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An Introduction to Neutrosophic Minimal Structure Spaces

M. Karthika [1], M. Parimala [1,*] and F. Smarandache [2]

[1] Department of Mathematics, Bannari Amman Institute of Technology, Sathyamangalam - 638 401, Tamil Nadu, India ; karthikamuthusamy1991@gmail.com, rishwanthpari@gmail.com

[2]Mathematics & Science Department, University of New Maxico, 705 Gurley Ave, Gallup, NM 87301, USA; fsmarandache@gmail.com

[*] Correspondence: rishwanthpari@gmail.com

Abstract. This paper is an introduction of neutrosophic minimal structure space and addresses properties of neutrosophic minimal structure space. Neutrosophic set has plenty of applications. This motivates us to present the concept of neutrosophic minimal structure space. We defined neutrosophic minimal structure space, closure and interior of a set, subspace. Some properties of neutrosophic minimal structure space are also studied. Finally, Decision making problem solved using score function.

Keywords: Neutrosophic minimal structure; N_m-closure; N_m-interior; N_m-connectedness.

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1. **Introduction**

Zadeh's [23] Fuzzy set laid the foundation of many theories such as intuitionistic fuzzy set and neutrosophic set, rough sets etc. Later, researchers developed K. T. Atanassov's [4] intuitionistic fuzzy set theory in many fields such as differential equations, topology, computer science and so on. F. Smarandache [20, 21] found that some objects have indeterminacy or neutral other than membership and non-membership. So he coined the notion of neutrosophy. Researchers [12, 15–18] applied the concept of neutrosophy when object has inconsistent, incomplete information. The universal set X and $\emptyset$ forms a topology (Munkrer [11]). Popa [14] introduced minimal structures and defined separation axioms using minimal structure. M. Alimohammady, M. Roohi [5] introduced fuzzy minimal structure in lowen sense. S.Bhattacharya (Halder) [6] presented the concept of intuitionistic fuzzy minimal space.

1.1. *Motivation and Objective*

In general topology, the whole set and empty set forms a space with minimal structure. Supra topological space is also a space with neutrosophic minimal structure. These are all the generalization of topological spaces. Our objective is to introduce neutrosophic universal set and neutrosophic null set with neutrosophic minimal structure. It is a generalization of neutrosophic topological space. This paper consisting of basic definitions such as interior, closure, open, closed, subspace with minimal structure and its properties.

1.2. *Limitations*

Neutrosophic topological space, neutrosophic supra topological space are space with neutrosophic minimal structure. The converse is not true that is space with neutrosophic minimal structure is not a neutrosophic supra topological space or neutrosophic topological space.

In section 1, the basic definitions are presented which are useful for our paper and in section 2, the basic definitions of neutrosophic minimal structure space are presented. In further sections some properties of neutrosophic minimal structure space are also investigated. Finally, we introduced an algorithm to solve some applications of neutrosophic minimal structure space. Note that neutrosophic topological space, neutrosophic supra topological space are neutrosophic minimal structure space but converse is not true.

2. **Preliminaries**

In this section, we presented the basic definitions developed by [15, 19–21].

Definition 2.1. [20, 21] A neutrosophic set(in short NS) U on a set $X \neq \emptyset$ is defined by

$U = \{\langle a, T_U(a), I_U(a), F_U(a)\rangle : a \in X\}$ where $T_U : X \to [0,1]$, $I_U : X \to [0,1]$ and $F_U : X \to [0,1]$ denotes the membership of an object, indeterminacy and non-membership of an object, for each $a \in X$ to U, respectively and $0 \leq T_U(a) + I_U(a) + F_U(a) \leq 3$ for each $a \in X$.

Definition 2.2. [19] Let $U = \{\langle a, T_U(a), I_U(a), F_U(a)\rangle : a \in X\}$ be a neutrosophic set.

(i) A neutrosophic set U is an empty set i.e., $U = 0_\sim$ if 0 is membership of an object and 1 is an indeterminacy and non-membership of an object respectively. i.e., $0_\sim = \{x, (0,1,1) : x \in X\}$

(ii) A neutrosophic set U is a universal set i.e., $U = 1_\sim$ if 1 is membership of an object and 0 is an indeterminacy and non-membership of an object respectively. $1_\sim = \{x, (1,0,0) : x \in X\}$

(iii) $U_1 \cup U_2 = \{a, max\{T_{U_1}(a), T_{U_2}(a)\}, min\{I_{U_1}(a), I_{U_2}(a)\}, min\{F_{U_1}(a), F_{U_2}(a)\} : a \in X\}$

(iv) $U_1 \cap U_2 = \{a, min\{T_{U_1}(a), T_{U_2}(a)\}, max\{I_{U_1}(a), I_{U_2}(a)\}, max\{F_{U_1}(a), F_{U_2}(a)\} : a \in X\}$

(v) $U_1^C = \{a, F_U(a), 1 - I_U(a), T_U(a) : a \in X\}$

Definition 2.3. [19] A neutrosophic topology (NT) in Salama's sense on a nonempty set X is a family τ of NSs in X satisfying three axioms:

(1) Empty set ($0_\sim$) and universal set($1_\sim$) are members of τ.

(2) $U_1 \cap U_2 \in \tau$ where $U_1, U_2 \in \tau$.

(3) $\bigcup_{i=1}^{\infty} U_i \in \tau$ where each $U_i \in \tau$.

Each neutrosophic sets in neutrosophic topological spaces are called neutrosophic open sets. Its complements are called neutrosophic closed sets.

Definition 2.4. [19] Let NS U in NTS X. Then a neutrosophic interior of U and a neutrosophic closure of U are defined by

n-int(U) = max $\{F : F\, is\, an\, Neutrosophic\, open\, set\, in\, X\, and\, F \leq U\}$ and

n-cl(U) = min $\{F : F\, is\, an\, Neutrosophic\, closed\, set\, inX\, and\, F\ \geq U\}$ respectively.

Definition 2.5. [15] A neutrosophic supra topology (in short, NST) on a nonempty set X is a family τ of NSs in X satisfying the following axioms:

(1) Empty set ($0_\sim$) and universal set($1_\sim$) are members of τ.

(2) $\bigcup_{i=1}^{\infty} U_i \in \tau$ where each $U_i \in \tau$.

3. Neutrosophic Minimal Structure Spaces

Neutrosophic minimal structure space is defined and studied its properties in this section.

Definition 3.1. Let the neutrosophic minimal structure space over a universal set X be denoted by N_m. N_m is said to be neutrosophic minimal structure space (in short, NMS) over X if it satisfying following the axiom:

(1) $0_\sim, 1_\sim \in N_m$.

A family of neutrosophic minimal structure space is denoted by (X, N_{mX})

Note that neutrosophic empty set and neutrosophic universal set can form a topology and it is known as neutrosophic minimal structure space.

Each neutrosophic set in neutrosophic minimal structure space is neutrosophic minimal open set.

The complement of neutrosophic minimal open set is neutrosophic minimal closed set.

Remark 3.2. Each neutrosophic set in neutrosophic minimal structure space is neutrosophic minimal open set.
The complement of neutrosophic minimal open set is neutrosophic minimal closed set.
In this paper, we refer definition 2.2 for basic operations.

Example 3.3. We know that $0_\sim = \{x, (0, 1, 1)\}$ & $1_\sim = \{x, (1, 0, 0)\}$ are neutrosophic minimal open sets. Lets find out their complements.
$0_\sim^C = \{x, (1, 0, 0)\} = 1_\sim$ and $1_\sim^C = \{x, (0, 1, 1)\} = 0_\sim$. This clears that $0_\sim$ and $1_\sim$ are both neutrosophic minimal open and closed set.

Remark 3.4. From Definition 3.1. the following are obvious

(1) Neutrosophic supra topological spaces are neutrosophic minimal structure space but converse not true.
(2) Similarly, Neutrosophic topological spaces are neutrosophic minimal structure space but converse is not true.

The following Example 3.5 proves the above Remark 3.4.

Example 3.5. Let $A = \{< 0.6, 0.4, 0.3 >: a\}$, $B = \{< 0.6, 0.5, 0.1 >: a\}$ are neutrosophic sets over the universal set $X = \{a\}$. Then the neutrosophic minimal structure space is $N_m = \{0, 1, A, B\}$. But N_m is not a neutrosophic topological space and not a neutrosophic supra topological space, since arbitrary union and finite intersection doesn't hold in N_m.

Definintion 3.6. A is N_m-closed if and only if $N_m cl(A) = A$.
Similarly, A is a N_m-open if and only if $N_m int(A) = A$.

Definintion 3.7. Let N_m be any neutrosophic minimal structure space and A be any neutrosophic set. Then

(1) Every $A \in N_m$ is open and its complement is closed.
(2) N_m-closure of $A = min\{F : F\ is\ a\ neutrosophic\ minimal\ closed\ set\ and\ F \geq A\}$ and its denoted by $N_m cl(A)$.
(3) N_m-interior of $A = max\{F : F\ is\ a\ neutrosophic\ minimal\ open\ set\ and\ F \leq A\}$ and it is denoted by $N_m int(A)$.

In general $N_m int(A)$ is subset of A and A is a subset of $N_m cl(A)$.

Proposition 3.8. Suppose A and B are any neutrosophic set of neutrosophic minimal structure space N_m over X. Then

i. $N_m^C = \{0, 1, A_i^C\}$ where A_i^C is a complement of neutrosophic set A_i.
ii. $X - N_m int(B) = N_m cl(X - B)$.
iii. $X - N_m cl(B) = N_m int(X - B)$.
iv. $N_m cl(A^C) = (N_m cl(A))^C = N_m int(A)$.
v. N_m closure of an empty set is an empty set and N_m closure of a universal set is a universal set. Similarly, N_m interior of an empty set and universal set respectively an empty and a universal set.
vi. If B is a subset of A then $N_m cl(B) \leq N_m cl(A)$ and $N_m int(B) \leq N_m int(A)$.
vii. $N_m cl(N_m cl(A)) = N_m cl(A)$ and $N_m int(N_m int(A)) = N_m int(A)$.
viii. $N_m cl(A \vee B) = N_m cl(A) \vee N_m cl(B)$
ix. $N_m cl(A \wedge B) = N_m cl(A) \wedge N_m cl(B)$

Proof. (i) We know that $A^C = X - A$. Then $N_m cl(X - A) = N_m cl(A^C) = (N_m cl(A))^C = N_m int(A)$, from (iv).
Similarly for (ii).
(vi) Let $B \leq A$. We know that $B \leq N_m cl(B)$ and $A \leq N_m cl(B)$. So $B \leq N_m cl(B) \leq A \leq N_m cl(A)$. Therefore $N_m cl(B) \leq N_m cl(A)$.
Proof of (vii) is straight forward.
(viii) We know that $A \leq A \vee B$ and $B \leq A \vee B$. $N_m cl(A) \leq N_m cl(A \vee B)$ and $N_m cl(B) \leq N_m cl(A \vee B)$ this implies $N_m cl(A) \vee N_m cl(B) \leq N_m cl(A \vee B)$.$\longrightarrow (*)$
Also $A \leq N_m cl(A)$ and $B \leq N_m cl(B) \Rightarrow A \vee B \leq N_m cl(A) \vee N_m cl(B)$. $N_m cl(A \vee B) \leq N_m cl(N_m cl(A) \vee N_m cl(B)) = N_m cl(A) \vee N_m cl(B) \longrightarrow (**)$.
From (*) and (**), we have $N_m cl(A \vee B) = N_m cl(A) \vee N_m cl(B)$.

Example 3.9. Consider Example 3.5, the complement of N_m is $\{0, 1, A^C, B^C\}$ where $A^C = \{< 1 - 0.6, 1 - 0.4, 1 - 0.3 > /a : a \in X\} = \{< 0.4, 0.6, 0.7 > /a : a \in X\}$ and $B^C = \{< 1 - 0.6, 1 - 0.5, 1 - 0.1 > /a : a \in X\} = \{< 0.4, 0.5, 0.9 > /a : a \in X\}$.

Definintion 3.10. A function $f : (X, N_{mX}) \to (Y, N_{mY}))$ is called neutrosophic minimal continuous function if and only if $f^{-1}(V) \in N_{mX}$ whenever $V \in N_{mY}$.

Definintion 3.11. Boundary of a neutrosophic set A (in short Bd(A)) of neutrosophic minimal structure (X, N_{mX}) is the intersection of $N_m closure$ of the set A and $N_m closure$ of $X - A$. i.e., $Bd(A) = N_m cl(A) \cap N_m cl(X - A)$

Theorem 3.12. If (X, N_{mX}) and (Y, N_{mY}) are neutrosophic minimal structure space . Then

(1) Identity map from (X, N_{mX}) to (Y, N_{mY}) is a neutrosophic minimal continuous function.

(2) Any constant function which maps from (X, N_{mX}) to (Y, N_{mY}) is a neutrosophic minimal continuous function.

Proof. The proof is obvious.

Theorem 3.13. Let the map f from neutrosophic minimal structure space (X, N_{mX}) to neutrosophic minimal structure space (Y, N_{mY}). Then the following are equivalent,

(1) The map f is a neutrosophic minimal continuous function.

(2) $f^{-1}(V)$ is a neutrosophic minimal closed set for each neutrosophic minimal closed set $V \in N_{mY}$. .

(3) $N_m cl(f^{-1}(V)) \leq f^{-1}(N_m cl(V))$, for each $V \in N_{mY}$.

(4) $N_m cl(f(A)) \geq f(N_m cl(A))$, for each $A \in N_{mX}$.

(5) $N_m int(f^{-1}(V)) \geq f^{-1}(N_m int(V))$, for each $V \in N_{mX}$.

Proof. (1) $\Rightarrow$ (2): Let A be a N_m-closed in Y. Then $f^{-1}(A)^C = f^{-1}(A^C) \in N_{mX}$.
(2) $\Rightarrow$ (3): $N_m cl(f^{-1}(A) = \wedge\{D : f^{-1}(A) \leq D, D^C \in N_{mX}\} \leq \wedge\{f^{-1}(D) : A \leq D, D^C \in N_{mY}\} = f^{-1}(\{D : A \leq D^C \in N_{mY}\}) = f^{-1}(N_m cl(A))$.
(3) $\Rightarrow$ (4): Since $A \leq f^{-1}(f(A))$, then $N_m cl(A) \leq N_m cl f^{-1}(f(A)) \leq f^{-1}(N_m cl(f(A)))$. Therefore $f(N_m cl(A)) \leq N_m cl(f(A))$.
(4) $\Rightarrow$ (5): $f(N_m int(f^{-1}(A)))^C = f(N_m cl(f^{-1}(A))^C) = f(N_m cl(f(A)^C)) \leq N_m cl(f(f^{-1}(A^C))) \leq N_m cl(A^C) = (N_m int(A))^C$. This implies that $N_m int(f^{-1}(B))^C \leq f^{-1}(N_m int(A))^C = (f^{-1}(N_m int(A)))^C$.
Taking complement on both sides, $f^{-1}(N_m int(A)) \leq N_m int(f^{-1}(B))$.

Definition 3.14. Let (X, N_{mX}) be neutrosophic minimal structure space.

i. Arbitrary union of neutrosophic minimal open sets in (X, N_{mX}) is neutrosophic minimal open. (Union Property)

ii. Finite intersection of neutrosophic minimal open sets in (X, N_{mX}) is neutrosophic minimal open. (intersection Property)

4. Neutrosophic Minimal Subspace

In this section, we introduced the neutrosophic minimal subspace and investigate some properties of subspace.

Definition 4.1. Let A be a neutrosophic set in neutrosophic minimal structure space (X, N_{mX}). Then Y is said to be neutrosophic minimal subspace if $(Y, N_{mY}) = \{A \cap U : U \in N_{mY}\}$.

Lemma 4.2. If neutrosophic set b in the basis B for neutrosophic minimal structure space X. Then the collection $B_Y = \{b \cap Y : Y \subset X\}$ is a basis for neutrosophic minimal subspace on Y.

Proof. Given a neutrosophic set A in X and C is a neutrosophic set in both A and subset Y of X. Consider a basis element b of B such that C in b and in Y. Then $C \in B \cap Y \subset U \cap Y$. Hence B_Y is a basis for the neutrosophic minimal subspace on the set Y.

Lemma 4.3. Let (Y, N_{mY}) be a subspace of (X, N_{mX}). If A is a neutrosophic set in Y and $Y \subset X$. Then A is in (X, N_{mX}).

Proof. Given that neutrosophic set A in (Y, N_{mY}). $A = Y \cap B$ for some neutrosophic set $B \in X$. Since Y and B in X. Then A is in X.

Proposition 4.4. Suppose (Y, N_{mY}) is a neutrosophic minimal subspace of (X, τ_X).

(1) If the neutrosophic minimal structure space (X, N_{mX}) has the union property, then the subspace (Y, N_{mY}) also has union property.

(2) If the neutrosophic minimal structure space (X, N_{mX}) has the intersection property, then the subspace (Y, N_{mY}) also has union property.

Proof. Suppose the family of open set $\{V_i : i \in Y\}$ in neutrosophic minimal subspace(Y, N_{mY}) then there exist a family of open sets $\{U_j : j \in X\}$ in neutrosophic minimal structure space (X, N_{mX}) such that $V_i = U_j \cap A, \forall i \in Y$ where $A \in N_{mY}$. $\bigcup_{(i \in Y)} V_i = \bigcup_{(j \in X)} (U_j \cap A) = \bigcup_{(i \in Y)} U_j \cap A$. Since (X, N_{mX}) has union property then (Y, N_{mY}) also has union property. The proof of (ii) is similarly to (i).

Definition 4.5. Suppose (B, N_{mB}) and (C, N_{mC}) are neutrosophic minimal subspaces of neutrosophic minimal structure spaces (Y, N_{mY}) and (Z, N_{mZ}) respectively. Also, suppose that f is a mapping from (Y, N_{mY}) to (Z, N_{mZ}) is a mapping. We say that f is a mapping from (B, N_{mB}) into (C, N_{mC}) if the image of B under f is a subset of C.

Definition 4.6. Suppose (A, N_{mA}) and (B, N_{mB}) are neutrosophic minimal subspaces of neutrosophic minimal structure spaces (Y, N_{mY}) and (Z, N_{mZ}) respectively. The mapping f from (A, N_{mA}) into (B, N_{mB}) is called a

(1) comparative neutrosophic minimal continuous, if $f^1(W) \wedge A \in N_{mA}$ for every neutrosophic minimal structure set W in B,

(2) comparative neutrosophic minimal open, if $f(V) \in N_{mB}$ for every fuzzy set $V \in N_{mA}$.

X/E	c_1	c_2	c_3	....	c_n
a_1	d_{11}	d_{12}	d_{13}	....	d_{1n}
a_2	d_{21}	d_{22}	d_{23}	....	d_{2n}
.	.	.	.	.	.
a_m	d_{m1}	d_{m2}	d_{m3}	....	d_{mn}

TABLE 1. Attributes and Alternative

5. Applications

The application of neutrosophic minimal structure space is based on the minimal element and maximal element. In neutrosophic minimal structure space, $0_\sim$ is the minimal element and $1_\sim$ is the maximal element. The application of neutrosophic minimal structure space used in consumer theory where the customer has only two objective. In consumer theory, the customer has either minimize purchase cost and maximize the quantity or maximize the durability.

The following steps are proposed to take better decision.

Step 1.

Input m Attributes and n alternatives (See TABLE 1).

Step 2. Construct the neutrosophic minimal structure from the data. $\tau_k = \{0_\sim, 1_\sim, U_k\}$ where $U_k = \{d_{1k}, d_{2k} .... d_{mk}\}$

Step 3. compute the neutrosophic score function (in short, NF) using the following simple formula, $NF(U_k) = \frac{1}{3m}[\sum_{i=1}^{m}[2 + T_i - I_i - F_i]]$

Step 4. Arrange the score function U_k which we calculated in step 3 in ascending order. Choose the largest score value U_k for better decision.

Lets consider the following example. Let the set of variety of cars be $X = \{C_1, C_2, C_3\}$ and the parameter set $E = \{a = cost\ of\ the\ car, b = safety, c = maintenance\}$. A customer will assign minimum value of $0_\sim$ to bad features,maximum $1_\sim$ to the best feature of the product. Membership, indeterminacy and non-membership values taken from customer's review rating. Membership referred to cost of the car is worth to the model, safe and low maintenance cost. Non-membership referred to cost of the car is not worth to the model, not safe due to break failure or some other reason and high maintenance cost. Indeterminacy referred to neutrality of cost of the car, safe if drive safe and maintenance is neutral. Let us assume TABLE 2. values are taken from customer review rating for the models C_1, C_2 and C_3 with parameters a, b and c.

Step 2. The neutrosophic minimal structure

$\tau_1 = \{0_\sim, 1_\sim, U_1\}$ where $U_1 = \{(0.6, 0.2, 0.4), (0.7, 0.3, 0.4), (0.6, 0.3, 0.4)\}$

Similarly, $\tau_2 = \{0_\sim, 1_\sim, U_2\}$ where $U_2 = \{(0.6, 0.3, 0.4), (0.6, 0.3, 0.4), (0.5, 0.2, 0.4)\}$

X/E	C_1	C_2	C_3
a	(0.6,0.2,0.4)	(0.6,0.3,0.4)	(0.7,0.3,0.4)
b	(0.7,0.3,0.4)	(0.6,0.3,0.4)	(0.8,0.2,0.2)
c	(0.6,0.3,0.4)	(0.5,0.2,0.4)	(0.6,0.2,0.3)

Table 2. Input matrix

$\tau_3 = \{0_\sim, 1_\sim, U_3\}$ where $U_3 = \{(0.7, 0.3, 0.4), (0.8, 0.2, 0.2), (0.6, 0.2, 0.3)\}$

Step 3. Neutrosophic score functions are

$$NS(U_1) = 0.6556$$
$$NS(U_2) = 0.6333$$
$$NS(U_3) = 0.7222$$

Step 4. The neutrosophic score functions are arranged in ascending order as follows $U_2 \leq U_1 \leq U_3$. Based on score function, U_3 is the largest score function. U_3 related to the model C_3. Hence Model C_3 is best to buy.

Comparison Analysis: The existing and proposed notion of neutrosophic minimal structure space is compared in the below table.

Spaces	Uncertainty	Truth value of parameter	Uncertainty of parameter	False value of parameter.
Minimal structure space	-	-	-	-
Fuzzy minimal structure space	Present	Present	-	-
Intuitionistic Minimal structure space	Present	Present	Present	-
Neutrosophic minimal structure space	Present	Present	Present	present

Table 3. Comparison Table

6. Conclusions

In this paper, Neutrosophic minimal structure space is introduced and some of its properties investigated along with this. Neutrosophic minimal continuous and subspace are also investigated with few properties. Finally, application of neutrosophic minimal structure space is discussed. Future work of this paper is to investigate and study various open sets and separation axioms in neutrosophic minimal structure space. Also the application part discussed in this work leads to analyze in weak structure.

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