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Functions of $\text{Neu}_{g\zeta^*H}$ in NT Spaces

Myvizhi Muthuswamy ^{1,*} 

¹ Department of Mathematics, KPR Institute of Engineering and Technology, Coimbatore, 641407, Tamilnadu, India; myvizhi.m@kpriet.ac.in.

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Abstract

In this paper, the concept of $g\zeta^*$ -Neutrosophic Continuous Functions and $g\zeta^*$ -Neutrosophic Irresolute Functions were introduced and their characterizations were analyzed. Furthermore, the work is extended to $g\zeta^*$ -Homeomorphism and some of its properties are explored in Neutrosophic topological spaces.

Keywords: Neutrosophic Continuous Functions, Neutrosophic Irresolute Functions, Homeomorphism, Neutrosophic Topological Spaces.

1 | Introduction

Topology is traditionally defined as the mathematical study of shapes and topological spaces. Topology is an area of mathematics, which deals with the properties of space that is preserved under continuous deformations including stretching and bending. The term topology was introduced by Johann Benedict Listing in the 19th century. The theory of fuzzy topological spaces was introduced and developed by C.L. Chang (1968) [9]. Lowen innovatively proposed fuzzy topology in 1976. Later topological structures in fuzzy topological spaces were generalized to intuitionistic fuzzy topological spaces by Coker (1997) [10], A.A.Salama (2012) [52], and S.A.Albawi (2012) [53] devised the concept of Neutrosophic topological spaces. They extended the concept to generalized Neutrosophic topological spaces, and Neutrosophic Crisp topological concepts and studied various properties.

General topology or point-set topology is one of the most basic and traditional divisions within topology which studies the topological properties along with its structure. It is the foundation for several areas of research in topology such as Nano topology, digital topology, fuzzy topology, supra topology, Bi topology, and so on. Many authors like Abd El-Monsef M.E[1-3], Balachandaran K[11-13], Dontchev J[18-26], Hatir E[29-31], Jafari S[4, 14-17, 32-34], Jankovic D[35-37], Lellis Thivagar M[38-44], Levine N[45-48], Noiri T[49,50], Sundaram P[55-59], Tong J[60,61] and Veerakumar M.K.R.S[62] have contributed in the field of general topology.

A fuzzy set is a class of objects with a continuum of grades of membership and is characterized by the membership (characteristic) function, which assigns to each object a grade of membership ranging between zero and one. The notions of inclusion, union, intersection, complement, relation, convexity, etc., are extended to such sets, and various properties of these notions in the context of fuzzy sets are established.



Corresponding Author: myvizhi.m@kpriet.ac.in



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The traditional fuzzy set was introduced by Lot Aliasker Zadeh (1965) [63] which was characterized by the grade of the membership value. A fuzzy subset A of a universal set U is a function $A:U \rightarrow I$, where I is the interval $[0, 1]$ and is called a membership function.

The intuitionistic fuzzy set is an extension of the fuzzy set introduced by Atanassov (1983) [5-7] and is found to be more efficient in dealing with vagueness and ambiguity. It is characterized by a membership function $\mu_A(x)$ and a non-membership function $\gamma_A(x)$ with their sum being less than or equal to one $\mu_A(x) + \gamma_A(x) \leq 1$. This relaxes the enforced duality $\gamma_A(x) \leq 1 - \mu_A(x)$ from fuzzy set theory. An intuitionistic fuzzy set allows one to address the positive and negative sides of an imprecise concept separately. An intuitionistic fuzzy set is beneficial in decision-making problems, particularly in the case of medical diagnosis, sales analysis, new product marketing, financial services, etc. In recent times various applications of intuitionistic fuzzy sets have been used in artificial intelligence like intuitionistic fuzzy expert systems, intuitionistic fuzzy neural networks, intuitionistic fuzzy decision making, intuitionistic fuzzy machine learning, and intuitionistic fuzzy semantic representations. Using the notion of intuitionistic fuzzy sets, Dogan Coker (1997) [10] introduced the notion of intuitionistic fuzzy topological spaces. Exploring the fundamental definitions with appropriate examples, he acquainted the definitions of intuitionistic fuzzy continuity, intuitionistic fuzzy compactness, and intuitionistic fuzzy connectedness and obtained several preservation properties and some characterizations concerning intuitionistic fuzzy connectedness.

The neutrosophic set was introduced by Smarandache [54] and the details of the neutrosophic sets are a generalization of intuitionistic fuzzy set. Salama A. A and Alblowi [53] introduced Neutrosophic topological space by using Neutrosophic sets in the year of 2012 and also Neutrosophic closed set and neutrosophic continuous function were introduced by the same author Salama A. A [52]. Arokiarani et al. [1] introduced the neutrosophic α -closed set in the year of 2017. Neutrosophic Homeomorphism plays an important role in Neutrosophic topology. Parimala M et al [51] presented by Neutrosophic Homeomorphism.

In this work, we introduced the $Neu_{g\zeta^*}\text{-CF}$ and $Neu_{g\zeta^*}\text{-IF}$ and also investigate the characteristics of $Neu_{g\zeta^*H}\text{-Functions}$.

2 | Preliminary Results

Definition 2.1. [53] Let $\mathbb{J}$ be a non-empty fixed set. A Neu set E is an object having the form $E = \{\langle j, \mu_p(E(j)), \sigma_q(E(j)), v_r(E(j)) \rangle \text{ for every } j \in \mathbb{J}\}$, where $\mu_p(E(j))$ represents the membership, $\sigma_q(E(j))$ represents indeterminacy and $v_r(E(j))$ represents non-membership functions of each element $j \in \mathbb{J}$ to the set E .

Remark 2.1. [53] A Neu set $E = \{\langle j, \mu_p(E(j)), \sigma_q(E(j)), v_r(E(j)) \rangle \text{ for every } j \in \mathbb{J}\}$ and it can be denoted as an ordered triple $\{\langle \mu_p(E(j)), \sigma_q(E(j)), v_r(E(j)) \rangle\}$ on $\mathbb{J}$.

Definition 2.2. [51] In Neu Topological Spaces,

for every $j \in \mathbb{J}$, $0_{(N)}$ defined as

$$0_{(N)} = \langle j, 0, 0, 1 \rangle$$

$$0_{(N)} = \langle j, 0, 1, 1 \rangle$$

$$0_{(N)} = \langle j, 0, 1, 0 \rangle$$

$$0_{(N)} = \langle j, 0, 0, 0 \rangle$$

for every $j \in \mathbb{J}$, $1_{(N)}$ defined as

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Definition 2.3. [51] Let E be the neu set of the form $E = \{\langle j, \mu_p(E(j)), \sigma_q(E(j)), v_r(E(j)) \rangle \text{ for every } j \in \mathbb{J}\}$ and then $[E^c]$ defined as: $E^c = \{\langle j, 1 - \mu_p(E(j)), 1 - \sigma_q(E(j)), 1 - v_r(E(j)) \rangle \text{ for every } j \in \mathbb{J}\}$.

Definition 2.4. [52] Let E and F be two neu sets of the form, $E = \{\langle j, \mu_p(E(j)), \sigma_q(E(j)), v_r(E(j)) \rangle \text{ for every } j \in \mathbb{J}\}$

and $F = \{\langle j, \mu_p(F(j)), \sigma_q(F(j)), v_r(F(j)) \rangle \text{ for every } j \in \mathbb{J}\}$. Then,

- i). The Subsets of E and F defined as $E \subseteq F$ if and only if $\mu_p(E(j)) \leq \mu_p(F(j)), \sigma_q(E(j)) \geq \sigma_q(F(j)), v_r(E(j)) \geq v_r(F(j))$
- ii). The Subsets of $E = F$ if and only if $E \subseteq F$ and $F \subseteq E$
- iii). The Union of subsets E and F defined as

$$E \cup F = \{j, \max[\mu_p(E(j)), \mu_p(F(j))], \max[\sigma_q(E(j)), \sigma_q(F(j))], \min[v_r(E(j)), v_r(F(j))]\} \text{ for every } j \in \mathbb{J}.$$

- iv). The Intersection of subsets E and F defined as

$$E \cap F = \{j, \min[\mu_p(E(j)), \mu_p(F(j))], \min[\sigma_q(E(j)), \sigma_q(F(j))], \max[v_r(E(j)), v_r(F(j))]\} \text{ for every } j \in \mathbb{J}.$$

Definition 2.5. [52] A Neu topological space $(\mathbb{J}, \tau)$ satisfies the following conditions:

- i). $0_{(N)}, 1_{(N)} \in \tau$
- ii). $K_1 \cap K_2 \in \tau$ for any $K_1, K_2 \in \tau$
- iii). $\cup K_i \in \tau$ for every $\{K_i : i \in I\} \subseteq \tau$.

Then $(\mathbb{J}, \tau)$ is called a Neu topological space.

Definition 2.6. [54] Let E be a Neu set in $(\mathbb{J}, \tau)$. Then

- i). $\text{Neu}_{\text{int}(E)} = \cup\{F / F \text{ is a Neu-O set in } (\mathbb{J}, \tau) \text{ and } F \subseteq E\};$
- ii). $\text{Neu}_{\text{cl}(E)} = \cap\{F / F \text{ is a Neu-C set in } (\mathbb{J}, \tau) \text{ and } F \supseteq E\}.$

3 | $\text{Neu}_{g\zeta^*}\text{-CF}$ in NTS's

Definition 3.1. A function $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ is said to be $\text{Neu}_{g\zeta^*}\text{-Continuous Functions}$ (briefly $\text{Neu}_{g\zeta^*}\text{-CF}$) if $\mathcal{D}^{-1}(\mathcal{P})$ is $\text{Neu}_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$ for each Neu-CS in (S, ω) .

Theorem 3.1. Each $\text{Neu}_{g\zeta^*}\text{-CF}$ is $\text{Neu}_{g_s}\text{-CF}$ (resp. $\text{Neu}_{\alpha_g}\text{-CF}, \text{Neu}_{gp}\text{-CF}, \text{Neu}_{gsp}\text{-CF}$). Converse is not true as shown in the following example.

Proof: Let $\mathcal{P}$ be a Neu-CS in (S, ω) . Since $\mathcal{D}$ is $\text{Neu}_{g\zeta^*}\text{-CF}$, $\mathcal{D}^{-1}(\mathcal{P})$ is $\text{Neu}_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$. Since each $\text{Neu}_{g\zeta^*}\text{-CS}$ is $\text{Neu}_{g_s}\text{-CS}$ (resp. $\text{Neu}_{\alpha_g}\text{-CS}, \text{Neu}_{gp}\text{-CS}, \text{Neu}_{gsp}\text{-CS}$), therefore $\mathcal{D}^{-1}(\mathcal{P})$ is $\text{Neu}_{g_s}\text{-CS}$ (resp. $\text{Neu}_{\alpha_g}\text{-CS}, \text{Neu}_{gp}\text{-CS}, \text{Neu}_{gsp}\text{-CS}$) in $(\mathcal{R}, \vartheta)$. Hence $\mathcal{D}$ is $\text{Neu}_{g_s}\text{-CF}$ (resp. $\text{Neu}_{\alpha_g}\text{-CF}, \text{Neu}_{gp}\text{-CF}, \text{Neu}_{gsp}\text{-CF}$).

Example 3.1. Assume $\mathbb{I} = \{u, v, w\}$ and then the Neu sets D_1, D_2, D_3, D_4 and H_1, H_2, H_3, H_4 are defined as

$$D_1 = \{(0.3, 0.3, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\}$$

$$D_2 = \{(0.4, 0.6, 0.6), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\}$$

$$D_3 = \{(0.4, 0.6, 0.6), (0.3, 0.2, 0.2), (0.3, 0.3, 0.2)\}$$

$$D_4 = \{(0.3, 0.3, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\} \text{ and}$$

$$H_1 = \{(0.4, 0.4, 0.4), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\}$$

$$H_2 = \{(0.3, 0.2, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\}$$

$$H_3 = \{(0.4, 0.4, 0.4), (0.3, 0.2, 0.2), (0.3, 0.2, 0.2)\}$$

$$H_4 = \{(0.3, 0.2, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\}$$

$$Neu_{g\zeta^*}\text{-CS} = \{(0.2, 0.2, 0.2), (0.5, 0.4, 0.4), (0.3, 0.3, 0.2)\} \text{ and}$$

$$Neu_{gs}\text{-CS} = \{(0.3, 0.2, 0.2), (0.3, 0.2, 0.2), (0.4, 0.4, 0.4)\}. \text{ Here } \mathcal{D}^{-1}(H_3^c) \text{ is } Neu_{gs}\text{-CS not } Neu_{g\zeta^*}\text{-CS}.$$

Example 3.2. Assume $\mathbb{I} = \{u, v, w\}$ and then the Neu sets D_1, D_2, D_3, D_4 and I_1, I_2, I_3, I_4 are defined as

$$D_1 = \{(0.3, 0.3, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\}$$

$$D_2 = \{(0.4, 0.6, 0.6), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\}$$

$$D_3 = \{(0.4, 0.6, 0.6), (0.3, 0.2, 0.2), (0.3, 0.3, 0.2)\}$$

$$D_4 = \{(0.3, 0.3, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\} \text{ and}$$

$$I_1 = \{(0.3, 0.3, 0.4), (0.4, 0.3, 0.3), (0.3, 0.4, 0.4)\}$$

$$I_2 = \{(0.3, 0.3, 0.2), (0.4, 0.3, 0.4), (0.3, 0.5, 0.5)\}$$

$$I_3 = \{(0.3, 0.3, 0.2), (0.4, 0.3, 0.4), (0.3, 0.5, 0.5)\}$$

$$I_4 = \{(0.3, 0.3, 0.4), (0.4, 0.3, 0.3), (0.3, 0.4, 0.4)\}$$

$$Neu_{g\zeta^*}\text{-CS} = \{(0.2, 0.2, 0.2), (0.5, 0.4, 0.4), (0.3, 0.3, 0.2)\} \text{ and}$$

$$Neu_{\alpha g}\text{-CS} = \{(0.3, 0.5, 0.5), (0.4, 0.3, 0.3), (0.3, 0.3, 0.2)\}. \text{ Here } \mathcal{D}^{-1}(H_4^c) \text{ is } Neu_{\alpha g}\text{-CS not } Neu_{g\zeta^*}\text{-CS}.$$

Example 3.3 Assume $\mathbb{I} = \{u, v, w\}$ and then the Neu sets D_1, D_2, D_3, D_4 and F_1, F_2, F_3, F_4 are defined as

$$D_1 = \{(0.3, 0.3, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\}$$

$$D_2 = \{(0.4, 0.6, 0.6), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\}$$

$$D_3 = \{(0.4, 0.6, 0.6), (0.3, 0.2, 0.2), (0.3, 0.3, 0.2)\}$$

$$D_4 = \{(0.3, 0.3, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\} \text{ and}$$

$$F_1 = \{(0.4, 0.5, 0.6), (0.5, 0.6, 0.6), (0.4, 0.5, 0.3)\}$$

$$F_2 = \{(0.4, 0.5, 0.5), (0.5, 0.4, 0.4), (0.3, 0.4, 0.5)\}$$

$$F_3 = \{(0.4, 0.5, 0.6), (0.5, 0.4, 0.4), (0.3, 0.4, 0.5)\}$$

$$F_4 = \{(0.4, 0.5, 0.5), (0.5, 0.6, 0.6), (0.4, 0.5, 0.3)\}$$

$$Neu_{g\zeta^*}\text{-CS} = \{(0.2, 0.2, 0.2), (0.5, 0.4, 0.4), (0.3, 0.3, 0.2)\} \text{ and}$$

$$Neu_{gp}\text{-CS} = \{(0.3, 0.4, 0.5), (0.5, 0.4, 0.4), (0.3, 0.4, 0.5)\}. \text{ Here } \mathcal{D}^{-1}(F_3^c) \text{ is } Neu_{gp}\text{-CS not } Neu_{g\zeta^*}\text{-CS}.$$

Example 3.4. Assume $\mathbb{I} = \{u, v, w\}$ and then the Neu sets D_1, D_2, D_3, D_4 and J_1, J_2, J_3, J_4 are defined as

$$D_1 = \{(0.3, 0.3, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\}$$

$$D_2 = \{(0.4, 0.6, 0.6), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\}$$

$$D_3 = \{(0.4, 0.6, 0.6), (0.3, 0.2, 0.2), (0.3, 0.3, 0.2)\}$$

$$D_4 = \{(0.3, 0.3, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\} \text{ and}$$

$$J_1 = \{(0.4, 0.6, 0.4), (0.5, 0.4, 0.3), (0.4, 0.6, 0.5)\}$$

$$J_2 = \{(0.3, 0.6, 0.5), (0.3, 0.2, 0.2), (0.4, 0.4, 0.4)\}$$

$$J_3 = \{(0.4, 0.6, 0.4), (0.3, 0.2, 0.2), (0.4, 0.4, 0.4)\}$$

$$J_4 = \{(0.3, 0.6, 0.5), (0.5, 0.4, 0.3), (0.4, 0.6, 0.5)\}$$

$$Neu_{g\zeta^*}\text{-CS} = \{(0.2, 0.2, 0.2), (0.5, 0.4, 0.4), (0.3, 0.3, 0.2)\} \text{ and}$$

$$Neu_{gsp}\text{-CS} = \{(0.4, 0.6, 0.5), (0.5, 0.4, 0.3), (0.3, 0.6, 0.5)\}. \text{ Here } \mathcal{D}^{-1}(J_4^c) \text{ is } Neu_{gsp}\text{-CS not } Neu_{g\zeta^*}\text{-CS.}$$

Theorem 3.2. The composition of two $Neu_{g\zeta^*}\text{-CF}$'s is also a $Neu_{g\zeta^*}\text{-CF}$.

Proof: Let $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ and $\ell: (S, \omega) \rightarrow (\mathcal{W}, \rho)$ are two $Neu_{g\zeta^*}\text{-CF}$'s.

Let $\mathfrak{M}$ be a $Neu\text{-CS}$ in $(\mathcal{W}, \rho)$, then $l^{-1}(\mathfrak{M})$ is $Neu\text{-CS}$ in (S, ω) , since l is Neu-continuous, $Neu_{g\zeta^*}\text{-Continuity}$ of $\mathcal{D}$ implies that $\mathcal{D}^{-1}(l^{-1}(\mathfrak{M})) = (l \circ \mathcal{D})(\mathfrak{M})$ is $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$. Hence $l \circ \mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$.

4 | $Neu_{g\zeta^*}\text{-IF}$ in NTS's

Definition 4.1. A function $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ is called $Neu_{g\zeta^*}\text{-Irresolute Functions}$ (briefly $Neu_{g\zeta^*}\text{-IF}$) if $\mathcal{D}^{-1}(\mathfrak{M})$ is a $Neu_{g\zeta^*}\text{-CS}$ of $(\mathcal{R}, \vartheta)$ for every $Neu_{g\zeta^*}\text{-CS}$ $\mathfrak{M}$ of (S, ω) .

Theorem 4.1. Let $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ and $\ell: (S, \omega) \rightarrow (\mathcal{W}, \rho)$ are any two functions, then

- i). $l \circ \mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (\mathcal{W}, \rho)$ is $Neu_{g\zeta^*}\text{-CF}$ if l is Neu-CF and $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$.
- ii). $l \circ \mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (\mathcal{W}, \rho)$ is $Neu_{g\zeta^*}\text{-IF}$ if both l and $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-IF}$.
- iii). $l \circ \mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (\mathcal{W}, \rho)$ is $Neu_{g\zeta^*}\text{-CF}$ if l is $Neu_{g\zeta^*}\text{-CF}$ and $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-IF}$.

Proof:

- i). Let us assume that $\mathcal{P}$ is a Neu-CS in $(\mathcal{W}, \rho)$. Since l is Neu-CF, $l^{-1}(\mathcal{P})$ is Neu-CS in (S, ω) . Since $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$, $\mathcal{D}^{-1}(l^{-1}(\mathcal{P})) = (l \circ \mathcal{D})^{-1}(\mathcal{P})$ is $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$, Therefore $l \circ \mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$.
- ii). Let us assume that $\mathcal{P}$ is a $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{W}, \rho)$. Since l is $Neu_{g\zeta^*}\text{-IF}$, $l^{-1}(\mathcal{P})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . Since $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-IF}$, $\mathcal{D}^{-1}(l^{-1}(\mathcal{P})) = (l \circ \mathcal{D})^{-1}(\mathcal{P})$ is $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$, Therefore $l \circ \mathcal{D}$ is $Neu_{g\zeta^*}\text{-IF}$.
- iii). Let us assume that $\mathcal{P}$ is a Neu-CS in $(\mathcal{W}, \rho)$. Since l is $Neu_{g\zeta^*}\text{-CF}$, $l^{-1}(\mathcal{P})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . Since $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-IF}$, $\mathcal{D}^{-1}(l^{-1}(\mathcal{P})) = (l \circ \mathcal{D})^{-1}(\mathcal{P})$ is $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$, Therefore $l \circ \mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$.

5 | $Neu_{g\zeta^*H}\text{-Functions}$ in NTS's

Definition 5.1. A function $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ is said to be $Neu_{g\zeta^*H}\text{-Functions}$ if $\mathcal{D}$ is bijective, $\mathcal{D}$ and $\mathcal{D}^{-1}$ are $Neu_{g\zeta^*}\text{-CF}$.

Theorem 5.1. Each $Neu_{g\zeta^*H}$ -Functions is Neu_{gSH} -Functions.

Proof: Let $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ be $Neu_{g\zeta^*H}$ -Functions, then $\mathcal{D}$ is bijective, $Neu_{g\zeta^*CF}$ and $Neu_{g\zeta^*OF}$. Let $\mathfrak{M}$ be Neu-CS in (S, ω) , then $\mathcal{D}^{-1}(\mathfrak{M})$ is $Neu_{g\zeta^*CS}$ in $(\mathcal{R}, \vartheta)$. Since each $Neu_{g\zeta^*CS}$ is $Neu_{gS}CS$, then $\mathcal{D}^{-1}(\mathfrak{M})$ is $Neu_{gS}CS$ in $(\mathcal{R}, \vartheta)$, Therefore $\mathcal{D}$ is $Neu_{gS}CF$. Let $\mathfrak{S}$ be Neu-OS in $(\mathcal{R}, \vartheta)$, then $\mathcal{D}(\mathfrak{S})$ is $Neu_{g\zeta^*OS}$ in (S, ω) . Since each $Neu_{g\zeta^*OS}$ is $Neu_{gS}OS$, then $\mathcal{D}(\mathfrak{S})$ is $Neu_{gS}OS$ in (S, ω) , therefore $\mathcal{D}$ is $Neu_{gS}OF$. Hence $\mathcal{D}$ is Neu_{gSH} -Functions.

Example 5.1. Assume $\mathbb{I} = \{u, v, w\}$ and then the Neu sets D_1, D_2, D_3, D_4 and H_1, H_2, H_3, H_4 are defined as:

$$\begin{aligned} D_1 &= \{(0.3, 0.3, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\} \\ D_2 &= \{(0.4, 0.6, 0.6), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\} \\ D_3 &= \{(0.4, 0.6, 0.6), (0.3, 0.2, 0.2), (0.3, 0.3, 0.2)\} \\ D_4 &= \{(0.3, 0.3, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\} \text{ and} \\ H_1 &= \{(0.4, 0.4, 0.4), (0.5, 0.4, 0.4), (0.3, 0.2, 0.2)\} \\ H_2 &= \{(0.3, 0.2, 0.2), (0.3, 0.2, 0.2), (0.4, 0.6, 0.6)\} \\ H_3 &= \{(0.4, 0.4, 0.4), (0.3, 0.2, 0.2), (0.3, 0.2, 0.2)\} \\ H_4 &= \{(0.3, 0.2, 0.2), (0.5, 0.4, 0.4), (0.4, 0.6, 0.6)\} \end{aligned}$$

Then the families $\gamma = \{0_{(N)}, 1_{(N)}, D_1, D_2, D_3, D_4\}$ and $\eta = \{0_{(N)}, 1_{(N)}, H_1, H_2, H_3, H_4\}$ are Neu Topologies on $\mathbb{I}$. Thus, $(\mathbb{I}, \gamma)$ and $(\mathbb{I}, \eta)$ are Neu Topological Spaces. Define $\mathcal{D}: (\mathbb{I}, \gamma) \rightarrow (\mathbb{I}, \eta)$ as $\mathcal{D}(u) = u, \mathcal{D}(v) = v, \mathcal{D}(w) = w$. Then $\mathcal{D}$ is Neu_{gSH} -Function but not $Neu_{g\zeta^*H}$ -Function. Hence in $(\mathbb{I}, \gamma)$,

$$Neu_{g\zeta^*CS} = \{(0.2, 0.2, 0.2), (0.5, 0.4, 0.4), (0.3, 0.3, 0.2)\} \text{ and}$$

$$Neu_{gS}CS = \{(0.3, 0.2, 0.2), (0.3, 0.2, 0.2), (0.4, 0.4, 0.4)\}. \text{ Here } \mathcal{D}^{-1}(H_3^c) \text{ is } Neu_{gS}CS \text{ but not } Neu_{g\zeta^*CS}.$$

$$Neu_{g\zeta^*OS} = \{(0.3, 0.3, 0.2), (0.5, 0.4, 0.4), (0.2, 0.2, 0.2)\} \text{ and}$$

$$Neu_{gS}OS = \{(0.4, 0.4, 0.4), (0.3, 0.2, 0.2), (0.3, 0.2, 0.2)\} \text{ is } Neu_{gS}OS \text{ but not } Neu_{g\zeta^*OS}.$$

Theorem 5.2. For any bijective function $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ then the following statement is equivalent.

- i). $\mathcal{D}^{-1}: (S, \omega) \rightarrow (\mathcal{R}, \vartheta)$ is $Neu_{g\zeta^*CF}$.
- ii). $\mathcal{D}$ is a $Neu_{g\zeta^*OF}$.
- iii). $\mathcal{D}$ is a $Neu_{g\zeta^*CF}$.

Proof:

- i). $\Rightarrow$ (ii) Let $\mathfrak{B}$ is an Neu-OS in $(\mathcal{R}, \vartheta)$, then $\mathcal{R} - \mathfrak{B}$ is Neu-CS in $(\mathcal{R}, \vartheta)$. Since $\mathcal{D}^{-1}$ is $Neu_{g\zeta^*CF}$, then $(\mathcal{D}^{-1})^{-1}(\mathfrak{B})$ is $Neu_{g\zeta^*CS}$ in (S, ω) . That is $\mathcal{D}(\mathcal{R} - \mathfrak{B})$ is $Neu_{g\zeta^*CS}$ in (S, ω) , that is $S - \mathcal{D}(\mathfrak{B})$ is $Neu_{g\zeta^*CS}$ in (S, ω) . Therefore $\mathcal{D}(\mathfrak{B})$ is $Neu_{g\zeta^*OS}$ in (S, ω) . Thus $\mathcal{D}$ is $Neu_{g\zeta^*OF}$.
- ii). $\Rightarrow$ (iii) Let $\mathfrak{I}$ is an Neu-CS in $(\mathcal{R}, \vartheta)$, then $\mathcal{R} - \mathfrak{I}$ is Neu-OS in $(\mathcal{R}, \vartheta)$. Since $\mathcal{D}$ is $Neu_{g\zeta^*OF}$, then $\mathcal{D}(\mathcal{R} - \mathfrak{I})$ is $Neu_{g\zeta^*OS}$ in (S, ω) . That is $S - \mathcal{D}(\mathfrak{I})$ is $Neu_{g\zeta^*OS}$ in (S, ω) . Therefore $\mathcal{D}(\mathfrak{I})$ is $Neu_{g\zeta^*CS}$ in (S, ω) . Thus $\mathcal{D}$ is $Neu_{g\zeta^*CF}$.

- iii). $\Rightarrow$ (ii) Let $\mathfrak{C}$ is an Neu-CS in $(\mathcal{R}, \vartheta)$, then $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$, then $\mathcal{D}(\mathfrak{C})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . That is $(\mathcal{D}^{-1})^{-1}(\mathfrak{C})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) , hence $\mathcal{D}^{-1}$ is $Neu_{g\zeta^*}\text{-CF}$.

Theorem 5.3. Let $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ is bijective and $Neu_{g\zeta^*}\text{-CF}$, then the following statements are equivalent.

- i). $\mathcal{D}$ is a $Neu_{g\zeta^*}\text{-OF}$.
- ii). $\mathcal{D}$ is a $Neu_{g\zeta^*H}\text{-Function}$.
- iii). $\mathcal{D}$ is a $Neu_{g\zeta^*}\text{-CF}$.

Proof:

- i). $\Rightarrow$ (ii) Let us assume that $\mathcal{D}$ is a $Neu_{g\zeta^*}\text{-OF}$. Since $\mathcal{D}$ is bijective and $Neu_{g\zeta^*}\text{-CF}$, $\mathcal{D}$ is $Neu_{g\zeta^*H}\text{-Function}$.
- ii). $\Rightarrow$ (iii) Let us assume that $\mathcal{D}$ is a $Neu_{g\zeta^*H}\text{-Function}$. Then $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-OF}$. If $\mathfrak{I}$ is Neu-CS in $\mathcal{R}$, then $\mathcal{D}(\mathcal{R} - \mathfrak{I})$ is $Neu_{g\zeta^*}\text{-OS}$ in (S, ω) . That is $S - \mathcal{D}(\mathfrak{I})$ is $Neu_{g\zeta^*}\text{-OS}$ in (S, ω) . Therefore $\mathcal{D}(\mathfrak{I})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . Hence $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$.
- iii). $\Rightarrow$ (i) Let us assume that $\mathfrak{B}$ is Neu-OS in $(\mathcal{R}, \vartheta)$. Then $\mathcal{R} - \mathfrak{B}$ is Neu-CS in $(\mathcal{R}, \vartheta)$. Since $\mathcal{D}$ is $Neu_{g\zeta^*}\text{-CS}$, then $\mathcal{D}(\mathcal{R} - \mathfrak{B})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . That is $S - \mathcal{D}(\mathfrak{B})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . Hence $\mathcal{D}(\mathfrak{B})$ is $Neu_{g\zeta^*}\text{-OS}$ in (S, ω) .

Theorem 5.4. The composition of two $Neu_{g\zeta^*H}\text{-Functions}$ is also a $Neu_{g\zeta^*H}\text{-Function}$.

Proof:

Assume $\mathcal{D}: (\mathcal{R}, \vartheta) \rightarrow (S, \omega)$ and $\ell: (S, \omega) \rightarrow (\mathcal{W}, \rho)$ are two $Neu_{g\zeta^*}\text{-CF}$. Assume $\mathfrak{B}$ is a Neu-CS in $(\mathcal{W}, \rho)$. Since ℓ is a $Neu_{g\zeta^*}\text{-CF}$, $\ell^{-1}(\mathfrak{B})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . Since any $Neu_{g\zeta^*}\text{-CS}$ is Neu-CS, $\ell^{-1}(\mathfrak{B})$ is Neu-CS in (S, ω) . Since $\mathcal{D}$ is a $Neu_{g\zeta^*}\text{-CF}$, $(\mathcal{D}^{-1}(\ell^{-1}(\mathfrak{B})) = \ell \circ \mathcal{D}(\mathfrak{B})$ is $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{R}, \vartheta)$, therefore $\ell \circ \mathcal{D}$ is also $Neu_{g\zeta^*}\text{-CF}$.

Assume $\mathcal{G}$ is a Neu-CS in $(\mathcal{R}, \vartheta)$ then $\mathcal{R} - \mathcal{G}$ is a Neu-OS in $(\mathcal{R}, \vartheta)$. Since $\mathcal{D}$ is $Neu_{g\zeta^*H}\text{-Functions}$, then $\mathcal{D}(\mathcal{R} - \mathcal{G})$ is a $Neu_{g\zeta^*}\text{-OS}$ in (S, ω) , implies $\mathcal{D}(\mathcal{G})$ is $Neu_{g\zeta^*}\text{-CS}$ in (S, ω) . Since any $Neu_{g\zeta^*}\text{-CS}$ is Neu-CS, then $\mathcal{D}(\mathcal{G})$ is Neu-CS in (S, ω) , then $S - \mathcal{D}(\mathcal{G})$ is Neu-OS in (S, ω) . Since ℓ is $Neu_{g\zeta^*H}\text{-Functions}$, $\ell(S - \mathcal{D}(\mathcal{G}))$ is $Neu_{g\zeta^*}\text{-OS}$ in $(\mathcal{W}, \rho)$, implies $\ell(\mathcal{D}(\mathcal{G})) = \ell \circ \mathcal{D}(\mathcal{G})$ is $Neu_{g\zeta^*}\text{-CS}$ in $(\mathcal{W}, \rho)$ therefore $\ell \circ \mathcal{D}$ is $Neu_{g\zeta^*}\text{-CF}$ and $Neu_{g\zeta^*}\text{-OF}$, implies $\ell \circ \mathcal{D}$ is $Neu_{g\zeta^*H}\text{-Functions}$.

6 | Conclusion

In this paper, we defined the notion of $Neu_{g\zeta^*}\text{-CF}$ and $Neu_{g\zeta^*}\text{-IF}$ in neutrosophic topological spaces and its relation with details. Along with that some of their properties were discussed. Also, introduce the new class of $Neu_{g\zeta^*H}\text{-functions}$ and studied some of their properties in Neutrosophic Topological Spaces. In future work, we will use the neutrosophic complex sets and their characterizations.

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Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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