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Original Article

On Slightly N$g^{\#}$− Continuous Functions in Neutrosophic Topological Space

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Abstract — *In this article, we present and study a new class of Neutrosophic functions namely, slightly Neutrosophic $g^{\#}$− continuous functions. Moreover, we discuss its relationship with some other related functions.*

Keywords — *N$g^{\#}$− closed set, N$g^{\#}$− open set, N$g^{\#}$− continuous function, N$g^{\#}$− contra continuous function, slightly N$g^{\#}$− continuous function.*

I. INTRODUCTION

In 1965, Zadeh [21] introduced fuzzy set theoryas a mathematical tool for dealing with uncertainities where each element had a degree of membership. The Intuitionistic fuzzy set was introduced by Atanassov[2] in 1983 as a generalizationof fuzzy set, where besides the degree of membership and the degree of non- membership of each element. Smarandache [8] introduced the idea of Neutrosophic set and explained, neutrosophic set is a generalization of Intuitionistic fuzzyset. In 2014 Salama et.al. [17] initiated further studies into Neutrosophic closed sets and Neutrosophic continuous functions. Recently Pious Missier et.al.[11],[12], introduced the concept of N$g^{\#}$− closed sets, continuous and irresolute mappings, in Neutrosophic Topological Spaces. Here, the notion of N$g^{\#}$− closed sets is applied to introduce a new class of continuity in the consept of Neutrosophic topology called slightly N$g^{\#}$− continuous functions and investigate its properties.

II. PRELIMINARIES

Definition 2.1. [8]

A Neutrosophic set (NS) A_N is an object having the form $A_N = \{\langle x, \mu_{AN}(x), \sigma_{AN}(x), \gamma_{AN}(x)\rangle : x \in X\}$ where $\mu_{AN}(x), \sigma_{AN}(x)$ and $\gamma_{AN}(x)$ represent the degree of membership, degree of indeterminacy and the degree of non-membership respectively of each element $x \in X$ to the set A_N. A Neutrosophic set $A_N = \{\langle x, \mu_{AN}(x), \sigma_{AN}(x), \gamma_{AN}(x)\rangle : x \in X\}$ can be identified as an ordered triple $\langle \mu_{AN}(x), \sigma_{AN}(x), \gamma_{AN}(x)\rangle$ in $]{-0}, 1{+}[$ on X.

Definition 2.2. [17]

For any two Neutrosophic sets $A_N = \{\langle x, \mu_{AN}(x), \sigma_{AN}(x), \gamma_{AN}(x)\rangle : x \in X\}$ and $B_N = \{\langle x, \mu_{BN}(x), \sigma_{BN}(x), \gamma_{BN}(x)\rangle : x \in X\}$ we have

1. $A_N \subseteq B_N \Longleftrightarrow \mu_{AN}(x) \leq \mu_{BN}(x), \sigma_{AN}(x) \leq \sigma_{BN}(x)$ and $\gamma_{AN}(x) \geq \gamma_{BN}(x)$.
2. $A_N \cap B_N = \langle x, \mu_{AN}(x) \wedge \mu_{BN}(x), \sigma_{AN}(x) \wedge \sigma_{BN}(x)$ and $\gamma_{AN}(x) \vee \gamma_{BN}(x)\rangle$.
3. $A_N \cup B_N = \langle x, \mu_{AN}(x) \vee \mu_{BN}(x), \sigma_{AN}(x) \vee \sigma_{BN}(x)$ and $\gamma_{AN}(x) \wedge \gamma_{BN}(x)\rangle$.

Definition 2.3. [17] Let $A_N = \langle \mu_{AN}(x), \sigma_{AN}(x), \gamma_{AN}(x) \rangle$ be a N*S* on X, then the complement A_N^c defined as

$A_N^c = \{\langle x, \gamma_{AN}(x), 1 - \sigma_{AN}(x), \mu_{AN}(x) \rangle : x \in X\}$

Note that for any two Neutrosophic sets A_N and B_N,

- $(A_N \cup B_N)^c = A_N^c \cap B_N^c$
- $(A_N \cap B_N)^c = A_N^c \cup B_N^c$

Definition 2.4. [17] A Neutrosophic topology (NT) on a non-empty set X is a family τ of Neutrosophic subsets in X satisfies the following axioms:

1. $\mathbf{0}_N, \mathbf{1}_N \in \tau$
2. $R_{N1} \cap R_{N2} \in \tau$ for any $R_{N1}, R_{N2} \in \tau$
3. $\cup R_{Ni} \in \tau \ \forall \ R_{Ni} : i \in I \subseteq \tau$

Here the empty set $\mathbf{0}_N$ and the whole set $\mathbf{1}_N$ may be defined as follows:

1. $\mathbf{0}_N = \{\langle x, 0, 0, 1 \rangle : x \in X\}$
2. $\mathbf{1}_N = \{\langle x, 1, 1, 0 \rangle : x \in X\}$

Definition 2.5. [17] Let A_N be a N*S* in NTS X_N. Then

1. $Nint(A_N) = \cup\{G : G$ is a NOS in X_N and $G \subseteq A_N\}$ is called a Neutrosophic interior of A_N.
2. $Ncl(A_N) = \cap\{K : K$ is a NCS in X_N and $A_N \subseteq K\}$ is called Neutrosophic closure of A_N.

Definition 2.6. [9] A Neutrosophic set A_N of a NTS (X,τ) is called a neutrosophic N*αgCS* if $N\alpha cl(A_N) \subseteq U_N$, whenever $A_N \subseteq U_N$ and U_N is a NOS in X. The complement of N*αgCS* is N*αgOS*.

Definition 2.7. [11] A Neutrosophic set A_N of a NTS (X,τ) is called a Neutrosophic $g^\#$−closed ($Ng^\#CS$) if $Ncl(A_N) \subseteq Q_N$ whenever $A_N \subseteq Q_N$ and Q_N is N*αgOS* in X. The complement of $Ng^\#CS$ is $Ng^\#OS$.

Definition 2.8. [16] Let A_N be a N*S* in NTS X. Then

1. $Ng^\#int(A_N) = \cup\{G : G$ is a $Ng^\#OS$ in X and $G \subseteq A_N\}$ is called a Neutrosophic $g^\#$− interior of A_N.
2. $Ng^\#cl(A_N) = \cap\{K : K$ is a $Ng^\#CS$ in X and $A_N \subseteq K\}$ is called Neutrosophic $g^\#$− closure of A_N.

Definition 2.9. [12] A function $f_N : (X,\tau) \to (Y,\zeta)$ is said to be $Ng^\#$− continuous function if $f_N^{-1}(V_N)$ is a $Ng^\#$− closed set of (X,τ) for every neutrosophic closed set V_N of (Y,ζ).

Definition 2.10. [12] A function $f_N : (X,\tau) \to (Y,\zeta)$ is said to be Neutrosophic $g^\#$− irresolute function if $f_N^{-1}(V_N)$ is a $Ng^\#CS$ of (X,τ) for every $Ng^\#CS$ V_N of (Y,ζ).

Definition 2.11. [16] A Neutrosophic Topological space (X,τ) is called a $T_Ng^\#$− space if every $Ng^\#CS$ in (X,τ) is NCS in (X,τ).

Definition 2.12. [5] A function $f_N : (X,\tau) \to (Y,\zeta)$ is said to be neutrosophic contra continuous if $f_N^{-1}(V_N)$ is a neutrosophic closed set of (X,τ) for every neutrosophic open set (Y,ζ).

Definition 2.13. [13] A function $f_N : (X,\tau) \to (Y,\zeta)$ is said to be $Ng^\#$− contra continuous if $f_N^{-1}(V_N)$ is a $Ng^\#$− closed set of (X,τ) for every neutrosophic open set (Y,ζ).

Definition 2.14. [14] A function $f_N : (X,\tau) \to (Y,\zeta)$ is said to be perfectly $Ng^\#$− continuous if the inverse image of every $Ng^\#$− closed set in (Y,ζ) is both NOS and NCS (ie, Neutrosophic clopen set) in (X,τ).

Definition 2.15. [15] A function $f_N : (X,\tau) \to (Y,\zeta)$ is said to be totally N$g^{\#}-$ continuous if the inverse image of every Neutrosophic closed set in (Y,ζ) is both N$g^{\#}CS$ and N$g^{\#}OS$ (ie, N$g^{\#}-$ clopen set) in (X,τ).

III. SLIGHTLY Ng#− CONTINUOUS FUNCTIONS

Definition 3.1. A function $f_N : (X,\tau) \longrightarrow (Y,\zeta)$ is said to be slightly N$g^{\#}-$ continuous if the inverse image of every Neutrosophic clopen set in (Y,ζ) is N$g^{\#}CS$ in (X,τ).

Example 3.2. Let $X = \{l,m\} = Y$ Consider the Neutrosophic sets
$M_{N1} = \{\langle l,(0.6,0.5,0.3)\rangle,\langle m,(0.5,0.6,0.4)\rangle\}$, $M_{N2} = \{\langle l,(0.3,0.5,0.6)\rangle,\langle m,(0.4,0.4,0.5)\rangle\}$,
$M_{N3} = \{\langle l,(0.5,0.6,0.4)\rangle,\langle m,(0.6,0.5,0.3)\rangle\}$, $M_{N4} = \{\langle l,(0.4,0.4,0.5)\rangle,\langle m,(0.3,0.5,0.6)\rangle\}$.
Now Then $\tau = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$ and $\zeta = \{\mathbf{0}_N,M_{N3},M_{N4},\mathbf{1}_N\}$ are NT s on X and Y respectively. Define $f_N : (X,\tau) \to (Y,\zeta)$ by $f_N(l) = m$ and $f_N(m) = l$. Here $Ng^{\#}CS(X) = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$,$NCOS(Y) = \{\mathbf{0}_N,M_{N3},M_{N4},\mathbf{1}_N\}$. Now $f_N^{-1}(M_{N3}) = M_{N1}$ and $f_N^{-1}(M_{N4}) = M_{N2}$ are N$g^{\#}CS$ in (X,τ). Therefore, f_N is slightly N$g^{\#}-$ continuous.

Theorem 3.3. *Every* N$g^{\#}-$ *continuous function is slightly* N$g^{\#}-$ *continuous function.*
Proof. Let $f_N : (X,\tau) \to (Y,\zeta)$ be any neutrosophic function. Let A_N be a N− clopen in (Y,ζ). Then A_N is NCS in (Y,ζ). Since f_N is a N$g^{\#}-$ continuous function, $f_N^{-1}(A_N)$ is N$g^{\#}CS$ in (X,τ). Hence, f_N is totally N$g^{\#}-$ continuous function.

Remark 3.4. Reverse implication of above theorem need not be true as seen in the following example.
Example 3.5. Let $X = \{l,m\} = Y$ Consider the Neutrosophic sets
$M_{N1} = \{\langle l,(0.6,0.5,0.3)\rangle,\langle m,(0.5,0.6,0.4)\rangle\}$, $M_{N2} = \{\langle l,(0.3,0.5,0.6)\rangle,\langle m,(0.4,0.4,0.5)\rangle\}$,
$M_{N3} = \{\langle l,(0.5,0.6,0.4)\rangle,\langle m,(0.6,0.5,0.3)\rangle\}$, $M_{N4} = \{\langle l,(0.4,0.4,0.5)\rangle,\langle m,(0.3,0.5,0.6)\rangle\}$,
$M_{N5} = \{\langle l,(0.7,0.6,0.2)\rangle,\langle m,(0.6,0.7,0.3)\rangle\}$, $M_{N6} = \{\langle l,(0.2,0.4,0.7)\rangle,\langle m,(0.3,0.3,0.6)\rangle\}$.
Now Then $\tau = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$ and $\zeta = \{\mathbf{0}_N,M_{N3},M_{N4},M_{N5},\mathbf{1}_N\}$ are NT s on X and Y respectively. Define $f_N : (X,\tau) \to (Y,\zeta)$ by $f_N(l) = m$ and $f_N(m) = l$. Here $Ng^{\#}CS(X) = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$,$NCOS(Y) = \{\mathbf{0}_N,M_{N3},M_{N4},\mathbf{1}_N\}$. Now $f_N^{-1}(M_{N3}) = M_{N1}$ and $f_N^{-1}(M_{N4}) = M_{N2}$ are N$g^{\#}CS$ in (X,τ). Therefore, f_N is slightly N$g^{\#}-$ continuous. But M_{N6} is NCS in Y but $f_N^{-1}(M_{N6})$ is not N$g^{\#}CS$ in (X,τ). Therefore, f_N is not N$g^{\#}-$ continuous.

Theorem 3.6. *Every* N$g^{\#}-$ *contra continuous function is slightly* N$g^{\#}-$ *continuous function.*
Proof. Let $f_N : (X,\tau) \to (Y,\zeta)$ be any neutrosophic function. Let A_N be a N− clopen in (Y,ζ). Then A_N is NOS in (Y,ζ). Since f_N is a N$g^{\#}-$ contra continuous function, $f_N^{-1}(A_N)$ is N$g^{\#}CS$ in (X,τ). Hence, f_N is totally N$g^{\#}-$ continuous function.

Remark 3.7. Converse of above theorem need not be true as seen in the following example.
Example 3.8. Let $X = \{l,m\} = Y$ Consider the Neutrosophic sets
$M_{N1} = \{\langle l,(0.7,0.5,0.3)\rangle,\langle m,(0.6,0.6,0.4)\rangle\}$, $M_{N2} = \{\langle l,(0.3,0.5,0.7)\rangle,\langle m,(0.4,0.4,0.6)\rangle\}$,
$M_{N3} = \{\langle l,(0.6,0.6,0.4)\rangle,\langle m,(0.7,0.5,0.3)\rangle\}$, $M_{N4} = \{\langle l,(0.4,0.4,0.6)\rangle,\langle m,(0.3,0.5,0.7)\rangle\}$,
$M_{N5} = \{\langle l,(0.7,0.8,0.2)\rangle,\langle m,(0.7,0.8,0.3)\rangle\}$, $M_{N6} = \{\langle l,(0.2,0.2,0.7)\rangle,\langle m,(0.3,0.2,0.7)\rangle\}$.
Now Then $\tau = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$ and $\zeta = \{\mathbf{0}_N,M_{N3},M_{N4},M_{N6},\mathbf{1}_N\}$ are NT s on X and Y respectively. Define $f_N : (X,\tau) \to (Y,\zeta)$ by $f_N(l) = m$ and $f_N(m) = l$. Here $Ng^{\#}CS(X) = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$,$NCOS(Y) = \{\mathbf{0}_N,M_{N3},M_{N4},\mathbf{1}_N\}$. Now $f_N^{-1}(M_{N3}) = M_{N1}$ and $f_N^{-1}(M_{N4}) = M_{N2}$ are N$g^{\#}CS$ in (X,τ). Therefore, f_N is slightly N$g^{\#}-$ continuous. But M_{N6} is NOS in Y but $f_N^{-1}(M_{N6})$ is not N$g^{\#}CS$ in (X,τ). Therefore, f_N is not N$g^{\#}-$ contra continuous.

Remark 3.9. Composition of two slightly N$g^{\#}-$ continuous functions need not be a slightly N$g^{\#}-$ continuous function.
Example 3.10. Let $X = \{p,q\} = Y = Z$
$M_{N1} = \{\langle p,(0.7,0.5,0.3)\rangle,\langle m,(0.6,0.6,0.4)\rangle\}$, $M_{N2} = \{\langle p,(0.3,0.5,0.7)\rangle,\langle q,(0.4,0.4,0.6)\rangle\}$,
$M_{N3} = \{\langle p,(0.6,0.6,0.4)\rangle,\langle q,(0.7,0.5,0.3)\rangle\}$, $M_{N4} = \{\langle p,(0.4,0.4,0.6)\rangle,\langle q,(0.3,0.5,0.7)\rangle\}$,
$M_{N5} = \{\langle p,(0.2,0.3,0.8)\rangle,\langle q,(0.3,0.2,0.7)\rangle\}$, $M_{N6} = \{\langle p,(0.8,0.7,0.2)\rangle,\langle q,(0.7,0.8,0.3)\rangle\}$.
Now $(X,\tau) = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$, $(Y,\zeta) = \{\mathbf{0}_N,M_{N3},M_{N4},M_{N5},M_{N6},\mathbf{1}_N\} = (Z,\eta)$ are Neutrosophic topological spaces.
Then $\tau = \{\mathbf{0}_N,M_{N1},M_{N2},\mathbf{1}_N\}$,$\zeta = \{\mathbf{0}_N,M_{N3},M_{N4},M_{N6},\mathbf{1}_N\}$ and $\eta = \{\mathbf{0}_N,M_{N5},M_{N6},\mathbf{1}_N\}$ are Neutrosophic topologies on X,Y and Z

respectively. Define a function $f_N : (X,\tau) \to (Y,\zeta)$ by $f_N(p) = q$ and $f_N(q) = p$ and define a function $g_N : (Y,\zeta) \to (Z,\eta)$ by $g_N(p) = p$ and $g_N(q) = q$. Then f_N and g_N are slightly $Ng^\#-$ continuos functions. Now define a function $g_N \circ f_N : (X,\tau) \to (Z,\eta)$ by $g_N \circ f_N(p) = p$ and $g_N \circ f_N(q) = q$. Here M_{N5} and M_{N6} are NCOS in (Z,η). But $(g_N \circ f_N)^{-1}(M_{N5})$ is not a $Ng^\#CS$ in (X,τ). Hence $(g_N \circ f_N)$ is not a slightly $Ng^\#-$ continuous function.

Theorem 3.11. *Let $f_N : (X,\tau) \to (Y,\zeta)$ and $g_N : (Y,\zeta) \to (Z,\eta)$ be any two Neutrosophic mappings. Then*

1. $(g_N \circ f_N) : (X,\tau) \to (Z,\eta)$ *is slightly* $Ng^\#-$ *continuous if* g_N *is slightly* $Ng^\#-$ *continuous and* f_N *is* $Ng^\#-$ *irresolute.*
2. $(g_N \circ f_N) : (X,\tau) \to (Z,\eta)$ *is slightly* $Ng^\#-$ *continuous if* g_N *is* $Ng^\#-$ *continuous and* f_N *is* $Ng^\#-$ *irresolute.*
3. $(g_N \circ f_N) : (X,\tau) \to (Z,\eta)$ *is* $Ng^\#-$ *irresolute if* g_N *is perfectly* $Ng^\#-$ *continuous and* f_N *is slightly* $Ng^\#-$ *continuous.*
4. $(g_N \circ f_N) : (X,\tau) \to (Z,\eta)$ *is slightly* $Ng^\#-$ *continuous if* g_N *is* $Ng^\#-$ *contra continuous and* f_N *is* $Ng^\#-$ *irresolute.*

Proof. :

(1) Let W_N be a Neutrosophic clopen set in (Z,η). By hypothesis, $g_N^{-1}(W_N)$ is a $Ng^\#CS$ in (Y,ζ). Since f_N is a $Ng^\#-$ irresolute function, $f_N^{-1}(g_N^{-1}(W_N))$ is a $Ng^\#CS$ in (X,τ). Hence $g_N \circ f_N$ is a slightly $Ng^\#-$ continuous function.

(2) Let W_N be a Neutrosophic clopen set in (Z,η). Then W_N is NCS (Z,η). By hypothesis, $g_N^{-1}(W_N)$ is a $Ng^\#CS$ in (Y,ζ). Since f_N is a $Ng^\#-$ irresolute function, $f_N^{-1}(g_N^{-1}(W_N))$ is a $Ng^\#CS$ in (X,τ). Hence $g_N \circ f_N$ is a slightly $Ng^\#-$ continuous function.

(3) Let W_N be a $Ng^\#CS$ in (Z,η). Since f_N is perfectly $Ng^\#-$ continuous, $g_N^{-1}(W_N)$ is Neutrosophic clopen set in (Y,ζ). Since f_N is slightly $Ng^\#-$ continuous, $f_N^{-1}(g_N^{-1}(W_N))$ is $Ng^\#CS$ in (X,τ). Therefore $g_N \circ f_N$ is $Ng^\#-$ irresolute.

(4) Let W_N be a Neutrosophic clopen set in (Z,η). Then W_N is NOS (Z,η). By hypothesis, $g_N^{-1}(W_N)$ is a $Ng^\#CS$ in (Y,ζ). Since f_N is $Ng^\#-$ irresolute function, $f_N^{-1}(g_N^{-1}(W_N))$ is a $Ng^\#CS$ in (X,τ). Hence $g_N \circ f_N$ is a slightly $Ng^\#-$ continuous function.

VI. CONCLUSION

In this article we introduced a new class of continuous function in Neutrosophic Topological space called slightly $Ng^\#-$ continuous function. Further, characterizations of totally $Ng^\#-$ continuous functions are analyzed and studied their properties.

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