langle x, (\frac{a}{0.3}, \frac{b}{0.4}), (\frac{a}{0.3}, \frac{b}{0.4}), (\frac{a}{0.4}, \frac{b}{0.4}) \rangle$. Then the families $T = \{0_N, 1_N, A, B, A \cup B\}$ is neutrosophic topology on X. Thus, (X, T) is a neutrosophic topological space. Then C is called neutrosophic semi-supra open but not neutrosophic supra open set.

Proposition 2.2. Every neutrosophic α-supra open is neutrosophic semi-supra open

Proof. Let A be a neutrosophic α-supra open in (X, T), then $A \subseteq s\text{-}Nint(s\text{-}Ncl(s\text{-}Nint(A)))$. It is obvious that $s\text{-}Nint(s\text{-}Ncl(s\text{-}Nint(A))) \subseteq s\text{-}Ncl(s\text{-}Nint(A))$. Hence $A \subseteq s\text{-}Ncl(s\text{-}Nint(A))$.

The converse of Proposition 2.2., need not be true as shown in Example 2.2. □

Example 2.2. Let $X = \{a, b\}$. Define the neutrosophic sets A, B and C in X as follows:
$A = \langle x, (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.5}, \frac{b}{0.3}) \rangle$, $B = \langle x, (\frac{a}{0.1}, \frac{b}{0.2}), (\frac{a}{0.1}, \frac{b}{0.2}), (\frac{a}{0.6}, \frac{b}{0.5}) \rangle$
and $C = \langle x, (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.2}, \frac{b}{0.3}) \rangle$. Then the families $T = \{0_N, 1_N, A, B, A \cup B\}$ is neutrosophic topology on X.Thus, (X, T) is a neutrosophic topological space. Then C is called neutrosophic semi-supra open but not neutrosophic α-supra open set.

Proposition 2.3. Every neutrosophic regular supra open set is neutrosophic semi-supra open set

Proof. Let A be a neutrosophic regular supra open set in (X, T). Then $A \subseteq (s\text{-}Ncl(A))$. Hence $A \subseteq s\text{-}Ncl(s\text{-}Nint(A))$.

The converse of Proposition 2.3., need not be true as shown in Example 2.3. □

Example 2.3. Let $X = \{a, b\}$. Define the neutrosophic sets A, B and C in X as follows:
$A = \langle x, (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.5}, \frac{b}{0.3}) \rangle$, $B = \langle x, (\frac{a}{0.1}, \frac{b}{0.2}), (\frac{a}{0.1}, \frac{b}{0.2}), (\frac{a}{0.6}, \frac{b}{0.5}) \rangle$
and $C = \langle x, (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.2}, \frac{b}{0.3}), (\frac{a}{0.2}, \frac{b}{0.3}) \rangle$. Then the families $T = \{0_N, 1_N, A, B, A \cup B\}$ is neutrosophic topology on X. Thus, (X, T) is a neutrosophic topological space. Then C is neutrosophic semi-supra open but not neutrosophic regular-supra open set.

Definition 2.3. The neutrosophic semi-supra closure of a set A is denoted by $semi\text{-}s\text{-}Ncl(A) = \bigcup\{$ G :G is aneutrosophic semi-supra open set in X and $G \subseteq A\}$ and the neutrosophic semi-supra interior of a set A is denoted by $semi\text{-}s\text{-}Nint(A) = \bigcap\{$G :G is a neutrosophic semi-supra closed set in X and $G \supseteq A\}$.

Remark 2.1. It is clear that $semi\text{-}s\text{-}Nint(A)$ is a neutrosophic semi-supra open set and $semi\text{-}s\text{-}Ncl(A)$ is a neutrosophic semi-supra closed set.

Proposition 2.4. i) $\overline{semi - s - Nint(A)}$ = semi s-Ncl $(\overline{A})$

ii) $\overline{semi - s - Ncl(A)}$ = semi s-int $(\overline{A})$

iii) if $A \subseteq B$ then $semi\text{-}s\text{-}Ncl(A) \subseteq semi\text{-}s\text{-}Ncl(B)$ and $semi\text{-}s\text{-}Nint(A) \subseteq semi\text{-}s\text{-}Nint(B)$

Proof. It is obvious. □

Proposition 2.5. (i) The intersection of a neutrosophic supra open set and a neutrosophic semi-supra open set is a neutrosophic semi- supra open set.

(ii) The intersection of a neutrosophic semi-supra open set and aneutrosophic pre-supra open set is a neutrosophic pre-supra open set.

Proof. It is obvious. □

Definition 2.4. Let (X, T) and (Y, S) be two neutrosophic semi-supra open sets and R be a associated supra topology with T. A map $f : (X, T) \to (Y, S)$ is called neutrosophic semi- supra continuous map if the inverse image of each neutrosophic open set in Y is a neutrosophic semi- supra open in X.

Proposition 2.6. Every neutrosophic supra continuous map is neutrosophic semi-supra continuous map.

Proof. Let $f : (X, T) \to (Y, S)$ be a neutrosophic supra continuous map and A is a neutrosophic open set in Y. Then $f^{-1}(A)$ is a neutrosophic open set in X. Since R is associated with T. Then $T \subseteq R$. Therefore $f^{-1}(A)$ is a neutrosophic supra open set in X which is a neutrosophic supra open set in X. Hence f is aneutrosophic semi-supra continuous map. □

Remark 2.2. Every neutrosophic semi-supra continuous map need not be neutrosophic supra continuous map.

Proposition 2.7. Let (X, T) and (Y, S) be two neutrosophic topological spaces and R be a associated neutrosophic supra topology with T. Let f be a map from X into Y. Then the following are equivalent.

i) f is a neutrosophic semi-supra continuous map.

ii) The inverse image of a neutrosophic closed sets in Y is a neutrosophic semi closed set in X.

iii) Semi-s-Ncl($f^{-1}(A)$) $\subseteq f^{-1}(Ncl(A))$ for every neutrosophic set A in Y.

iv) $f(semi\text{-}s\text{-}Ncl(A)) \subseteq Ncl(f(A))$ for every neutrosophic set A in X.

v) $f^{-1}(Nint(B)) \subseteq semi\text{-}s\text{-}Nint(f^{-1}(B))$ for every neutrosophic set B in Y.

Proof. $(i) \Rightarrow (ii)$: Let A be a neutrosophic closed set in Y. Then $\overline{A}$ is neutrosophic open in Y, Thus $f^{-1}(\overline{A}) = \overline{f^{-1}(A)}$ is neutrosophic semi-open in X. It follows that $f^{-1}(A)$ is a neutrosophic semi-s closed set of X.
$(ii) \Rightarrow (iii)$: Let A be any subset of X. Since $Ncl(A)$ is neutrosophic closed in Y then it follows that $f^{-1}(Ncl(A))$ is neutrosophic semi-s closed in X. Therefore, $f^{-1}(Ncl(A)) = semi\text{-}s\text{-}Ncl(f^{-1}(Ncl(A)) \supseteq semi\text{-}s\text{-}Ncl(f^{-1}(A))$
$(iii) \Rightarrow (iv)$: Let A be any subset of X. By (iii) we obtain $f^{-1}(Ncl(f((A))) \supseteq semi\text{-}s\text{-}Ncl(f^{-1}(f(A))) \supseteq semi\text{-}s\text{-}Ncl(A)$ and hence $f(semi\text{-}s\text{-}Ncl(A)) \subseteq Ncl(f(A))$.
$(iv) \Rightarrow (v)$: Let $f(semi\text{-}s\text{-}Ncl(A)) \subseteq f(Ncl(A)$ for every neutrosophic set A in X. Then $semi\text{-}s\text{-}Ncl(A)) \subseteq f^{-1}(Ncl(f(A))$. $\overline{semi - s - Ncl(A)} \supseteq \overline{f^{-1}(Ncl(f(A)))}$ and $semi\text{-}s\text{-}Nint(\overline{A}) \supseteq f^{-1}(Nint(\overline{f(A)}))$. Then $semi\text{-}s\text{-}Nint(f^{-1}(B)) \supseteq f^{-1}(Nint(B))$. Therefore $f^{-1}(Nint(B)) \subseteq s\text{-}Nint(f^{-1}(B))$ for every B in Y.
$(v) \Rightarrow (i)$: Let A be a neutrosophic open set in Y. Therefore $f^{-1}(Nint(A)) \subseteq semi\text{-}s\text{-}Nint(f^{-1}(A))$, hence $f^{-1}(A) \subseteq semi\text{-}s\text{-}Nint(f^{-1}(A))$. But we know that $semi\text{-}s\text{-}Nint(f^{-1}(A)) \subseteq f^{-1}(A)$, then $f^{-1}(A) = semi\text{-}s\text{-}Nint(f^{-1}(A))$. Therefore $f^{-1}(A)$ is a neutrosophic semi-s-open set. □

Proposition 2.8. If a map $f : (X, T) \to (Y, S)$ is a neutrosophic semi-s-continuous and $g : (Y, S) \to (Z, R)$ is neutrosophic continuous, Then $g \circ f$ is neutrosophic semi-s-continuous.

Proof. Obvious. □

Proposition 2.9. Let a map $f : (X, T) \to (Y, S)$ be a neutrosophic semi-supra continuous map, then one of the following holds

i) $f^{-1}(semi\text{-}s\text{-}Nint(A)) \subseteq Nint(f^{-1}(A))$ for every neutrosophic set A in Y.

ii) $Ncl(f^{-1}(A)) \subseteq f^{-1}(semi\text{-}s\text{-}Ncl(A))$ for every neutrosophic set A in Y.

iii) $f(Ncl(B)) \subseteq semi\text{-}s\text{-}Ncl(f(B))$ for every neutrosophic set B in X.

Proof. Let A be any neutrosophic open set of Y, then condition (i) is satisfied, then $f^{-1}(semi\text{-}s\text{-}Nint(A)) \subseteq Nint(f^{-1}(A))$. We get, $f^{-1}(A) \subseteq Nint(f^{-1}(A))$. Therefore $f^{-1}(A)$ is a neutrosophic supra open set. Every neutrosophic supra open set is a neutrosophic semi supra open set. Hence f is a neutrosophic semi-s-continuous function. If condition (ii) is satisfied, then we can easily prove that f is a neutrosophic semi -s continuous function if condition (iii) is satisfied, and A is any neutrosophic open set of Y, then $f^{-1}(A)$ is a set in X and $f(Ncl(f^{-1}(A)) \subseteq semi\text{-}s\text{-}Ncl(f(f^{-1}(A)))$. This implies $f(Ncl(f^{-1}(A))) \subseteq semi\text{-}s\text{-}Ncl(A)$. This is nothing but condition (ii). Hence f is a neutrosophic semi-s-continuous function. □

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