NEUTROSOPHIC STRONGLY $\alpha$-GENERALIZED SEMI CLOSED SETS

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ABSTRACT. The purpose of this paper is to introduce and study the concepts of Neutrosophic strongly $\alpha$-generalized semi-closed sets and Neutrosophic strongly $\alpha$-generalized semi-open sets. Some of their properties are explored.

1. INTRODUCTION AND PRELIMINARIES


Definition 1.1. [4,5] Let $X$ be a non empty set and Neutrosophic sets $A$ and $B$ in the form $A = \{ (x, \eta_A(x), \sigma_A(x), \nu_A(x)) \mid x \in X \}$, $B = \{ (x, \eta_B(x), \sigma_B(x), \nu_B(x)) \mid x \in X \}$ then

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Definition 1.2. \[9\] A Neutrosophic topology on a non empty set \(X\) is a family \(\tau_N\) of Neutrosophic subsets in \(X\) satisfying the following axioms:

1. \(0_N, 1_N \in \tau_N;\)
2. \(G_1 \cap G_2 \in \tau_N\) for any \(G_1, G_2 \in \tau_N;\)
3. \(\bigcup G_i \in \tau_N\) for any family \(\{G_i \mid i \in J\} \subseteq \tau_N;\)

the pair \((X, \tau_N)\) is called a Neutrosophic topological space. The elements in \(\tau_N\) are called as Neutrosophic open sets. The Neutrosophic set \(A\) is closed if and only if \(A^c\) is Neutrosophic open.

Definition 1.3. Let \((X, \tau_N)\) be Neutrosophic topological spaces. The Neutrosophic closure and Neutrosophic interior of \(A\) are defined by

1. \(N-cl(A) = \bigcap\{K \mid K\ is\ a\ Neutrosophic\ closed\ set\ in\ X\ and\ A \subseteq K\};\)
2. \(N-int(A) = \bigcup\{G \mid G\ is\ a\ Neutrosophic\ open\ set\ in\ X\ and\ G \subseteq A\}.\)

Definition 1.4. Let \((X, \tau_N)\) be a Neutrosophic topological space. The subset \(A\) is:

1. Neutrosophic regular closed set \[1\] (N-RCS in short) if \(A = N-cl(N-int(A)).\)
2. Neutrosophic \(\alpha\) closed set \[1\] (N-\(\alpha\)CS in short) if \(N-cl(N-int(N-cl((A)))) \subseteq (A).\)
3. Neutrosophic semi closed set \[6\] (N-SCS in short) if \(N-int(N-cl(A)) \subseteq A.\)
4. Neutrosophic pre closed set \[11\] (N-PCS in short) if \(N-cl(N-int(A)) \subseteq A.\)
5. Neutrosophic semipreclosed set \[8\] (N-SPCS in short) if \(N-int(N-cl(N-int(A)) \subseteq A.\)
6. Neutrosophic generalised closed set \[3\] (N-GCS in short) if \(N-cl(A) \subseteq U\) whenever \(A \subseteq U\) and \(U\) is a N-OS in \(X.\)
7. Neutrosophic generalised semi closed set \[10\] (N-GSCS in short) if \(N-scl(A) \subseteq U\) whenever \(A \subseteq U\) and \(U\) is a N-OS in \(X.\)
8. Neutrosophic \(\alpha\) generalised closed set \[7\] (N-\(\alpha\)GCS in short) if \(N-\alpha cl(A) \subseteq U\) whenever \(A \subseteq U\) and \(U\) is a N-OS in \(X.\)
Proof. Theorem 2.1. Every $X \subseteq U$ whenever $A \subseteq U$ and $U$ is a $U$.

2. Neutrosophic strongly-α-generalized semi closed sets

Definition 2.1. A $NSA$ in $(X, \tau)$ is said to be a Neutrosophic strongly $\alpha$-generalized semi-closed set (briefly $N\alpha GSCS$) $N\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and $U$ is a $NGSOS$ in $(X, \tau)$ and the family of all $N\alpha GSCS$ of a $NTS$ $(X, \tau)$ is denoted by $N\alpha GSC(X)$.

Example 1. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a $NT$ on $X$, where $V = \langle x, (\frac{7}{10}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$. Then the $NSA = \langle x, (\frac{1}{10}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$ is a $N\alpha GSCS$ in $(X, \tau)$.

Theorem 2.1. Every $NCS$ in $(X, \tau)$ is a $N\alpha GSCS$ but not conversely.

Proof. Assume that $A$ is a $NCS$ in $(X, \tau)$. Let us consider a $NSA \subseteq U$ where $U$ is a $NGSOS$ in $X$. Since $N\alpha cl(A) \subseteq Ncl(A)$ and $A$ is a $NCS$ in $X$, $N\alpha cl(A) \subseteq Ncl(A) = A \subseteq U$ and $U$ is $NGSOS$. That is $N\alpha cl(A) \subseteq U$. Therefore, $A$ is $N\alpha GSCS$ in $X$.

Example 2. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a $NT$ on $X$, where $V = \langle x, (\frac{1}{5}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$. Then the $NSA = \langle x, (\frac{1}{10}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$ is $N\alpha GSCS$ but not a $NCS$ in $X$.

Theorem 2.2. Every $N\alpha CS$ in $(X, \tau)$ is a $N\alpha GSCS$ in $(X, \tau)$ but not conversely.

Proof. Let $A$ be a $N\alpha CS$ in $X$. Let us consider a $NSA \subseteq U$ is a $NGSOS$ in $(X, \tau)$. Since $A$ is a $N\alpha CS$, $N\alpha cl(A) = A$. Hence $N\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and $U$ is $NGSOS$. Therefore, $A$ is a $N\alpha GSCS$ in $X$.

Example 3. Let $X = \{a, b\}$. Let $\tau = \{0_N, V_1, V_2, 1_N\}$ be a $NT$ on $X$, where $V_1 = \langle x, (\frac{2}{5}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$ and $V_2 = \langle x, (\frac{1}{10}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$. Consider $NSA = \langle x, (\frac{4}{5}, 1, \frac{1}{2}), (\frac{3}{5}, 1, \frac{2}{5}) \rangle$ which is $N\alpha GSCS$ but not $N\alpha CS$, since $Ncl(Nin(Ncl(A))) = 1_N \notin A$.

Theorem 2.3. Every $NRCS$ in $(X, \tau)$ is a $N\alpha GSCS$ in $(X, \tau)$ but not conversely.

Proof. Let $A$ be a $NRCS$ in $(X, \tau)$. Since every $NRCS$ is a $NCS$, $A$ is a $NCS$ in $X$. Hence by Theorem 2.1, $A$ is a $N\alpha GSCS$ in $X$. □
Example 4. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{5}, \frac{1}{2}, \frac{5}{7}), (\frac{3}{5}, \frac{1}{2}, \frac{5}{7}) \rangle$. Consider ANS $A = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ which is a $NsaGSCS$ but not $NRCS$ in $X$ as $Ncl(Nint(A)) = 0_N \subseteq A$.

Theorem 2.4. Every $NsaGSCS$ in $(X, \tau)$ is a $N\alpha GSCS$ in $(X, \tau)$ but not conversely.

Proof. Assume that $A$ is a $NsaGSCS$ in $(X, \tau)$. Let us consider $NS A \subseteq U^*$ where $U^*$ is a $NSOS$ in $X$. Since every $NSOS$ is a $NGSOS$ and by hypothesis $N_{\alpha cl}(A) \subseteq U^*$, whenever $A \subseteq U^*$ and $U^*$ is a $NGSOS$ in $X$. We have $N_{\alpha cl}(A) \subseteq U^*$, whenever $A \subseteq U^*$ and $U^*$ is a $NSOS$ in $X$. Hence $A$ is a $N\alpha GSCS$ in $X$.

Example 5. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{5}{7}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$. Then the NS $A = \langle x, (\frac{7}{10}, \frac{1}{2}, \frac{5}{7}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ is a $N\alpha GSCS$ but not a $NsaGSCS$ in $X$.

Remark 2.1. A NP closedness is independent of $NsaGS$ closedness.

Example 6. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{5}{7}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$. Then the NS $A = \langle x, (\frac{7}{10}, \frac{1}{2}, \frac{5}{7}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ is NPCS but not $NsaGSCS$.

Example 7. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$. Then the NS $A = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ is $NsaGSCS$ but not a NPCS.

Remark 2.2. A NSP closedness is independent of $NsaGSCS$ closedness.

Example 8. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$. Then the NS $A = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ is NSPCS but not $NsaGSCS$.

Example 9. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$. Then the NS $A = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ is $NsaGSCS$ but not NSPCS.

Remark 2.3. A $N_{\gamma CS}$ in $(X, \tau)$ need not be a $NsaGSCS$.

Example 10. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$. Then the NS $A = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{7}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{1}{2}) \rangle$ is $N_{\gamma CS}$ but not $NsaGSCS$. 
The relations between various types of Neutrosophic closed sets are given in the following diagram.

The reverse implications are not true in general.

**Remark 2.4.** The intersection of any two $N_{\alpha}GSCS$ is not a $N_{\alpha}GSCS$ in general as can be seen in the following example.

**Example 11.** Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a NT on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{1}{5}), (\frac{2}{5}, \frac{1}{2}, \frac{3}{5}) \rangle$. Then the NS $A = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{1}{5}), (\frac{7}{10}, \frac{1}{2}, \frac{3}{10}) \rangle$ and $B = \langle x, (\frac{9}{10}, \frac{1}{2}, \frac{1}{10}), (\frac{2}{10}, \frac{1}{2}, \frac{1}{2}) \rangle$ are $N_{\alpha}GSCS$ in $X$. Now $A \cap B = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{1}{5}), (\frac{7}{10}, \frac{1}{2}, \frac{1}{2}) \rangle \subseteq U^* = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{1}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{3}{5}) \rangle$ and $U^*$ is $NGSOS$ in $X$. But $N\alpha cl(A \cap B) = 1_N \not\subseteq U^*$. Therefore, $A \cap B$ is not a $N_{\alpha}GSCS$ in $X$.

**Theorem 2.5.** Let $(X, \tau)$ be a NTS. Then for every $A \in N_{\alpha}GSC(X)$ and for every NS $B$ in $X$, $A \subseteq B \subseteq N\alpha cl(A)$ implies $B \in N_{\alpha}GSC(X)$.

**Proof.** Let $B \subseteq U^*$ where $U^*$ is a $NGSOS$ in $X$. Since $A \subseteq B$, $A \subseteq U^*$. Since $A$ is a $N_{\alpha}GSCS$ in $X$, $N\alpha cl(A) \subseteq U^*$. By hypothesis $B \subseteq N\alpha cl(A)$. This implies $N\alpha cl(B) \subseteq N\alpha cl(A) \subseteq U^*$. Therefore, $N\alpha cl(B) \subseteq U^*$. Hence $B$ is a $N_{\alpha}GSCS$ in $X$. □

The independent relations between various types of Neutrosophic closed sets are given in the following diagram.
In this diagram, $A \not\leftrightarrow B$ denotes A and B are independent and $A \not\implies B$ denotes A need not be B.

**Theorem 2.6.** If $A$ is a NGSOS and a $N\alpha GSCS$, then $A$ is a $N\alpha CS$ in $X$.

**Proof.** Let $A$ be a NGSOS in $X$. Since $A \subseteq A$, by hypothesis $N\alpha cl(A) \subseteq A$. But always $A \subseteq N\alpha cl(A)$. Therefore, $N\alpha cl(A) = A$. Hence $A$ is a $N\alpha CS$ in $X$. $\square$

**Theorem 2.7.** Let $(X, \tau)$ be a NTS. Then $A$ is a $N\alpha GSCS$ if and only if $A \bar{q} F$ implies $N\alpha cl(A) \bar{q} F$ for every NGSCS $F$ of $X$.

**Proof.** Necessary Part: Let $F$ be a NGSCS and $A \bar{q} F$. Then $A \subseteq \hat{F}$ where $\hat{F}$ is a NGSOS in $X$. By assumption $N\alpha cl(A) \subseteq \hat{F}$. Hence $N\alpha cl(A) \bar{q} F$.

Sufficient Part: Let $F$ be NGSCS in $X$ such that $A \subseteq \hat{F}$. By hypothesis, $A \bar{q} F$ implies $N\alpha cl(A) \bar{q} F$. This implies $N\alpha cl(A) \subseteq \hat{F}$ whenever $A \subseteq \hat{F}$ and $\hat{F}$ is a NGSOS in $X$. Hence $A$ is a $N\alpha GSCS$ in $X$. $\square$

3. Neutrosophic strongly $\alpha$-generalized semi-open sets

In this section we introduce Neutrosophic strongly $\alpha$-generalized semi-open sets and study some of its properties.

**Definition 3.1.** A NS $A$ is said to be Neutrosophic strongly $\alpha$-generalized semi-open set (briefly $N\alpha GSO S$) in $(X, \tau)$ if the complement $A^c$ is a $N\alpha GSCS$ in $X$. The family of all $N\alpha GSO S$ of a NTS $(X, \tau)$ is denoted by $N\alpha GSO(X)$.

**Theorem 3.1.** For any NTS $(X, \tau)$, every NOS is a $N\alpha GSO S$ but not conversely.
Proof. Let $A$ be a $NOS$ in $X$. Then $A^c$ is a $NCS$ in $X$. By Theorem 2.1, $A^c$ is a $NsαGSCS$ in $X$. Hence $A$ is a $NsαGSOS$ in $X$. □

Example 12. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a $NT$ on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{3}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{3}{5}) \rangle$. Consider the $NS$ $A = \langle x, (\frac{9}{10}, \frac{1}{2}, \frac{1}{10}), (\frac{7}{10}, \frac{1}{2}, \frac{3}{10}) \rangle$. Since $A^c$ is a $NsαGSCS$, $A$ is a $NsαGSOS$ but not $NOS$ in $X$.

Theorem 3.2. In any $NTS (X, \tau)$ every $NαOS$ is a $NsαGSOS$ but not conversely.

Proof. Let $A$ be a $NαOS$ in $X$. Then $A^c$ is a $NαCS$ in $X$. By Theorem 2.2, $A^c$ is a $NsαGSCS$ in $X$. Hence $A$ is a $NsαGSOS$ in $X$. □

Example 13. Let $X = \{a, b\}$. Let $\tau = \{0_N, V_1, V_2, 1_N\}$ be a $NT$ on $X$, where $V_1 = \langle x, (\frac{3}{5}, \frac{1}{2}, \frac{1}{2}), (\frac{3}{10}, \frac{1}{2}, \frac{3}{5}) \rangle$ and $V_2 = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{3}{5}), (\frac{1}{2}, \frac{1}{2}, \frac{7}{10}) \rangle$. Then the $NS$ $A = \langle x, (\frac{1}{10}, \frac{1}{2}, \frac{5}{10}), (\frac{1}{10}, \frac{1}{2}, \frac{4}{5}) \rangle$ is a $NsαGSOS$ in $X$ but not a $NαOS$ in $X$.

Theorem 3.3. In any $NTS (X, \tau)$, every $NROS$ is a $NsαGSOS$ but not conversely.

Proof. Let $A$ be a $NROS$ in $X$. Then $A^c$ is a $NRCS$ in $X$. By Theorem 2.3, $A^c$ is a $NsαGSCS$ in $X$. Hence $A$ is a $NsαGSOS$ in $X$. □

Example 14. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a $NT$ on $X$, where $V = \langle x, (\frac{1}{5}, \frac{1}{2}, \frac{2}{5}), (\frac{1}{5}, \frac{1}{2}, \frac{1}{5}) \rangle$. Then the $NS$ $A = \langle x, (\frac{1}{5}, \frac{1}{2}, \frac{1}{2}), (\frac{3}{10}, \frac{1}{2}, \frac{3}{10}) \rangle$ is a $NsαGSOS$ in $X$ but not a $NROS$ in $X$.

Theorem 3.4. In any $NTS (X, \tau)$, every $NsαGSOS$ is a $NαGSOS$ but not conversely.

Proof. Let $A$ be a $NsαGSOS$ in $X$. Then $A^c$ is a $NsαGSCS$ in $X$. By Theorem 2.4, $A^c$ is a $NαGSOS$ in $X$. Hence $A$ is a $NαGSOS$ in $X$. □

Example 15. Let $X = \{a, b\}$. Let $\tau = \{0_N, V, 1_N\}$ be a $NT$ on $X$, where $V = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{2}{5}), (\frac{3}{10}, \frac{1}{2}, \frac{1}{5}) \rangle$. Then the $NS$ $A = \langle x, (\frac{1}{10}, \frac{1}{2}, \frac{1}{2}), (\frac{3}{10}, \frac{1}{2}, \frac{3}{10}) \rangle$ is a $NαGSOS$ in $X$ but not a $NsαGSOS$ in $X$.

Remark 3.1. The union of any two $NsαGSOS$ is not a $NsαGSOS$ in general.

Example 16. Let $X = \{a, b\}$. Let $\tau = \{0_N, V_1, V_2, 1_N\}$ be a $NT$ on $X$, where $V_1 = \langle x, (\frac{1}{5}, \frac{1}{2}, \frac{3}{5}), (\frac{3}{10}, \frac{1}{2}, \frac{3}{5}) \rangle$, $V_2 = \langle x, (\frac{1}{10}, \frac{1}{2}, \frac{1}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{2}{5}) \rangle$ are $NsαGSOS$ in $X$. Now $V_1 \cup V_2 = \langle x, (\frac{3}{10}, \frac{1}{2}, \frac{3}{10}), (\frac{1}{2}, \frac{1}{2}, \frac{2}{5}) \rangle$ is not a $NsαGSOS$ in $X$. 


Theorem 3.5. A NS $A$ of a NTS $(X, \tau)$ is a $N_{sa}GSOS$ if and only if $F \subseteq a_{int}(A)$ whenever $F$ is a NGSCS in $X$ and $F \subseteq A$.

Proof. Necessary Part: Let $A$ be a $N_{sa}GSOS$ in $X$. Let $F$ be a NGSCS in $X$ and $F \subseteq A$. Then $\hat{F}$ is a NGSOS in $X$ such that $A' \subseteq \hat{F}$ . Since $A'$ is a $N_{sa}GSCS$, we have $N_{acl}(A') \subseteq \hat{F}$ . Hence $(N_{a}(A')) \subseteq \hat{F}$ . Therefore, $F \subseteq N_{a}(A)$.

Sufficient Part: Let $A$ be a NS in $X$ and let $F \subseteq N_{a}(A)$ whenever $F$ is a NGSCS in $X$ and $F \subseteq A$. Then $A' \subseteq \hat{F}$ and $\hat{F}$ is a NGSOS. By hypothesis, $(N_{a}(A')) \subseteq \hat{F}$, which implies $N_{acl}(A') \subseteq \hat{F}$. Therefore, $A$ is a $N_{sa}GSCS$ in $X$. Hence $A$ is a $N_{sa}GSOS$ in $X$. □

Theorem 3.6. If $A$ is a $N_{sa}GSOS$ in $(X, \tau)$, then $A$ is a NGSOS in $(X, \tau)$.

Proof. Let $A$ be a $N_{sa}GSOS$ in $X$. This implies $A$ is a $N_{a}GSOS$ in $X$. Since every $N_{a}GSOS$ is a NGSOS, $A$ is a NGSOS in $X$. □

References


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