Neutrosophic Nano ideal topological structure

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Abstract: This paper addressed the concept of Neutrosophic nano ideal topology which is induced by the two literature, they are nano topology and ideal topological spaces. We defined its local function, closed set and also defined and give new dimnesion to codense ideal by incorporating it to ideal topological structures. we investigate some properties of neutrosophic nano topology with ideal.

Keywords: neutrosophic nano ideal, neutrosophic nano local function, topological ideal, neutrosophic nano topological ideal.

1 Introduction and Preliminaries

In 1983, K. Atanassov [1] proposed the concept of IFS(intuitionstic fuzzy set) which is a generalization of FS(fuzzy set) [17], where each element has true and false membership degree. Smarandache [15] coined the concept of NS (neutrosophic set) which is new dimension to the sets. Neutrosophic set is classified into three independently related functions namely, membership, indeterminacy function and non-membership function. Lellis Thivagar [8], introduced the new notion of neutrosophic nano topology, which consist of upper, lower approximation and boundary region of a subset of a universal set using an equivalence class on it. There have been wide range of studies on neutrosophic sets, ideals and nano ideals [9, 10, 11,12,13,14]. Kuratowski [7] and Vaidyanathaswamy [16] introduced the new concept in topological spaces, called ideal topological spaces and also local function in ideal topological space was defined by them. Afterwards the properties of ideal topological spaces studied by Hamlett and Jankovic[5,6].

In this paper, we introduce the new concept of neutrosophic nano ideal topological structures, which is a generalized concept of neutrosophic nano and ideal topological structure. Also defined the codense ideal in neutrosophic nano topological structure.
We recall some relevant basic definitions which are useful for the sequel and in particular, the work of M. L. Thivagar [8], Parimala et al [9], F. Smarandache [15].

Definition 1.1. Let U be universe of discourse and R be an indiscernibility relation on U. Then U is divided into disjoint equivalence classes. The pair (U, R) is said to be the approximation space. Let F be a NS in U with the true μ_F, the indeterminancy σ_F and the false function ν_F. Then,

(i) The lower approximation of F with respect to equivalence class R is the set denoted by $\overline{N}(F)$ and defined as follows
$\overline{N}(F) = \left\{ \left\langle a, \mu_{\overline{R}(F)}(a), \sigma_{\overline{R}(F)}(a), \nu_{\overline{R}(F)}(a) \right\rangle |y \in [a]_R, a \in U \right\}$

(ii) The higher approximation of F with respect to equivalence class R is the set is denoted by $\underline{N}(F)$ and defined as follows, $\underline{N}(F) = \left\{ \left\langle a, \mu_{\underline{R}(F)}(a), \sigma_{\underline{R}(F)}(a), \nu_{\underline{R}(F)}(a) \right\rangle |y \in [a]_R, a \in U \right\}$

(iii) The boundary region of F with respect to equivalence class R is the set of all objects is denoted by $B(F)$ and defined by$B(F) = \overline{N}(F) - \underline{N}(F)$.

where,

$$\mu_{\overline{R}(F)}(a) = \bigcup_{y_1 \in [a]_R} \mu_F(y_1),\ \sigma_{\overline{R}(F)}(a) = \bigcup_{y_1 \in [a]_R} \sigma_F(y_1),$$
$$\nu_{\overline{R}(F)}(a) = \bigcap_{y_1 \in [a]_R} \nu_F(y_1).\ \mu_{\underline{R}(F)}(a) = \bigcap_{y_1 \in [a]_R} \mu_F(y_1),$$
$$\sigma_{\underline{R}(F)}(a) = \bigcap_{y_1 \in [a]_R} \sigma_F(y_1),\ \nu_{\underline{R}(F)}(a) = \bigcap_{y_1 \in [a]_R} \nu_F(y_1).$$

Definition 1.2. Let U be a nonempty set and the neutrosophic sets X and Y in the form $X = \{\langle a, \mu_X(a), \sigma_X(a), \nu_X(a)\rangle,$
and $Y = \{\langle a, \mu_Y(a), \sigma_Y(a), \nu_Y(a)\rangle, a \in U\}$. Then the following statements hold:

(i) $0_N = \{\langle a, 0, 0, 1\rangle, a \in U\}$ and $1_N = \{\langle a, 1, 1, 0\rangle, a \in U\}$.

(ii) $X \subseteq y$ if and only if $\mu_X(a) \leq \mu_Y(a), \sigma_X(a) \leq \sigma_Y(a), \nu_X(a) \geq \nu_Y(a)$ for all $a \in U$.

(iii) $X = Y$ if and only if $X \subseteq Y$ and $Y \subseteq X$.

(iv) $X^C = \{\langle a, \nu_X(a), 1 - \sigma_X(a), \mu_X(a)\rangle, a \in U\}$.

(v) $X \cap Y$ if and only if $\mu_X(a) \wedge \mu_X(a), \sigma_X(a) \wedge \sigma_Y(a), \nu_Y(a) \vee \nu_Y(a)$ for all $a \in U$.

(vi) $X \cup Y$ if and only if $\mu_Y(a) \vee \mu_Y(a), \sigma_X(a) \vee \sigma_Y(a), \nu_X(a) \wedge \nu_Y(a)$ for all $a \in U$.

(vii) $X - Y$ if and only if $\mu_X(a) \wedge \nu_Y(a), \sigma_X(a) \wedge 1 - \sigma_Y(a), \nu_X(a) \vee \mu_Y(a)$ for all $a \in U$.

Definition 1.3. Let X be a non-empty set and I is a neutrosophic ideal (NI for short) on X if

(i) $A_1 \in I$ and $B_1 \subseteq A_1 \Rightarrow B_1 \in I$ [heredity],

(ii) $A_1 \in I$ and $B_1 \in I \Rightarrow A_1 \cup B_1 \in I$ [finite additivity].

2 Neutrosophic nano ideal topological spaces

In this section we introduce a new type of local function in neutrosophic nano topological space. Before that we shall consider the following concepts.

Neutrosophic nano ideal topological space(in short NNI) is denoted by $(U, \tau_{\mathcal{N}}(F), I)$, where $(U, \tau_{\mathcal{N}}(F), I)$ is a neutrosophic nano topological space(in short NNT) $(U, \tau_{\mathcal{N}}(F))$ with an ideal I on U

Definition 2.1. Let $(U, \tau_{\mathcal{N}}(F), I)$ be a NNI with an ideal I on U and $(.)^*_{\mathcal{N}}$ be a set of operator from $P(U)$ to $P(U) \times P(U)$ ($P(U)$ is the set of all subsets of U). For a subset $X \subset U$, the neutrosophic nano local function $X^*_{\mathcal{N}}(I, \tau_{\mathcal{N}}(F))$ of X is the union of all neutrosophic nano points (NNP, for short) $C(\alpha, \beta, \gamma)$ such that $X^*_{\mathcal{N}}(I, \tau_{\mathcal{N}}(F)) = \vee\{C(\alpha, \beta, \gamma) \in U : X \cap G \notin I \text{for all } G \in N(C(\alpha, \beta, \gamma))\}$. We will simply write $X^*_{\mathcal{N}}$ for $X^*_{\mathcal{N}}(I, \tau_{\mathcal{N}}(F))$.

Example 2.2. Let $(U, \tau_{\mathcal{N}}(F))$ be a neutrosophic nano topological space with an ideal I on U and for every $X \subseteq U$.

(i) If $I = \{0_\sim\}$, then $X^*_{\mathcal{N}} = \mathcal{N}cl(X)$,

(ii) If $I = P(U)$, then $X^*_{\mathcal{N}} = 0_\sim$.

Theorem 2.3. Let $(U, \tau_{\mathcal{N}}(F))$ be a NNT with ideals I, I' on U and X, B be subsets of U. Then

(i) $X \subseteq B \Rightarrow X^*_{\mathcal{N}} \subseteq B^*_{\mathcal{N}}$,

(ii) $I \subseteq I' \Rightarrow X^*_{\mathcal{N}}(I') \subseteq X^*_{\mathcal{N}}(I)$,

(iii) $X^*_{\mathcal{N}} = \mathcal{N}cl(X^*_{\mathcal{N}}) \subseteq \mathcal{N}cl(X)$ ($X^*_{\mathcal{N}}$ is a neutrosophic nano closed subset of $\mathcal{N}cl(X)$),

(iv) $(X^*_{\mathcal{N}})^*_{\mathcal{N}} \subseteq X^*_{\mathcal{N}}$,

(v) $X^*_{\mathcal{N}} \cup B^*_{\mathcal{N}} = (X \cup B)^*_{\mathcal{N}}$,

(vi) $X^*_{\mathcal{N}} - B^*_{\mathcal{N}} = (X - B)^*_{\mathcal{N}} - B^*_{\mathcal{N}} \subseteq (X - B)^*_{\mathcal{N}}$,

(vii) $V \in \tau_{\mathcal{N}}(F) \Rightarrow V \cap X^*_{\mathcal{N}} = V \cap (V \cap X)^*_{\mathcal{N}} \subseteq (V \cap X)^*_{\mathcal{N}}$ and

(viii) $J \in I \Rightarrow (X \cup J)^*_{\mathcal{N}} = X^*_{\mathcal{N}} = (X - J)^*_{\mathcal{N}}$.

Proof. (i) Let $X \subset B$ and $a \in X^*_{\mathcal{N}}$. Assume that $a \notin B^*_{\mathcal{N}}$. We have $G_{\mathcal{N}} \cap B \in I$ for some $G_{\mathcal{N}} \in G_{\mathcal{N}}(a)$. Since $G_{\mathcal{N}} \cap X \subseteq G_{\mathcal{N}} \cap B$ and $G_{\mathcal{N}} \cap B \in I$, we obtain $G_{\mathcal{N}} \cap X \in I$ from the definition of ideal. Thus, we have $a \notin X^*_{\mathcal{N}}$. This is a contradiction. Clearly, $X^*_{\mathcal{N}} \subseteq B^*_{\mathcal{N}}$.
(ii) Let $I \subseteq I'$ and $a \in X^*_{\mathcal{N}}(I')$. Then we have $G_{\mathcal{N}} \cap X \notin I'$ for every $G_{\mathcal{N}} \in G_{\mathcal{N}}(a)$. By hypothesis, we obtain $G_{\mathcal{N}} \cap X \notin I$. So $a \in X^*_{\mathcal{N}}(I)$.
(iii) Let $a \in X^*_{\mathcal{N}}$. Then for every $G_{\mathcal{N}} \in G_{\mathcal{N}}(a), G_{\mathcal{N}} \cap X \notin I$. This implies that $G_{\mathcal{N}} \cap X \neq 0_\sim$. Hence

$a \in \mathcal{N}cl(X)$.
(iv) From (iii), $(X^*_{\mathcal{N}})^*_{\mathcal{N}} \subseteq \mathcal{N}cl(X^*_{\mathcal{N}}) = X^*_{\mathcal{N}}$, since $X^*_{\mathcal{N}}$ is a neutrosophic nano closed set.
The proofs of the other conditions are also obvious.
Theorem 2.4. If $(U, \tau_{\mathcal{N}}(F), I)$ is a NNT with an ideal I and $X \subseteq X^*_{\mathcal{N}}$, then $X^*_{\mathcal{N}} = \mathcal{N}cl(X^*_{\mathcal{N}}) = \mathcal{N}cl(X)$.
Proof. For every subset X of U, we have $X^*_{\mathcal{N}} = \mathcal{N}cl(X^*) \subseteq \mathcal{N}cl(X)$, by Theorem 2.3. (iii) $X \subseteq X^*_{\mathcal{N}}$ implies that $\mathcal{N}cl(X) \subseteq Ncl(X^*_{\mathcal{N}})$ and so $X^*_{\mathcal{N}} = \mathcal{N}cl(X^*_{\mathcal{N}}) = \mathcal{N}cl(X)$.

Definition 2.5. Let $(U, \tau_{\mathcal{N}}(F))$ be a NNT with an ideal I on U. The set operator $\mathcal{N}cl^*$ is called a neutrosophic nano$*$-closure and is defined as $\mathcal{N}cl^*(X) = X \cup X^*_{\mathcal{N}}$ for $X \subseteq a$.

Theorem 2.6. The set operator $\mathcal{N}cl^*$ satisfies the following conditions:

(i) $X \subseteq \mathcal{N}cl^*(X)$,

(ii) $\mathcal{N}cl^*(0_\sim) = 0_\sim$ and $\mathcal{N}cl^*(1_\sim) = 1_\sim$,

(iii) If $X \subset B$, then $\mathcal{N}cl^*(X) \subseteq \mathcal{N}cl^*(B)$,

(iv) $\mathcal{N}cl^*(X) \cup \mathcal{N}cl^*(B) = \mathcal{N}cl^*(X \cup B)$.

(v) $\mathcal{N}cl^*(\mathcal{N}cl^*(X)) = \mathcal{N}cl^*(X)$.

Proof. The proofs are clear from Theorem 2.3 and the definition of $\mathcal{N}cl^*$.
Now, $\tau_{\mathcal{N}}(F)^*(I, \tau_{\mathcal{N}}(F)) = \{V \subset U : \mathcal{N}cl^*(U - V) = U - V\}$. $\tau_{\mathcal{N}}(F)^*(I, \tau_{\mathcal{N}}(F))$ is called neutrosophic nano$*$-topology which is finer than $\tau_{\mathcal{N}}(F)$ (we simply write $\tau_{\mathcal{N}}(F)^*$ for $\tau_{\mathcal{N}}(F)^*(I, \tau_{\mathcal{N}}(F))$). The elements of $\tau_{\mathcal{N}}(F)^*(I, \tau_{\mathcal{N}}(F))$ are called neutrosophic nano$*$-open (briefly, $\mathcal{N}*$-open) and the complement of an $\mathcal{N}*$-open set is called neutrosophic nano$*$-closed (briefly, $\mathcal{N}*$-closed). Here $\mathcal{N}cl^*(X)$ and $\mathcal{N}int^*(X)$ will denote the closure and interior of X respectively in $(U, \tau_{\mathcal{N}}(F)^*)$.
Remark 2.7. (i) We know from Example 2.2 that if $I = \{0_\sim\}$ then $X^*_{\mathcal{N}} = \mathcal{N}cl(X)$. In this case, $\mathcal{N}cl^*(X) = \mathcal{N}cl(X)$.
(ii) If $(U, \tau_{\mathcal{N}}(F), I)$ is a NNI with $I = \{0_\sim\}$, then $\tau_{\mathcal{N}}(F)^* = \tau_{\mathcal{N}}(F)$.
Definition 2.8. A basis $\beta(I, \tau_{\mathcal{N}}(F))$ for $\tau_{\mathcal{N}}(F)^*$ can be described as follows:
$\beta(I, \tau_{\mathcal{N}}(F)) = \{X - B : X \in \tau_{\mathcal{N}}(F), B \in I\}$.
Theorem 2.9. Let $(U, \tau_{\mathcal{N}}(F))$ be a NNT and I be an ideal on U. Then $\beta(I, \tau_{\mathcal{N}}(F))$ is a basis for $\tau_{\mathcal{N}}(F)^*$.

Proof. We have to show that for a given space $(U, \tau_{\mathcal{N}}(F))$ and an ideal I on U, $\beta(I, \tau_{\mathcal{N}}(F))$ is a basis for $\tau_{\mathcal{N}}(F)^*$. If $\beta(I, \tau_{\mathcal{N}}(F))$ is itself a neutrosophic nano topology, then we have $\beta(I, \tau_{\mathcal{N}}(F)) = \tau_{\mathcal{N}}(F)^*$ and all the open sets of $\tau_{\mathcal{N}}(F)^*$ are of simple form $X - B$ where $X \in \tau_{\mathcal{N}}(F)$ and $B \in I$.
Theorem 2.10. Let $(U, \tau_{\mathcal{N}}(F), I)$ be a NNT with an ideal I on U and $X \subseteq U$. If $X \subseteq X^*_{\mathcal{N}}$, then

(i) $\mathcal{N}cl(X) = \mathcal{N}cl^*(X)$,

(ii) $\mathcal{N}int(U - X) = \mathcal{N}int^*(U - X)$.

Proof. (i) Follows immediately from Theorem 2.4.
(ii) If $X \subseteq X^*_{\mathcal{N}}$, then $\mathcal{N}cl(X) = \mathcal{N}cl^*(X)$ by (i) and so $U - \mathcal{N}cl(X) = U - \mathcal{N}cl^*(X)$. Therefore, $\mathcal{N}int(U - X) = \mathcal{N}int^*(U - X)$.

Theorem 2.11. Let $(U, \tau_{\mathcal{N}}(F), I)$ be a NNT with an ideal I on U and $X \subseteq X$. If $X \subseteq X^*_{\mathcal{N}}$, then $X^*_{\mathcal{N}} = \mathcal{N}cl(X^*_{\mathcal{N}}) = n\text{-}cl(X) = \mathcal{N}cl^*(X)$.

Definition 2.12. A subset A of a neutrosophic nano ideal topological space $(U, \tau_{\mathcal{N}}(F), I)$ is $\mathcal{N}*$-dense in itself (resp. $\mathcal{N}*$-perfect) if $X \subseteq X^*_{\mathcal{N}}$ (resp. $X = X^*_{\mathcal{N}}$).

Remark 2.13. A subset X of a neutrosophic nano ideal topological space $(U, \tau_{\mathcal{N}}(F), I)$ is $\mathcal{N}^*$-closed if and only if $X^*_{\mathcal{N}} \subseteq X$.

For the relationship related to several sets defined in this paper, we have the following implication:

$$\mathcal{N}*\text{-dense in itself} \Leftarrow \mathcal{N}*\text{-perfect} \Rightarrow \mathcal{N}^*\text{-closed}$$

The converse implication are not satisfied asthe following shows.

Example 2.14. Let U be the universe, $X = \{P_1, P_2, P_3, P_4, P_5\} \subset U$, $U/R = \{\{P_1, P_2\}, \{P_3\}, \{P_4, P_5\}\}$ and $\tau_{\mathcal{N}}(F) = \{1_\sim, 0_\sim, \overline{\mathcal{N}}, \underline{\mathcal{N}}, B\}$ and the ideal $I = 0_\sim, 1_\sim$. For $X = \{< P_1, (.5, .4, .7) >, < P_2, (.6, .4, .5) >, < P_3, (.4, .5, .4) >, < P_4, (.7, .3, .4) >, < P_5, (.8, .5, .2) >\}$, $\underline{N}(X) = \{\frac{P_1, P_2}{.5,.4,.7}, \frac{P_3}{.4,.5,.4}, \frac{P_4, P_5}{.7,.3,.4}\}$, $\overline{N}(X) = \{\frac{P_1, P_2}{.6,.4,.5}, \frac{P_3}{.4,.5,.4}, \frac{P_4, P_5}{.8,.5,.2}\}$, $B(X) = \{\frac{P_1, P_2}{.6,.4,.5}, \frac{P_3}{.4,.5,.4}, \frac{P_4, P_5}{.4,.3,.7}\}$. If $I = 0_\sim$ then $X^*_{\mathcal{N}} = Ncl(a)$. Thus $X \subseteq X^*_{\mathcal{N}}$. Hence X is $\mathcal{N}^*$-dense but not $\mathcal{N}^*$-perfect.
If $I = 1_\sim$ then $X^*_{\mathcal{N}} = 0_\sim$. Thus $X \supseteq X^*_{\mathcal{N}}$. Hence $X^*_{\mathcal{N}}$ is $\mathcal{N}^*$-closed but not $\mathcal{N}^*$-perfect.

Lemma 2.15. Let $(U, \tau_{\mathcal{N}}(F), I)$ be a NNI and $X \subseteq U$. If X is $\mathcal{N}*$-dense in itself, then $X^*_{\mathcal{N}} = \mathcal{N}cl(X^*_{\mathcal{N}}) = \mathcal{N}cl(X) = \mathcal{N}cl^*(X)$.
Proof. Let X be $\mathcal{N}*$-dense in itself. Then we have $X \subseteq X^*_{\mathcal{N}}$ and using Theorem 2.11 we get$X^*_{\mathcal{N}} = \mathcal{N}cl(X^*_{\mathcal{N}}) = \mathcal{N}cl(X) = \mathcal{N}cl^*(X)$.

Lemma 2.16. If $(U, \tau_{\mathcal{N}}(F), I)$ is a NNT with an ideal I and $X \subseteq U$, then $X^*_{\mathcal{N}}(I, \tau_{\mathcal{N}}(F)) = X^*_{\mathcal{N}}(I, \tau_{\mathcal{N}}(F)^*)$ and hence $\tau_{\mathcal{N}}(F)^* = \tau_{\mathcal{N}}(F)^{**}$.

3 $\tau_{\mathcal{N}}(F)$-codence ideal

n this section we incorporated codence ideal [5] in ideal topological space and introduce similar concept in neutrosophic nano ideal topological spaces.

Definition 3.1. An ideal I in a space $(U, \tau_{\mathcal{N}}(F), I)$ is called $\tau_{\mathcal{N}}(F)$-codense ideal if $\tau_{\mathcal{N}}(F) \cap I = \{0_\sim\}$.
Following theorems are related to $\tau_{\mathcal{N}}(F)$-codense ideal.

Theorem 3.2. Let $(U, \tau_{\mathcal{N}}(F), I)$ be an NNI and I is $\tau_{\mathcal{N}}(F)$-codense with $\tau_{\mathcal{N}}(F)$. Then $U = U^*_{\mathcal{N}}$.
Proof. It is obvious that $U^*_{\mathcal{N}} \subseteq U$. For converse, suppose $a \in U$ but $a \notin U^*_{\mathcal{N}}$. Then there exists $G_x \in \tau_{\mathcal{N}}(F)(a)$ such that $G_x \cap U \in I$. That is $G_x \in I$, a contradiction to the fact that $\tau_{\mathcal{N}}(F) \cap I = \{0_\sim\}$. Hence $U = U^*_{\mathcal{N}}$.

Theorem 3.3. Let $(U, \tau_{\mathcal{N}}(F), I)$ be a NNI. Then the following conditions are equivalent:

(i) $U = U^*_{\mathcal{N}}$.

(ii) $\tau_{\mathcal{N}}(F) \cap I = \{0_\sim\}$.

(iii) If $J \in I$, then $\mathcal{N}int(J) = 0_\sim$.

(iv) For every $X \in \tau_{\mathcal{N}}(F)$, $X \subseteq X^*_{\mathcal{N}}$.

Proof. By Lemma 2.16, we may replace '$\tau_{\mathcal{N}}(F)$' by '$\tau_{\mathcal{N}}(F)^*$' in (ii), '$\mathcal{N}int(J) = 0_\sim$' by '$\mathcal{N}int^*(J) = 0_\sim$' in (iii) and '$X \in \tau_{\mathcal{N}}(F)$' by '$X \in \tau_{\mathcal{N}}(F)^*$' in (iv).

4 Conclusions

this paper, we introduced the notion of neutrosophic nano ideal topological structures and investigated some relations over neutrosophic nano topology and neutrosophic nano ideal topological structures and studied some of its basic properties. In future, it motivates to apply this concepts in graph structures.

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