Almost Strongly $N_{nc}\theta e$-continuous Functions

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Abstract. We introduce and investigate a new class of functions called almost strongly $N_{nc}\theta e$-continuous functions via $N_{nc}\theta e$-open sets in $N_{nc}$ topological spaces. Also, some equivalent condition of almost strongly $N_{nc}\theta e$-continuous functions are proved.

Keywords and phrases: $N_{nc}\theta e$-regular, $N_{nc}\theta e$-closed, almost strongly $N_{nc}\theta e$-continuity.

1. Introduction

Smarandache’s neutrosophic framework have wide scope of constant applications for the fields of Computer Science, Information Systems, Applied Matheamtics, Artificial Intelligence, Mechanics, dynamic, Medicine, Electrical & Electronic, and Management Science and so forth [1, 2, 3, 4, 22, 23]. Topology is an classical subject, as a generalization topological spaces numerous kinds of topological spaces presented throughout the year. Smarandache [17] characterized the Neutrosophic set on three segment Neutrosophic sets (T-Truth, F-Falsehood, I-Indeterminacy). Neutrosophic topological spaces (nts’s) presented by Salama and Alblowi [14]. Lellies Thivagar et al. [9] was given the geometric existence of $N_{nc}$ topology, which is a non-empty set equipped with $N$ arbitrary topologies. Lellis Thivagar et al. [10] introduced the notion of $N_{nc}$-open (closed) sets and $N_{nc}$-continuous in $N_{nc}$ neutrosophic crisp topological spaces. Al-Hamido et al. [5] investigate the chance of extending the idea of neutrosophic crisp topological spaces into $N$-neutrosophic crisp topological spaces and examine a portion of their essential properties. The concept of continuity is the most important subject in topology. In 2008, the notion of $e$-continuous functions was introduced and studied by Ekici [7] and in 2010, the notion of strongly $\theta e$-continuous function was introduced by Özkoc and Aslim [12]. In 1984, Noiri and Kang introduced the notion of almost strong $\theta e$-continuity. Recently, three generalizations of almost strong $\theta e$-continuity are obtained by Beceren et al. [6], Park et al. [13] and Noiri and Zorlutuna [11]. The aim of this paper is to introduce and investigate a new class of functions, called almost strongly $N_{nc}\theta e$-continuous functions via $N_{nc}\theta e$-open sets in $N_{nc}$ topological spaces.

2. Preliminaries

Salama and Smarandache [16] presented the idea of a neutrosophic crisp set in a set $P$ and defined the inclusion between two neutrosophic crisp sets, the intersection (union) of two neutrosophic
crisp sets, the complement of a neutrosophic crisp set, neutrosophic crisp empty (resp., whole) set as more than two types. And they studied some properties related to neutrosophic crisp set operations. However, by selecting only one type, we define the inclusion, the intersection (union), and neutrosophic crisp empty (resp., whole) set again and discover a few properties.

**Definition 2.1** Let $P$ be a non-empty set. Then $H$ is called a neutrosophic crisp set (in short, ncs) in $P$ if $H$ has the form $H = (H_1, H_2, H_3)$, where $H_1, H_2,$ and $H_3$ are subsets of $P$.

The neutrosophic crisp empty (resp., whole) set, denoted by $\phi_n$ (resp., $P_n$) is an ncs in $P$ defined by $\phi_n = (\phi, \phi, P)$ (resp. $P_n = (P, P, \phi)$). We will denote the set of all ncs’s in $P$ as $ncS(P)$.

In particular, Salama and Smarandache [15] classified a neutrosophic crisp set as the followings.

A neutrosophic crisp set $H = (H_1, H_2, H_3)$ in $P$ is called a neutrosophic crisp set of Type 1 (resp. 2 & 3) (in short, ncs-Type 1 (resp. 2 & 3)), if it satisfies $H_1 \cap H_2 = H_2 \cap H_3 = H_3 \cap H_1 = \phi$ (resp. $H_1 \cap H_2 = H_2 \cap H_3 = H_3 \cap H_1 = \phi$ and $H_1 \cup H_2 \cup H_3 = P$ & $H_1 \cap H_2 \cap H_3 = \phi$ and $H_1 \cup H_2 \cup H_3 = P$). $ncS_1(P)$ ($ncS_2(P)$ and $ncS_3(P)$) means set of all ncs Type 1 (resp. 2 and 3).

**Definition 2.2** Let $H = (H_1, H_2, H_3), M = (M_1, M_2, M_3) \in ncS(P)$. Then $H$ is said to be contained in (resp. equal to) $M$, denoted by $H \subseteq M$ (resp. $H = M$), if $H_1 \subseteq M_1, H_2 \subseteq M_2$ and $H_3 \supseteq M_3$ (resp. $H \subseteq M$ and $M \subseteq H$); $H^c = (H_3^c, H_2^c, H_1^c); H \cap M = (H_1 \cap M_1, H_2 \cap M_2, H_3 \cap M_3); H \cup M = (H_1 \cup M_1, H_2 \cup M_2, H_3 \cup M_3)$. Let $(S_j)_{j \in J} \subseteq ncS(P)$, where $H_j = (H_{j_1}, H_{j_2}, H_{j_3})$. Then $\bigcap_{j \in J} H_j$ (simply $\bigcap H_j$) = $(\bigcap H_{j_1}, \bigcap H_{j_2}, \bigcup H_{j_3}); \bigcup_{j \in J} H_j$ (simply $\bigcup H_j$) = $(\bigcup H_{j_1}, \bigcup H_{j_2}, \bigcap H_{j_3})$.

The following are the quick consequence of Definition 2.2.

**Proposition 2.1** [8] Let $L, M, O \in ncS(P)$. Then

(i) $\phi_n \subseteq L \subseteq P_n$,

(ii) if $L \subseteq M$ and $M \subseteq O$, then $L \subseteq O$,

(iii) $L \cap M \subseteq L$ and $L \cap M \subseteq M$,

(iv) $L \subseteq L \cup M$ and $M \subseteq L \cup M$,

(v) $L \subseteq M$ iff $L \cap M = L$,

(vi) $L \subseteq M$ iff $L \cup M = M$.

Likewise the following are the quick consequence of Definition 2.2.

**Proposition 2.2** [8] Let $L, M, O \in ncS(P)$. Then

(i) $L \cup L = L, L \cap L = L$ (Idempotent laws),

(ii) $L \cup M = M \cup L, L \cap M = M \cap L$ (Commutative laws),

(iii) (Associative laws) : $L \cup (M \cup O) = (L \cup M) \cup O, L \cap (M \cap O) = (L \cap M) \cap O$,

(iv) (Distributive laws) : $L \cup (M \cap O) = (L \cup M) \cap (L \cup O), L \cap (M \cup O) = (L \cap M) \cup (L \cup O)$,

(v) (Absorption laws) : $L \cup (L \cap M) = L, L \cap (L \cup M) = L$,

(vi) (DeMorgan’s laws) : $(L \cup M)^c = L^c \cap M^c, (L \cap M)^c = L^c \cup M^c$,

(vii) $(L^c)^c = L$,

(viii) (a) $L \cup \phi_n = L, L \cap \phi_n = \phi_n$,

(b) $L \cup P_n = P_n, L \cap P_n = L$,

(c) $P_n^c = \phi, \phi_n^c = P_n$,

(d) in general, $L \cup L^c \neq P_n, L \cap L^c \neq \phi_n$.

**Proposition 2.3** [8] Let $L \in ncS(P)$ and let $(L_j)_{j \in J} \subseteq ncS(P)$. Then
(i) $(\bigcap L_j)^c = \bigcup L_j^c$, $(\bigcup L_j)^c = \bigcap L_j^c$.
(ii) $L \cap (\bigcup L_j) = \bigcup (L \cap L_j)$, $L \cup (\bigcap L_j) = \bigcap (L \cup L_j)$.

**Definition 2.3** [15] A neutrosophic crisp topology (briefly, *ncts*) on a non-empty set $P$ is a family $\tau$ of *nc* subsets of $P$ satisfying the following axioms

(i) $\phi_n, P_n \in \tau$.
(ii) $H_1 \cap H_2 \in \tau \ \forall \ H_1 \ & \ H_2 \in \tau$.
(iii) $\bigcup_a H_a \in \tau$, for any $\{H_a : a \in J\} \subseteq \tau$.

Then $(P, \tau_n)$ is a neutrosophic crisp topological space (briefly, *ncts* ) in $P$. The $\tau$ elements are called neutrosophic crisp open sets (briefly, *ncos*) in $P$. A *ncs* $C$ is closed set (briefly, *nccts*) iff its complement $C^c$ is *ncos*.

**Definition 2.4** [5] Let $P$ be a non-empty set. Then $\tau_{1nc}, \tau_{2nc}, \cdots, \tau_{Nnc}$ are *N*-arbitrary crisp topologies defined on $P$ and the collection $\tau_{nnc} = \{S \subseteq P : S = (\bigcup_{j=1}^N H_j) \cup (\bigcap_{j=1}^N L_j), H_j, L_j \in \tau_{jnc}\}$ is called $N$ neutrosophic crisp (briefly, *Nnc*)-topology on $P$ if the axioms are satisfied:

(i) $\phi_n, P_n \in \tau_{nnc}$.
(ii) $\bigcup_{j=1}^\infty S_j \in \tau_{nnc} \ \forall \ \{S_j\}_{j=1}^{\infty} \in \tau_{nnc}$.
(iii) $\bigcap_{j=1}^n S_j \in \tau_{nnc} \ \forall \ \{S_j\}_{j=1}^{n} \in \tau_{nnc}$.

Then $(P, \tau_{nnc})$ is called a $\tau_{nnc}$-topological space (briefly, $\tau_{nnc}$ts) on $P$. The $\tau_{nnc}$ elements are called $\tau_{nnc}$-open sets ($\tau_{nnc}$os) on $P$ and its complement is called $\tau_{nnc}$-closed sets ($\tau_{nnc}$cs) on $P$. The elements of $P$ are known as $\tau_{nnc}$-sets ($\tau_{nnc}$s) on $P$.

**Definition 2.5** [5] Let $(P, \tau_{nnc})$ be $\tau_{nnc}$ts on $P$ and $H$ be an $\tau_{nnc}$s on $P$, then the $\tau_{nnc}$ interior of $H$ (briefly, $\tau_{nnc}$int($H$)) and $\tau_{nnc}$ closure of $H$ (briefly, $\tau_{nnc}$cl($H$)) are defined as

(i) $\tau_{nnc}$int($H$) = $\bigcup\{S : S \subseteq H \ & \ S$ is a $\tau_{nnc}$os in $P\}$ & $\tau_{nnc}$cl($H$) = $\bigcap\{C : H \subseteq C \ & \ C$ is a $\tau_{nnc}$s in $P\}$.
(ii) $\tau_{nnc}$-regular open [18] set (briefly, $\tau_{nnc}$ros) if $H = \tau_{nnc}$int($\tau_{nnc}$cl($H$)).
(iii) $\tau_{nnc}$-pre open set (briefly, $\tau_{nnc}$pos) if $H \subseteq \tau_{nnc}$int($\tau_{nnc}$cl($H$)).
(iv) $\tau_{nnc}$-semi open set (briefly, $\tau_{nnc}$sos) if $H \subseteq \tau_{nnc}$cl($\tau_{nnc}$int($H$)).
(v) $\tau_{nnc}$-a-open set (briefly, $\tau_{nnc}$aos) if $H \subseteq \tau_{nnc}$int($\tau_{nnc}$cl($\tau_{nnc}$int($H$))).
(vi) $\tau_{nnc}$-a-open set [19] (briefly, $\tau_{nnc}$aos) if $H \subseteq \tau_{nnc}$cl($\tau_{nnc}$int($\tau_{nnc}$int($H$))).
(vii) $\tau_{nnc}$-a-open set (briefly, $\tau_{nnc}$aos) if $H \subseteq \tau_{nnc}$int($\tau_{nnc}$cl($\tau_{nnc}$int($H$))).
(viii) $\tau_{nnc}$-a-open set[18] (briefly, $\tau_{nnc}$aos) if $H \subseteq \tau_{nnc}$cl($\tau_{nnc}$int($\tau_{nnc}$int($H$))) \cup \tau_{nnc}$int($\tau_{nnc}$cl($\tau_{nnc}$int($H$))).

The complement of an $\tau_{nnc}$ros (resp. $\tau_{nnc}$sos, $\tau_{nnc}$pos, $\tau_{nnc}$aos, $\tau_{nnc}$aos, $\tau_{nnc}$bos, $\tau_{nnc}$aos & $\tau_{nnc}$g aos) is called an $\tau_{nnc}$-regular (resp. $\tau_{nnc}$-semi, $\tau_{nnc}$-pre, $\tau_{nnc}$-a, $\tau_{nnc}$-bos, $\tau_{nnc}$aos & $\tau_{nnc}$g aos) closed set (briefly, $\tau_{nnc}$rcs (resp. $\tau_{nnc}$scs, $\tau_{nnc}$pcs, $\tau_{nnc}$acs, $\tau_{nnc}$acs & $\tau_{nnc}$g cs)) in $P$.

The family of all $\tau_{nnc}$ros (resp. $\tau_{nnc}$sos, $\tau_{nnc}$pos, $\tau_{nnc}$pcs, $\tau_{nnc}$scs, $\tau_{nnc}$acs, $\tau_{nnc}$acs, $\tau_{nnc}$acs, $\tau_{nnc}$acs & $\tau_{nnc}$g cs) of $P$ is denoted by $\tau_{nnc}$ros($P$) (resp. $\tau_{nnc}$sos($P$), $\tau_{nnc}$pos($P$), $\tau_{nnc}$pcs($P$), $\tau_{nnc}$scs($P$), $\tau_{nnc}$acs($P$), $\tau_{nnc}$acs($P$), $\tau_{nnc}$acs($P$), $\tau_{nnc}$acs($P$), $\tau_{nnc}$acs($P$) & $\tau_{nnc}$g cs($P$)).
Definition 2.6 [20] A set $H$ is said to be a
(i) $N_{nc}\delta$ interior of $H$ (briefly, $N_{nc}\text{int}_{\delta}(H)$) is defined by $N_{nc}\text{int}_{\delta}(H) = \cup\{S : S \subseteq H \& S$ is a $N_{nc}\text{os}\}$.
(ii) $N_{nc}\delta$ closure of $H$ (briefly, $N_{nc}\text{cl}_{\delta}(H)$) is defined by $N_{nc}\text{cl}_{\delta}(H) = \cup\{p \in P : N_{nc}\text{int}(N_{nc}\text{cl}(L)) \cap H \neq \phi, p \in L \& L$ is a $N_{nc}\text{os}\}$.

Definition 2.7 [20] A set $H$ is said to be a
(i) $N_{nc}\delta$-open set (briefly, $N_{nc}\delta\text{os}$) if $H = N_{nc}\text{int}_{\delta}(H)$.
(ii) $N_{nc}\delta$-pre open set (briefly, $N_{nc}\delta\text{Pos}$) if $H \subseteq N_{nc}\text{int}(N_{nc}\text{cl}_{\delta}(H))$.
(iii) $N_{nc}\delta$-semi open set (briefly, $N_{nc}\delta\text{Sos}$) if $H \subseteq N_{nc}\text{cl}(N_{nc}\text{int}_{\delta}(H))$.
(iv) $N_{nc}\delta$-open set [21] (briefly, $N_{nc}\delta\text{os}$) if $H \subseteq N_{nc}\text{cl}(N_{nc}\text{int}_{\delta}(H)) \cup N_{nc}\text{int}(N_{nc}\text{cl}_{\delta}(H))$.

The complement of an $N_{nc}\delta\text{os}$ (resp. $N_{nc}\delta\text{Pos}, N_{nc}\delta\text{Sos}$ & $N_{nc}\delta\text{eo}$) is called an $N_{nc}\delta$ (resp. $N_{nc}\delta\text{pre}, N_{nc}\delta\text{semi} \& N_{nc}\delta\text{e}$) closed set (briefly, $N_{nc}\delta\text{cs}$ (resp. $N_{nc}\delta\text{Pcs}, N_{nc}\delta\text{Scs}$ & $N_{nc}\delta\text{ec}$)) in $P$.

The family of all $N_{nc}\delta\text{Pos}$ (resp. $N_{nc}\delta\text{Pcs}, N_{nc}\delta\text{Scs}, N_{nc}\delta\text{eos}, N_{nc}\delta\text{acs}, N_{nc}\delta\text{eos}$ & $N_{nc}\delta\text{ec}$) of $P$ is denoted by $N_{nc}\text{ROS}(P)$ (resp. $N_{nc}\text{RCS}(P), N_{nc}\text{SOS}(P), N_{nc}\text{SCS}(P), N_{nc}\delta\text{POS}(P), N_{nc}\delta\text{PCS}(P), N_{nc}\alpha\text{OS}(P), N_{nc}\alpha\text{CS}(P), N_{nc}\alpha\text{EOS}(P)$ & $N_{nc}\alpha\text{ES}(P)$).

The $N_{nc}\delta$-interior of $H$ (briefly, $N_{nc}\delta\text{int}(H)$) and $N_{nc}\delta$-closure of $H$ (briefly, $N_{nc}\delta\text{cl}(H)$) are defined as $N_{nc}\delta\text{int}(H) = \cup\{G : G \subseteq H$ and $G$ is a $N_{nc}\delta\text{eo}$ set in $P\}$ & $N_{nc}\delta\text{cl}(H) = \cap\{F : H \subseteq F$ and $F$ is a $N_{nc}\delta\text{e}$ set in $P\}$.

The $N_{nc}\delta$ semi-clousure, $N_{nc}\delta$ preclosure, $N_{nc}\delta$-b-closure and $N_{nc}\delta$-a-closure are similarly defined and are denoted by $N_{nc}\delta\text{Sc}(S), N_{nc}\delta\text{Pcl}(S), N_{nc}\delta\text{bcl}(S)$ and $N_{nc}\delta\text{acl}(S)$ respectively.

3. Almost strongly $N_{nc}\theta$ $\varepsilon$-continuous functions

Definition 3.1 Let $S$ be a $N_{nc}$ set on a $N_{nc}$ts $P$ is said to be $N_{nc}\varepsilon$-regular (briefly, $N_{nc}\varepsilon\text{r}$) if it is $N_{nc}\varepsilon\text{e}$ and $N_{nc}\varepsilon\text{c}$.

A point $p$ of $P$ is called an $N_{nc}\varepsilon\theta$-cluster point of $S$ if $N_{nc}\varepsilon\text{cl}(L) \cap S \neq \phi \forall N_{nc}\varepsilon\text{eo}$ set $L$ containing $p$. The set of all $N_{nc}\varepsilon\theta$-cluster points of $S$ is called the $N_{nc}\varepsilon\theta$-closure of $S$ and is denoted by $N_{nc}\varepsilon\text{cl}(S)$. A subset $S$ is said to be $N_{nc}\varepsilon\theta$-closed (briefly, $N_{nc}\varepsilon\theta\text{c}$) if $S = N_{nc}\varepsilon\text{cl}(S)$. The complement of an $N_{nc}\varepsilon\theta\text{c}$ set is called an $N_{nc}\varepsilon\theta$-open (briefly, $N_{nc}\varepsilon\theta\text{o}$) set. Also it is noted in that

$N_{nc}\varepsilon\text{r} \Rightarrow N_{nc}\varepsilon\theta\text{o} \Rightarrow N_{nc}\varepsilon\text{e}$

The family of all $N_{nc}\varepsilon\theta$ (resp. $N_{nc}\varepsilon\theta\text{o} \& N_{nc}\varepsilon\theta\text{c}$) subsets of $P$ is denoted by $N_{nc}\varepsilon\text{RS}(P)$ (resp. $N_{nc}\varepsilon\theta\text{OS}(P) \& N_{nc}\varepsilon\theta\text{CS}(P)$). The family of all $N_{nc}\varepsilon\text{r}$ (resp. $N_{nc}\varepsilon\theta\text{o} \& N_{nc}\varepsilon\theta\text{c}$) sets of $P$ containing a point $p$ of $P$ is denoted by $N_{nc}\varepsilon\text{RS}(P,p)$ (resp. $N_{nc}\varepsilon\theta\text{OS}(P,p) \& N_{nc}\varepsilon\theta\text{CS}(P,p)$).

Definition 3.2 The family of $N_{nc}\varepsilon\text{r}$ sets of a space $(P, N_{nc}\tau)$ forms a base for a smaller topology $N_{nc}\varepsilon\tau$ on $P$ called $N_{nc}$ semi-regularization of $N_{nc}\tau$. The space $(P, N_{nc}\tau)$ is said to be $N_{nc}$ semi-regular if $N_{nc}\varepsilon\tau = N_{nc}\tau$.

A space $(P, N_{nc}\tau)$ is called almost $N_{nc}$ regular (briefly, $aN_{nc}\text{Reg}$) if for any $N_{nc}\text{ro}$ set $U \subseteq P$ and each point $p \in L$, there is a $N_{nc}\text{ro}$ set $M$ of $P$ such that $p \in M \subseteq N_{nc}\text{cl}(M) \subseteq L$.

Lemma 3.1 Let $P$ be a $N_{nc}$ts. If $S$ is a $N_{nc}\text{P}$ set in $P$, then $N_{nc}\text{Sc}(S) = N_{nc}\text{int}(N_{nc}\text{cl}(S))$.

Lemma 3.2 Let $P$ be a $N_{nc}$ts and $S \subseteq P$ and $\{S_{\alpha} : \alpha \in \Lambda\} \subseteq \mathcal{P}(P)$. Then the following statements hold:

(i) $S \in N_{nc}\varepsilon\text{OS}(P)$ iff $N_{nc}\varepsilon\text{cl}(S) \in N_{nc}\varepsilon\text{R}(P)$.
(ii) $S$ is $N_{nc}e\theta o$ in $P$ iff for each $p \in S$, there exist $W \in N_{nc}eRS(P, p)$ such that $W \subseteq S$.

(iii) If $S_\alpha$ is $N_{nc}e\theta o$ in $P$ for each $\alpha \in \Lambda$, then $\bigcup_{\alpha \in \Lambda} S_\alpha$ is $N_{nc}e\theta o$ in $P$.

(iv) $S \in N_{nc}eRS(P)$ iff $S$ is $N_{nc}e\theta o$ and $N_{nc}e\theta e$.

**Lemma 3.3** Let $P$ be a $N_{nc}e\theta s$. Then the following statements hold:

(i) $N_{nc}e\theta ocl(M) = N_{nc}ocl(M)$ for each $N_{nc}e\theta o$ set $M$ of $P$.

(ii) $N_{nc}epcl(M) = N_{nc}ocl(M)$ for each $N_{nc}eO$ set $M$ of $P$.

**Lemma 3.4** Let $S$ be a subset of a space $P$. The set $S$ is $N_{nc}e\theta o$ in $P$ iff for each $p \in S$, there exists a $S \in N_{nc}eOS(P)$ containing $p$ such that $p \in N_{nc}ecl(L) \subseteq S$.

**Proof.** It can be proved directly using Lemma 3.2.

**Lemma 3.5** Let $P$ be a $N_{nc}e\theta s$ and $S \subseteq P$. Then:

(i) $N_{nc}e\theta ocl(P \setminus S) = P \setminus N_{nc}eint_\theta(S)$.

(ii) $N_{nc}eint_\theta(P \setminus S) = P \setminus N_{nc}ecl_\theta(S)$.

**Lemma 3.6** Let $P$ be a $N_{nc}e\theta s$. Then the following statement hold:

(i) $M \in N_{nc}e\theta oS(P) \Rightarrow N_{nc}eocl(M) \in N_{nc}eOS(P)$.

(ii) $M \in N_{nc}eSOS(P) \Rightarrow N_{nc}eocl(M) = N_{nc}epcl(M)$.

**Proof** (i) Let $M \in N_{nc}e\theta oS(P)$. We have

$$M \in N_{nc}e\theta oS(P) \Rightarrow M \subseteq N_{nc}eocl(N_{nc}eint(N_{nc}ecl(M)))$$

$$\Rightarrow N_{nc}eocl(M) \subseteq N_{nc}eocl(N_{nc}ecl(N_{nc}ecl(M))))$$

$$\overset{\text{Lemma 3.3}}{=} N_{nc}eocl(M) \subseteq N_{nc}eocl(N_{nc}ecl(M)))$$

$$= N_{nc}ecl(N_{nc}eint(N_{nc}ecl(M)))$$

(ii) Let $M \in N_{nc}eSOS(P)$. We have

$$N_{nc}eocl(M) = M \cup N_{nc}ecl(N_{nc}eint(N_{nc}ecl(M)))(M \in N_{nc}eSOS(P)$$

$$\Rightarrow M \subseteq N_{nc}ecl(N_{nc}eint(M))$$

$$\Rightarrow N_{nc}eocl(M) \subseteq M \cup N_{nc}ecl(N_{nc}eint(M)) = N_{nc}ep(M), M \subseteq P$$

$$\Rightarrow N_{nc}epcl(M) \subseteq N_{nc}eocl(M) \Rightarrow N_{nc}eocl(M) = N_{nc}epcl(M).$$

**Lemma 3.7** In a $N_{nc}$ space $P$, the intersection of an $N_{nc}eo$ set and an $N_{nc}eo$ set is an $N_{nc}eo$ set.

**Definition 3.3** A function $h : P \to Q$ is said to be almost strongly $N_{nc}e\theta$-continuous (briefly, $ast N_{nc}e\theta Cts$) if for each $p \in P$ and each $N_{nc}eo$ set $M$ containing $h(p)$, there exists an $N_{nc}eo$ set $L$ in $P$ containing $p$ such that $h(N_{nc}ecl(L)) \subseteq N_{nc}eint(N_{nc}ecl(M))$.

**Example 3.1** Let $P = \{u, v, w, x, y\}$, $nc\tau_1 = \{\phi, P, S_1, S_2, S_3\}$, $nc\tau_2 = \{\phi, P, \}$. $S_1 = \{\{w\}, \{\phi\}, \{u, v, x, y\}\}, S_2 = \{\{u, v\}, \{\phi\}, \{w, x, y\}\}, S_3 = \{\{u, v, w\}, \{\phi\}, \{p, y\}\}$, then we have $2_{nc}\tau = \{\phi, P, S_1, S_2, S_3\}$. Define $h : (P, 2_{nc}\tau) \to (P, 2_{nc}\tau)$ be an identity function. Then $h$ is a $ast 2_{nc}\theta Cts$.

**Theorem 3.1** For a function $h : P \to Q$, the followings are equivalent:

(i) $h$ is $ast N_{nc}e\theta Cts$.
(ii) for each $p \in P$ and each $N_{nc} \text{ro set } M$ containing $h(p)$, there exists an $N_{nc} \text{eo set } L$ in $P$
containing $p$ such that $h(N_{nc} \text{ecl}(L)) \subseteq M$,
(iii) for each $p \in P$ and each $N_{nc} \text{ro set } M$ containing $h(p)$, there exists an $N_{nc} \text{er set } L$ in $P$
containing $p$ such that $h(L) \subseteq M$,
(iv) for each $p \in P$ and each $N_{nc} \text{ro set } M$ containing $h(p)$, there exists an $N_{nc} \text{e} \theta \text{o set } L$ in $P$
containing $p$ such that $h(L) \subseteq M$,
(v) $h^{-1}(G) \in N_{nc} \text{e} \theta \text{OS}(P) \forall N_{nc} \text{ro set } G$ of $Q$,
(vi) $h^{-1}(F) \in N_{nc} \text{e} \theta \text{CS}(P) \forall N_{nc} \text{rc set } F$ of $Q$,
(vii) $h^{-1}(G) \in N_{nc} \text{e} \theta \text{OS}(P) \forall N_{nc} \delta \text{o set } G$ of $Q$,
(viii) $h^{-1}(F) \in N_{nc} \text{e} \theta \text{CS}(P) \forall N_{nc} \delta \text{c set } F$ of $Q$,
(ix) $h(N_{nc} \text{ecl}(\theta(S))) \subseteq N_{nc} \text{cl}(h(S)) \forall$ subset $S$ of $P$,
(x) $N_{nc} \text{ecl}(h^{-1}(T)) \subseteq h^{-1}(N_{nc} \text{cl}(\theta(T))) \forall$ subset $T$ of $Q$,
(xi) $N_{nc} \text{ecl}(h^{-1}(N_{nc} \text{cl}(N_{nc} \text{int}(N_{nc} \text{cl}(T)))) \subseteq h^{-1}(N_{nc} \text{cl}(T)) \forall$ subset $T$ of $Q$,
(xii) $N_{nc} \text{ecl}(h^{-1}(M)) \subseteq h^{-1}(N_{nc} \text{cl}(M)) \forall N_{nc} \gamma \text{o set } M$ of $Q$,
(xiii) $N_{nc} \text{ecl}(h^{-1}(M)) \subseteq h^{-1}(N_{nc} \text{cl}(M)) \forall N_{nc} \delta \text{o set } M$ of $Q$,
(xiv) $N_{nc} \text{ecl}(h^{-1}(M)) \subseteq h^{-1}(N_{nc} \text{cl}(M)) \forall N_{nc} \delta \text{o set } M$ of $Q$,
(xv) $N_{nc} \text{ecl}(h^{-1}(M)) \subseteq h^{-1}(N_{nc} \text{cl}(M)) \forall N_{nc} \delta \text{o set } M$ of $Q$,
(xvi) $N_{nc} \text{ecl}(h^{-1}(N_{nc} \text{cl}(N_{nc} \text{int}(M)))) \subseteq h^{-1}(F) \forall N_{nc} \text{c set } F$ of $Q$,
(xvii) $N_{nc} \text{ecl}(h^{-1}(N_{nc} \text{cl}(N_{nc} \text{int}(M)))) \subseteq h^{-1}(N_{nc} \text{cl}(M)) \forall N_{nc} \text{c set } M$ of $Q$,
(xviii) $h^{-1}(M) \subseteq N_{nc} \text{e} \text{int}\theta(h^{-1}(N_{nc} \text{cl}(M))) \forall N_{nc} \gamma \text{o set } M$ of $Q$,
(xix) $h^{-1}(M) \subseteq N_{nc} \text{e} \text{int}\theta(h^{-1}(N_{nc} \text{cl}(N_{nc} \text{cl}(M)))) \forall N_{nc} \gamma \text{o set } M$ of $Q$,
(xx) $h^{-1}(M) \subseteq N_{nc} \text{e} \text{int}\theta(h^{-1}(N_{nc} \text{cl}(N_{nc} \text{cl}(M)))) \forall N_{nc} \gamma \text{o set } M$ of $Q$,
(xxi) $h^{-1}(M) \subseteq N_{nc} \text{e} \text{int}\theta(h^{-1}(N_{nc} \text{cl}(N_{nc} \text{cl}(M)))) \forall N_{nc} \gamma \text{o set } M$ of $Q$,
(xxii) $h : P \rightarrow Q_s$ is $sN_{nc} \text{e} \theta \text{Cts}$, where $Q_s$ denotes the $N_{nc}$ semi regularization of $Q$.

**Proof.** (i) $\Rightarrow$ (ii): Let $p \in P$ and $M \in N_{nc} \text{ROS}(Q, h(p))$. We have

$(p \in P)(M \in N_{nc} \text{ROS}(Q, h(p)))$, $N_{nc} \text{ROS}(Q, h(p)) \subseteq U(Q, h(p))$

$\Rightarrow (p \in P)(M \in U(Q, h(p)))$, Hypothesis

$\Rightarrow (\exists L \in N_{nc} \text{e} \text{OS}(P, p))(h(N_{nc} \text{ecl}(L)) \subseteq N_{nc} \text{int}(N_{nc} \text{cl}(M)) = M)$.

(ii) $\Rightarrow$ (iii): Let $p \in P$ and $M \in N_{nc} \text{ROS}(Q, h(p))$. We have

$(p \in P)(M \in N_{nc} \text{ROS}(Q, h(p)))$, Hypothesis $\Rightarrow (\exists L \in N_{nc} \text{e} \text{OS}(P, p))(h(N_{nc} \text{ecl}(L)) \subseteq M)$

L' $\in N_{nc} \text{e} \text{OS}(P, p) \Rightarrow L = N_{nc} \text{ecl}(L) \in N_{nc} \text{e} \text{RS}(P, p)$  \hspace{1cm} (1)

(1), (2) $\Rightarrow (\exists L \in N_{nc} \text{e} \text{RS}(P, p))(h(L) \subseteq M)$.

(iii) $\Rightarrow$ (iv): Let $p \in P$ and $M \in N_{nc} \text{ROS}(Q, h(p))$. We have

$(p \in P)(M \in N_{nc} \text{ROS}(Q, h(p)))$, Hypothesis

$\Rightarrow (\exists L \in N_{nc} \text{e} \text{RS}(P, p))(h(L) \subseteq M)$, $N_{nc} \text{e} \text{RS}(P, p) \subseteq N_{nc} \text{e} \theta \text{OS}(P, p)$

$\Rightarrow (\exists L \in N_{nc} \text{e} \theta \text{OS}(P, p))(h(L) \subseteq M)$.

(iv) $\Rightarrow$ (v): Let $G \in N_{nc} \text{ROS}(Q, h(p))$ and $p \notin h^{-1}(G)$. We have
\((G \in \mathit{nc.ROS}(Q, h(p)))(p \notin h^{-1}(G)), \text{ Hypothesis}\)

\(\Rightarrow (\exists L \in \mathit{nc.e\Theta OS}(P, p))(h(L) \subseteq G) \Rightarrow (\exists L \in \mathit{nc.e\Theta OS}(P, p))(p \in L \subseteq h^{-1}(G)), \text{ Lemma 3.2}\)

\[
\left( \bigcup_{p \in h^{-1}(G)} L \in \mathit{nc.e\Theta OS}(P) \right) \left( \bigcup_{p \in h^{-1}(G)} L = h^{-1}(G) \right)
\]

\(\Rightarrow h^{-1}(G) \in \mathit{nc.e\Theta OS}(P)\).

\((v) \Rightarrow (vi)\): Let \(F \in \mathit{nc.RCS}(Q)\). We have

\[
F \in \mathit{nc.RCS}(Q) \iff P \setminus F \in \mathit{nc.ROS}(Q)
\]

\[
\Leftrightarrow h^{-1}(P \setminus F) \in \mathit{nc.e\Theta OS}(P)
\]

\[
\Leftrightarrow P \setminus h^{-1}(F) \in \mathit{nc.e\Theta OS}(P)
\]

\[
\Leftrightarrow h^{-1}(F) \in \mathit{nc.e\Theta CS}(P).
\]

\((vi) \Rightarrow (vii)\): Let \(M \in \mathit{nc.\delta OS}(Q)\). We have

\[
M \in \mathit{nc.\delta OS}(Q) \Rightarrow P \setminus M \in \mathit{nc.\delta CS}(Q)
\]

\[
\Rightarrow P \setminus M = \mathit{nc.cl}_{\delta}(P \setminus M)
\]

\[
\Rightarrow P \setminus M = \bigcap \{F | W \subseteq F, F \in \mathit{nc.RCS}(Q)\}, \text{ Hypothesis}
\]

\[
\Rightarrow (P \setminus M) \subseteq F \in \mathit{nc.RCS}(Q)
\]

\[
\Rightarrow h^{-1}(F) \in \mathit{nc.e\Theta CS}(P)\left(h^{-1}(P \setminus M) = \bigcap_{P \setminus M \subseteq F} h^{-1}(F)\right)
\]

\[
\Rightarrow h^{-1}(P \setminus M) \in \mathit{nc.e\Theta CS}(P)
\]

\[
\Rightarrow (P \setminus h^{-1}(M)) \in \mathit{nc.e\Theta CS}(P)
\]

\[
\Rightarrow h^{-1}(M) \in \mathit{nc.e\Theta OS}(P).
\]

\((vii) \Rightarrow (viii)\): Let \(F \in \mathit{nc.\delta CS}(Q)\). We have

\[
F \in \mathit{nc.\delta CS}(Q) \Rightarrow P \setminus F \in \mathit{nc.\delta OS}(Q)
\]

\[
\Rightarrow h^{-1}(P \setminus F) \in \mathit{nc.e\Theta OS}(P)
\]

\[
\Rightarrow P \setminus h^{-1}(F) \in \mathit{nc.e\Theta OS}(P)
\]

\[
\Rightarrow h^{-1}(F) \in \mathit{nc.e\Theta CS}(P).
\]

\((viii) \Rightarrow (ix)\): Let \(S \subseteq P\). We have

\[
A \subseteq P \Rightarrow \mathit{nc.cl}_{\delta}(h(S)) \in \mathit{nc.\delta CS}(Q), \text{ Hypothesis}
\]

\[
\Rightarrow h^{-1}(\mathit{nc.cl}_{\delta}(h(S))) \in \mathit{nc.e\Theta CS}(P), \quad p \notin h^{-1}(\mathit{nc.cl}_{\delta}(h(S)))
\]

\[
\Rightarrow (\exists L \in \mathit{nc.eOS}(P, p))(\mathit{nc.ecl}(L \cap h^{-1}(\mathit{nc.cl}_{\delta}(h(S)))) = \emptyset)
\]

\[
\Rightarrow (\exists L \in \mathit{nc.eOS}(P, p))(\mathit{nc.ecl}(L \cap S = \emptyset)
\]

\[
\Rightarrow p \notin \mathit{nc.ecl}_{\emptyset}(S).
\]

Then \(\mathit{nc.ecl}_{\emptyset}(S) \subseteq h^{-1}(\mathit{nc.cl}_{\delta}(h(S))) \Rightarrow h^{-1}(\mathit{nc.ecl}_{\emptyset}(S)) \subseteq \mathit{nc.cl}_{\delta}(h(S))\).
(ix) ⇒ (x): Let $T \subseteq Q$. We have
\[ T \subseteq Q \Rightarrow h^{-1}(T) \subseteq P, \text{Hypothesis} \]
\[ \Rightarrow h(N_{ncl}\delta(h^{-1}(T))) \subseteq N_{ncl}\delta(h(h^{-1}(T))) \subseteq N_{ncl}\delta(T) \]
\[ \Rightarrow N_{ncl}\delta(h^{-1}(T)) \subseteq h^{-1}(N_{ncl}\delta(T)). \]

(x) ⇒ (xi): Let $T \subseteq Q$. We have $T \subseteq Q$
\[ \Rightarrow N_{nccl}(N_{ncint}(N_{nccl}(T))) \in N_{ncRCS}(Q) \]
\[ \Rightarrow N_{nccl}(N_{ncint}(N_{nccl}(T))) \in N_{nc\delta CS}(Q), N_{nccl}(N_{ncint}(N_{nccl}(T))) \subseteq N_{nccl}(T). \]
\[ \Rightarrow N_{nccl}(h^{-1}(N_{nccl}(N_{ncint}(N_{nccl}(T))))) \subseteq h^{-1}(N_{nccl}(N_{nccl}(N_{ncint}(N_{nccl}(T))))) \]
\[ \Rightarrow N_{nccl}\delta(h^{-1}(N_{nccl}(N_{nccl}(N_{ncint}(N_{nccl}(T)))))) \subseteq h^{-1}(N_{nccl}(N_{nccl}(N_{ncint}(N_{nccl}(T))))))) \]
\[ \Rightarrow N_{nccl}\delta(h^{-1}(N_{nccl}(N_{ncint}(N_{nccl}(T)))))) \subseteq h^{-1}(N_{nccl}(N_{nccl}(N_{ncint}(N_{nccl}(T)))))) \]
\[ \Rightarrow N_{nccl}(h^{-1}(N_{nccl}(N_{nccl}(N_{ncint}(N_{nccl}(T)))))) \subseteq h^{-1}(N_{nccl}(T)). \]

(xi) ⇒ (xii): Let $M \in N_{nc\beta OS}(Q)$. We have
\[ M \in N_{nc\beta OS}(Q) \overset{(i)}{=} N_{nccl}(M) \in N_{ncRCS}(Q), \text{Hypothesis} \]
\[ \Rightarrow N_{nccl}\delta(h^{-1}(M)) \subseteq N_{nccl}\delta(h^{-1}(N_{nccl}(M))) \]
\[ = N_{nccl}\delta(h^{-1}(N_{nccl}(N_{ncint}(N_{nccl}(M))))) \subseteq h^{-1}(N_{nccl}(M)). \]

(xii) ⇒ (xiii): This is obvious since every $N_{ncSo}$ set is $N_{nc\beta\alpha}$.

(xiii) ⇒ (xiv): Let $M \in N_{nc\beta OS}(Q)$. We have
\[ M \in N_{nc\beta OS}(Q) \overset{\text{Lemma 3.6}}{=} N_{nc\alpha cl}(M) \in N_{ncSOS}(Q), \text{Hypothesis} \]
\[ \Rightarrow N_{nccl}\delta(h^{-1}(M)) \subseteq N_{nccl}\delta(h^{-1}(N_{nccl}(M))) \]
\[ \subseteq N_{nccl}\delta(h^{-1}(N_{nccl}(N_{ncint}(N_{nccl}(M))))) \subseteq h^{-1}(N_{nccl}(M)) \]
\[ \Rightarrow N_{nccl}(h^{-1}(M)) \subseteq h^{-1}(N_{nccl}(M)) \overset{\text{Lemma 3.3}}{=} h^{-1}(N_{nccl}(M)). \]

(xiv) ⇒ (xv): Let $M \in N_{ncSOS}(Q)$. We have
\[ M \in N_{ncSOS}(Q) \Rightarrow M \in N_{nc\beta OS}(Q), \text{Hypothesis} \]
\[ \Rightarrow N_{nccl}\delta(h^{-1}(M)) \subseteq h^{-1}(N_{nccl}(M)) \]
\[ \Rightarrow M \in N_{ncSOS}(Q) \overset{\text{Lemma 3.6}}{=} N_{nc\alpha cl}(M) = N_{ncpel}(M) \]
\[ \Rightarrow N_{nccl}(h^{-1}(M)) \subseteq h^{-1}(N_{ncpel}(M)). \]

(xv) ⇒ (xvi): Let $M \in N_{ncCS}(Q)$. We have
\[ M \in N_{ncCS}(Q) \Rightarrow N_{nccl}(N_{ncint}(M)) \in N_{ncSOS}(Q), \text{Hypothesis} \]
\[ \Rightarrow N_{nccl}(h^{-1}(N_{nccl}(N_{ncint}(M)))) \subseteq h^{-1}(N_{nccl}(N_{ncint}(N_{nccl}(M)))) \subseteq h^{-1}(M). \]

(xvi) ⇒ (xvii): Let $M \in N_{nc\sigma}$. We have $M \in N_{nc\sigma} \Rightarrow N_{nccl}(M) \in N_{ncCS}(Q)$, Hypothesis
\[ \Rightarrow N_{nccl}(h^{-1}(N_{nccl}(N_{ncint}(N_{nccl}(M))))) \]
\[ \subseteq h^{-1}(N_{nccl}(M))N_{nccl}(h^{-1}(N_{nccl}(M))) \subseteq h^{-1}(N_{nccl}(M)). \]
(xvii) ⇒ (xviii): Let $M \in N_{nc}\sigma$. We have

$M \in N_{nc}\sigma \Rightarrow Y \setminus N_{nc\text{cl}}(M) \in N_{nc}\sigma$

**Lemma 3.1.3.5**

$P \setminus N_{nc\text{ent}}(h^{-1}(N_{nc\text{scl}}(M)))$

$= N_{nc\text{cl}}(h^{-1}(Q \setminus N_{nc\text{int}}(N_{nc\text{cl}}(M)))) = N_{nc\text{cl}}(h^{-1}(N_{nc\text{cl}}(Q \setminus N_{nc\text{cl}}(M))))$, Hypothesis

$\Rightarrow P \setminus N_{nc\text{ent}}(h^{-1}(N_{nc\text{scl}}(M))) \subseteq h^{-1}(Q \setminus N_{nc\text{cl}}(M)) \subseteq P \setminus h^{-1}(M)$

$\Rightarrow h^{-1}(M) \subseteq N_{nc\text{int}}(h^{-1}(N_{nc\text{scl}}(M)))$.

(xviii) ⇒ (xix): Let $M \in N_{nc}POS(Q)$. We have

$M \in N_{nc}POS(Q) \Rightarrow N_{nc\text{scl}}(M) = N_{nc\text{int}}(N_{nc\text{cl}}(M))$, Hypothesis

$\overset{\text{Lemma 3.1.3.5}}{\Rightarrow} h^{-1}(M) \subseteq h^{-1}(N_{nc\text{scl}}(M)) \subseteq N_{nc\text{int}}(h^{-1}(N_{nc\text{scl}}(M)))$

$\subseteq N_{nc\text{int}}(h^{-1}(N_{nc\text{cl}}(M)))$.

(xix) ⇒ (xx) and (xx)⇒ (xxi) are clear.

(xxi)⇒ (xxii): Let $p \in P$ and $M \in N_{nc}OS(Q, h(p))$. We have

$(p \in P)(M \in N_{nc}OS(Q, h(p))) \Rightarrow (\exists G \in N_{nc}\text{ROS}(Q)) (h(p) \in G \subseteq M), \text{ Hypothesis}$

$\Rightarrow p \in h^{-1}(G) \subseteq N_{nc\text{ent}}(h^{-1}(G))$

$\Rightarrow h^{-1}(G) \in N_{nc\theta OS}(P)$

$\overset{\text{Lemma 3.2}}{\Rightarrow} (\exists L \in N_{nc\text{eO}}(P, p)) (N_{nc\text{cl}}(L) \subseteq h^{-1}(G))$

$\Rightarrow (\exists L \in N_{nc\text{eOS}}(P, p))(h(N_{nc\text{cl}}(L)) \subseteq G \subseteq M)$.

(xxii) ⇒ (i): Let $M \in N_{nc}OS(Q)$ and $p \in h^{-1}(M)$. We have

$(M \in N_{nc}OS(Q))(p \in h^{-1}(M)) \Rightarrow h(p) \in M \subseteq N_{nc\text{int}}(N_{nc\text{cl}}(M)) \in \sigma$, Hypothesis

$\Rightarrow (\exists L \in N_{nc\text{eOS}}(P, p))(N_{nc\text{cl}}(L) \subseteq h^{-1}(N_{nc\text{int}}(N_{nc\text{cl}}(M))))$

$\Rightarrow (\exists L \in N_{nc\text{eOS}}(P, p))(h(N_{nc\text{cl}}(L)) \subseteq N_{nc\text{int}}(N_{nc\text{cl}}(M)))$.

**Definition 3.4** Let $S$ be a subset of a $N_{nc}ts$ $P$. The $N_{nc}\theta$-frontier (briefly, $N_{nc}\theta Fr$) of $S$ is defined by $N_{nc}\theta Fr_{\sigma}(S) = N_{nc\text{cl}}(S) \setminus N_{nc\text{ent}}(S)$.

**Theorem 3.2** The set of all points $p \in P$ at which a function $h : P \rightarrow Q$ is not $ast N_{nc}\theta Cts$ coincides with the union of the $N_{nc}\theta Fr$ of the inverse images of $N_{nc}ro$ sets of $Q$ containing $h(p)$.

**Proof.** Let $S = \{p|h$ is not $ast N_{nc}\theta Cts$ at a point $p of P\}$. Then

$p \in S \Rightarrow (\exists M \in N_{nc}\text{ROS}(Q, h(p)))(\forall L \in N_{nc\text{eOS}}(P, p)) (h(N_{nc\text{cl}}(L)) \not\subseteq V)$

$\Rightarrow (\exists M \in N_{nc}\text{ROS}(Q, h(p)))(\forall L \in N_{nc\text{eOS}}(P, p)) (N_{nc\text{cl}}(L) \not\subseteq h^{-1}(M))$

$\Rightarrow (\exists M \in N_{nc}\text{ROS}(Q, h(p)))(\forall L \in N_{nc\text{eOS}}(P, p)) (N_{nc\text{cl}}(L) \cap (P \setminus h^{-1}(M)) \neq \emptyset)$ (3)

$\Rightarrow p \in N_{nc\text{ecl}}(P \setminus h^{-1}(M))$

$\Rightarrow p \in P \setminus N_{nc\text{ent}}(h^{-1}(M))$

$p \notin N_{nc\text{ent}}(h^{-1}(M))$,<!--.5}
Then we have

\[ S \subseteq \bigcup \{ N_{nc}eFr_\theta(h^{-1}(M)) | h(p) \in M \in N_{nc}ROS(Q) \} \]

Then we have \( \bigcup N_{nc}eFr_\theta(h^{-1}(M)) | h(p) \in M \in N_{nc}ROS(Q) \subseteq S \).

References

[1] Abdel-Basset M, Chang V, Mohamed M and Smarandache F 2019 A Refined Approach for Forecasting Based on Neutrosophic Time Series Symmetry vol 11 457.
[2] Abdel-Basset M, Manogaran G, Gamal A and Chang V 2019 A Novel Intelligent Medical Decision Support Model Based on Soft Computing and IoT IEEE Internet of Things Journal.
[3] Abdel-Basset M, and Mohamed M 2019 A novel and powerful framework based on neutrosophic sets to aid patients with cancer Future Generation Computer Systems vol 98 pp 144-153.
[4] Abdel-Basset M, Gamal A, Manogaran G and Long H V 2019 A novel group decision making model based on neutrosophic sets for heart disease diagnosis Multimedia Tools and Applications pp 1-26.
[5] Al-Hamido R K, Gharibah T, Jafari S and Smarandache F 2014 Neutrosophic crisp sets and neutrosophic crisp topological spaces Neutrosophic Sets and Systems vol 23 pp 96-109.
[6] Beceren Y, Gökşel S and Hatir E 1995 On almost strongly \( \theta \)-semicontinuous functions Bull. Calcutta Math. Soc. vol 87 pp 329-334.
[7] Erdal Ekici 2008 On \( \varepsilon \)-open sets, \( \mathcal{DP}^\ast \)-sets and \( \mathcal{DP}\varepsilon^\ast \)-sets and decomposition of continuity The Arabian Journal for Science and Engineering vol 33 pp 271-282.
[8] Hur K, Lim P K, Lee J G and Lee J 2017 The category of neutrosophic crisp sets Annals of Fuzzy mathematics and Informatics vol 14 pp 43-54.
[9] Lellis Thivagar M, Ramesh V, Arockia M D 2016 On new structure of \( N \)-topology Cogent Mathematics (Taylor and Francis) vol 3 pp 1204104.
[10] Lellis Thivagar M, Jafari S, Antonymsamy V and Sutha Devi V 2018 The ingenuity of neutrosophic topology via \( N \)-topology Neutrosophic Sets and Systems vol 19 pp 91-100.
[11] Noiri T and Zorlutuna I 2008 Almost strongly \( \theta \)-b-continuous functions Stud. Cercet. Stiint. Ser. Mat., Univ. Bacau, vol 18 pp 193-210.
[12] Ozhuc M and Aslim G 2010 On strongly \( \theta \)-c-continuous functions Bull. Korean Math. Soc., vol 47 pp 1025-1036.
[13] Park J H, Bae S W and Park Y B 2006 Almost strongly \( \theta \)-precontinuous functions Chaos Solitons Fractals vol 28 pp 32-41.
[14] Salama A A and Alblowi S A 2012 Generalized neutrosophic set and generalized neutrosophic topological spaces Journal computer sci. engineering vol 2 pp 31-35.
[15] Salama A A, Smarandache F and Kroumov V 2014 Neutrosophic crisp sets and neutrosophic crisp topological spaces Neutrosophic Sets and Systems vol 2 pp 25-30.
[16] Salama A A and Smarandache F 2015 Neutrosophic crisp set theory Educational Publisher Columbus Ohio USA.
[17] Smarandache F 2020 Neutrosophic and neutrosophic logic First International Conference on Neutrosophy, Neutrosophic Logic, Set, Probability, and Statistics, University of New Mexico, Gallup, NM 8701, USA.
[18] Vadivel A and John Sundar C 2020 \( \gamma \)-Open Sets in \( N_{nc}\)-Topological Spaces Advances in Mathematics: Scientific Journal vol 9 pp 2197-2202.
[19] Vadivel A and John Sundar C 2020 \( N_{nc}\beta \)-open sets Advances in Mathematics: Scientific Journal vol 9 pp 2203-2207.
[20] Vadivel A and John Sundar C \( N_{nc}\delta \)-open sets Submitted.
[21] Vadivel A and Thangaraja P \( \varepsilon \)-open sets \( N_{nc} \)-Topological Spaces Submitted.
[22] Venkateswaran Rao V and Srinivasa Rao Y Neutrosophic Pre-open sets and Pre-closed sets in Neutrosophic Topology International Journal of chemTech Research vol 10 pp 449-458.
[23] Wadei F, Al-Omeri and Saeid Jafari 2019 Neutrosophic pre-continuity multifunctions and almost pre-continuity multifunctions *Neutrosophic Sets and Systems* vol 27 pp 53-69.