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On new classes of neutrosophic continuous and contra mappings in neutrosophic topological spaces

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Abstract

The aim of this paper is to investigate some new types of neutrosophic continuous mappings like, neutrosophic α^*-continuous mapping $(N\alpha^* - CM)$, neutrosophic irresolute α^*-continuous mapping $(NI\alpha^* - CM)$, and neutrosophic strongly α^*-continuous mapping $(NS\alpha^* - CM)$ are given and some of their properties are studied. Moreover, new kind of neutrosophic contra continuous mappings is investigated in this work, it is called neutrosophic contra α^*-continuous mapping $(NC\alpha^* - CM)$.

Keywords: neutrosophic sets, neutrosophic topological space, neutrosophic α-open sets, neutrosophic α^*-open set.

1. Introduction

In 1998, the connotation of Contra continuity is investigated by Dontchev [6]. Also, the connotation of α^*-open set $(\alpha^* - OS)$ is shown [7]. The idea of neutrosophic sets is presented by Smarandache [35], in 2014, the connotations of "neutrosophic closed set "and" neutrosophic continuous function" are given. the neutrosophic set is studied in topology, algerbra and other fields. It is one of the non-classical sets, such as soft set, fuzzy sets, nano set, permutation sets and so on, see [1, 3, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 36]. In this research, we introduce a new types of neutrosophic mappings, they are said neutrosophic α^*-continuous and neutrosophic contra α^*-continuous mappings. Next, we studied and discussed their basic properties.

2. Preliminaries

Here basic definitions and notations, which are used in this section are referred from the references [2, 5, 9, 32, 34].

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Definition 2.1. *Assume that $\Psi \neq \emptyset$. A neutrosophic set (NS) θ is defined as*

$$\theta = \langle \alpha, \partial_{\varpi}(\alpha), \omega_{\theta}(\alpha), \ell_{\theta}(\alpha) : \alpha \in \Psi \rangle,$$

where $\partial_{\varpi}(\alpha)$ is the degree of membership, $\omega_{\theta}(\alpha)$ is the degree of indeterminacy and $\ell_{\theta}(\alpha)$ is the degree of nonmembership, for all $\alpha \in \Psi$.

Definition 2.2. *We say (Ψ, τ) is a neutrosophic topological space (NTS) if and only if τ is a collection of (NSs) in Ψ and it such that:*

(1) $1_N, 0_N \in \tau$, where $0_N = \{\langle \alpha, (0,1,1)\rangle : \alpha \in \Psi\}$ and $1_N = \{\langle \alpha, (1,0,0)\rangle : \alpha \in \Psi\}$,

(2) $A \cap \beta \in \tau$ for any $\theta, \beta \in \tau$,

(3) $\bigcup_{i \in I} A_i \in \tau$ for any arbitrary family $\{A_i \mid i \in I\} \subseteq \tau$.

Moreover, any $A \in \tau$ is called neutrosophic open set (NOS) and we say neutrosophic closed set (NCS) for its complement.

Definition 2.3. *Assume A is a neutrosophic set in (NTS) X.*

(i) The neutrosophic closure (resp., neutrosophic α-closure) of A is the intersection of all neutrosophic closed (resp., neutrosophic α-closed) sets containing A and is denoted by $\mathrm{Ncl}(A)$ (resp., $Ncl_{\alpha}(A)$).

(ii) The neutrosophic interior (resp., neutrosophic α-interior) of A is the union of all neutrosophic open (resp., neutrosophic α-open) sets are contained in A and is denoted by $\mathrm{Nint(A)}$ (resp., $\mathrm{Nint}_{\alpha}(A)$), where A is neutrosophic α-open set $(N\alpha - OS)$ (resp., neutrosophic semi α-open set (NSe $\alpha - OS$), neutrosophic α^*-open set $(N\alpha^* - OS)$ if $A \subseteq \mathrm{Nint}(\mathrm{Ncl}(\mathrm{Nint}(A)))$ (resp., $A \subseteq \mathrm{Ncl}(\mathrm{Nint}(\mathrm{Ncl}(\mathrm{Nint}(A))))$ or equivalently $A \subseteq \mathrm{Ncl}(\mathrm{Nint}(A)), A \subseteq \mathrm{Nint}_{\alpha}(\mathrm{Ncl}(\mathrm{Nint}_{\alpha}(A)))$. Also, their complement are called neutrosophic α-closed set $(N\alpha - CS)$ (resp., neutrosophic semi α-closed set $(NSe\alpha - CS)$, neutrosophic α^*- closed set $(N\alpha^* - CS)$.

The symbols of the above neutrosophic sets and their complements are referred as $N\alpha - O(X)$ (resp., NSe $\alpha - O(X), N\alpha^* - O(X))$, $N\alpha - C(X)$ (resp., SNe $\alpha - C(X), N\alpha^* - C(X)$).

Proposition 2.4. *(1) If A is $(N\alpha^* - OS)$ and B is (NOS), then $A \cap B$ is $(N\alpha^* - OS)$.*

(2) If $\{G_{\lambda}\}_{\lambda \in \Gamma}$ is a collection of $(N\alpha^* - OSs)$, then their union is also $(N\alpha^* - OSs)$.

Theorem 2.5. *Assume that X_1 and X_2 are two neutrosophic topological spaces (NTSs), $A_1 \subseteq X_1$ and $A_2 \subseteq X_1$. Then A_1 and A_2 are $(N\alpha^* - OSs)$ (resp., $(N\alpha^* - CSs)$) in X_1 and X_2, respectively if and only if $A_1 \times A_2$ is $(N\alpha^* - OS)$ $(\mathrm{resp.}, (N\alpha^* - CS))$ in $X_1 \times X_2$.*

Theorem 2.6. *Assume that W is a subspace of Z satisfies $G \subseteq W \subseteq Z$. The following assertions hold.*

(i) If $G \in N\alpha^* - O(Z)$, then $G \in N\alpha^* - O(W)$.

(ii) If $G \in N\alpha^* - O(W)$, then $G \in N\alpha^* - O(Z)$, where W is a neutrosophic closed subspace of Z.

Proposition 2.7. *(1) Every (NOS) (resp., $N\alpha$-open, Ncl-open) set is $(N\alpha^* - OS)$.*

(2) Every $(N\alpha^* - OS)$ *is* $(NSe\alpha - OS)$.

Definition 2.8. *A (NTS) X is called a*

(i) neutrosophic ultra-T_2 *(N-ultra-*T_2*) if for any* $t \neq h \in Z$, *there are two disjoint neutrosophic closed sets (NDCSs)* T, H *satisfy* $t \in T, h \in H$.

(ii) neutrosophic ultra normal, if for all neutrosophic closed sets (NCSs) T, F *with* $T \neq \emptyset \neq F$ *and* $T \cap F = \emptyset$, *there are two (NCSs)* D, H *with* $D \cap H = \emptyset$ *and* $T \subseteq D, F \subseteq H$.

(ii) neutrosophic strongly closed if for any homely of (NCSs) that form a cover of X has a finite sub-homely that form a cover of X, too.

3. The new types of neutrosophic α^*-continuity

The new types of neutrosophic α^*-continuity like; neutrosophic irresolute α^*-continuous mapping $(NI\alpha^* - CM)$, neutrosophic stronger α^*-continuous mapping $(NS\alpha^* - CM)$ and neutrosophic contra α^*-continuous mapping $(NC\alpha^* - CM)$ in this work are given. Furthermore, their relationships for these our notions are shown.

Definition 3.1. *Assume that* W_1 *and* W_2 *are NTSs and* $h : W_1 \to W_2$ *is any map from* W_1 *into* W_2. *We say h is a neutrosophic* α^**-continuous mapping* $(N\alpha^* - CM)$ *(resp., neutrosophic irresolute* α^**-continuous mapping* $(NI\alpha^* - CM)$, *neutrosophic stronger* α^* *-continuous mapping* $(NS\alpha^* - CM)$ *mapping if for each G (NOS) (resp.* $N\alpha^* - OS$) *in* W_2, *then* $h^{-1}(G)$ *is* $N\alpha^* - OS$ *(resp., (NOS)) in* W_1.

Lemma 3.2. *(1) Every* $(N\alpha^* - CM)$ *is* $(NI\alpha^* - CM)$.

(2) Every $(NI\alpha^* - CM)$ *is* $(NS\alpha^* - CM)$.

Proof . It follows from Proposition 2.7. □

Theorem 3.3. *Assume that* W_1 *and* W_2 *are NTSs and* $h : W_1 \to W_2$.

(i) If h is $(N\alpha^* - CM)$, *then* $h|_G : G \to W_2$ *is also, where G is (NOS) of* W_1.

(ii) If h is $(NI\alpha^* - CM)$, *then* $h|_G : G \to W_2$ *is also, where G is (NOS) of* W_1.

(iii) If h is $(NSa^* - CM)$, *then* $h|_G : G \to W_2$ *is also, where G is* $(N\alpha^* - OS)$ *of* W_1.

Proof . (i) Assume B is an (NOS) in W_2, since h is $(Na^* - CM)$, $h^{-1}(B)$ is $(N\alpha^* - OS)$ in W_1, since G is (NOS) in W_1. Hence, by Proposition 2.4, we have $h^{-1}(B) \cap G$ is $(N\alpha^* - OS)$ in W_1, but $(h|_G)^{-1}(B) = h^{-1}(B) \cap G$, thus by Theorem 2.6, $(h|_G)^{-1}(B)$ is $N\alpha^*-$ open in G.

(ii) and (iii) are similar to (i). □

Theorem 3.4. *Suppose that* $h : W_1 \to W_2$ *is any mapping and* $W_1 = T \cup H$, *where* T, H *are disjoint neutrosophic sets in* W_1. *Then,*

(i) h is $(N\alpha^* - CM)$ *if and only if* $h|_T$ *and* $h|_H$ *are also, where T and H are neutrosophic open sets.*

(ii) h *is* $(NI\alpha^* - CM)$ *if and only if* $h|_T$ *and* $h|_H$ *are also, where* T *and* H *are neutrosophic open sets.*

(iii) h *is (* $NS\alpha^* - CM$ *) if and only if* $h|_T$ *and* $h|_H$ *are also, where* T, H *are neutrosophic* α^**-open sets.*

Proof . (i) Suppose that G is (NOS) in W_2, since $h|_T$ and $h|_H$ are $(N\alpha^* - CM)$, $(h|_T)^{-1}(G)$ and $(h|_H)^{-1}(G)$ are $(N\alpha^* - OS)$ in W_1. So, their union is also, see Proposition 2.4. However, $h^{-1}(G) = (h|_T)^{-1}(G) \cup (h|_H)^{-1}(G)$ and hence $h^{-1}(G)$ is $(N\alpha^* - OS)$ in W_1. Thus h is $(N\alpha^* - CM)$. Sufficiency, follows by using Theorem 3.3. The proofs of (i) and (iii) are the same way of proof (i). □

Theorem 3.5. *Suppose* $h : W_1 \to W_2$ *is any mapping and* $h_T : h^{-1}(T) \to T$ *is defined as* $h_T(t) = h(t)$*, for any neutrosophic set* T *in* W_2 *and* $t \in h^{-1}(T)$*.*

(i) If h *is* $(N\alpha^* - CM)$*, then* h_T *is also, where* T *is (NOS) in* W_2*.*

(ii) If h *is* $(NI\alpha^* - CM)$ *(resp.,* $(NS\alpha^* - CM)$*), then* h_T *is also, where* T *is neutrosophic closed set (NCS) in* W_2*.*

Proof . We shall prove the second case. The first case is similar to (ii). Suppose that B is $(N\alpha^* - OS)$ in T. Since T is (NCS) in W_2, B is $(N\alpha^* - OS)$ in W_2, see Theorem 2.6(ii). Also, since h is $(NI\alpha^* - CM)$ (resp., $(NS\alpha^* - CM)$), $h^{-1}(B)$ is $(N\alpha^* - OS)$ (resp., (NOS)) in W_1. Therefore, $h^{-1}(B)$ is $(N\alpha^* - OS)$ (resp., (NOS)) in $h^{-1}(T)$, see Theorem 2.6(i). □

Theorem 3.6. *Suppose that* X_1, X_2, X_3 *are three (NTSs)* $L : X_1 \to X_2$ *and* $X_2 \subseteq X_3$*. If* $L : X_1 \to X_2$ *is* $(N\alpha^* - CM)$ *(resp., (NIa"-CM),* $(NS\alpha^* - CM)$*), then* $L : X_1 \to X_3$ *is also.*

Proof . Assume that A is(NOS) $(resp., (N\alpha^* - OS))$ in X_3, then A is (NOS) (resp., $(N\alpha^* - OS)$ in X_2, see Theorem 2.6(i) and hence $L^{-1}(A)$ is a neutrosophic α^*-open set $(N\alpha^* - OS, neutrosophicopen)$ in X_1, Now, we recall that the set $\{(x, L(x)), x \in X\} \subseteq X \times Y$ is called the neutrosophic graph of the mapping $L : X \to Y$ and is denoted by $NG(L)$. □

Theorem 3.7. *Suppose that* W_1 *and* W_2 *are two (NTSs),* $h : W_1 \to W_2$ *is any mapping and* $L : W_1 \to W_1 \times W_2$ *is a neutrosophic graph mapping of* h *defined by* $L(t) = (t, h(t))$*, for all* $t \in W_1$*. If* L *is* $(N\alpha^* - CM)$ *(resp., (NI* $\alpha^* - CM$*),* $(NS\alpha^* - CM)$*), then* h *is also.*

Proof . Assume that K is (NOS) (resp., $(N\alpha^* - OS)$) in W_2. Since W_1 is (NOS) (resp., $(Na^* - OS)$) in any NTS), $W_1 \times K$ is (NOS) (resp., $(Na^* - oS)$) in $W_1 \times W_2$, see Theorem 2.5. Therefore, $L^{-1}(W_1 \times K) = h^{-1}(K)$ is a neutrosophic a^*-open (resp., $(N\alpha^* - OS)$, (NOS)) in W_1. Hence, the proof is complete. □

4. Neutrosophic contra α^* -continuity:

In this section, we define a new type of neutrosophic α^*-continuity that we call it a neutrosophic contra α^*-continuous mapping ($NC\alpha^*$-CM) and several propositions related to this new notion are investigated.

Definition 4.1. *Assume that* W_1 *and* W_2 *are two (NTSs) and* $h : W_1 \to W_2$ *is a mapping, then* h *is called a neutrosophic contra* α^**-continuous mapping* $(NC\alpha^* - CM)$*. If* $h^{-1}(K)$ *is* $(N\alpha^* - CS)$ *in* W_1*, for any (NOS)* K *in* W_2*.*

Theorem 4.2. *Let $h : W_1 \to W_2$ be a mapping. The following statements are equivalent:*

(i) h is $(NC\alpha^* - CM)$,

(ii) for each $t \in W_1$ and each (NCS) K in W_2 containing $h(t)$, there exists $(N\alpha^* - OS)\, B$ in W_1, such that $\in B, h(B) \subseteq K$,

(iii) for every (NCS) K of W_2, $h^{-1}(K)$ is $(N\alpha^* - OS)$ of W_1.

Proof . (i) $\to$ (ii) Assume that $\in W_1$, and K is any (NCS) in W_2, then K^c is (NOS) in W_2. Thus $h^{-1}(K^c)$ is $(N\alpha^* - CS)$ in W_1, but $h^{-1}(K^c) = [h^{-1}(K)]^c$. Hence $h^{-1}(K)$ is $(N\alpha^* - OS)$ in W_1, and $t \in h^{-1}(K)$. Put $B = h^{-1}(K)$, thus $h(B) \subseteq K$.

(ii)$\to$(iii) Assume that K is a neutrosophic closed set in W_2 and $t \in h^{-1}(K)$, then $h(t) \in K$ and hence there exists $(N\alpha^* - OS)\, B$ containing $t, h(B) \subseteq K$, thus $t \in B = h^{-1}(K)$. So $h^{-1}(K) = \cup \{B_t \mid t \in h^{-1}(K)\}$. Hence by Proposition 2.4(1), we get $h^{-1}(K)$ is $(N\alpha^* - OS)$ in W_1.

(iii) $\to$ (i) Obviously holds. □

Theorem 4.3. *The restriction L_A of $(NC\alpha^* - CM)\, L : X \to Y$ to $(N\alpha^* - CS)\, A \subseteq X$ is also $(NC\alpha^* - CM)$.*

Proof . Assume that B is (NOS) in Y, thus $L^{-1}(B)$ is $(N\alpha^* - CS)$ in X. Since A is $(N\alpha^* - CS)$ in X, $L^{-1}(B) \cap A$ is also $(N\alpha^* - CS)$ in X and hence it is also $(Na^* - CS)$ in A, see Theorem 2.6(i), but $(L|_A)^{-1}(B) = L^{-1}(B) \cap A$, hence the proof is complete. □

Theorem 4.4. *If $L : X \to Y$ is $(NCa^* - CM)$, then $L_A : L^{-1}(A) \to A$ is also, where A is (NCS) in Y.*

Proof . Assume that B is (NCS) in A. Since A is (NCS) in Y, B is (NCS) in Y. Then $L^{-1}(B)$ is $(N\alpha^* - OS)$ in X. Since $L^{-1}(B) \subseteq L^{-1}(A) \subseteq X$, $L^{-1}(B)$ is $(N\alpha^* - OS)$ in $L^{-1}(A)$, see Theorem 2.6(i). □

Theorem 4.5. *Assume that X and Y are two (NTSs), $L : X \to Y$ is a mapping and $X = A \cup B$, where A, B are disjoint $(N\alpha^*-\ CSs)$ in X. Then $L|_A$ and $L|_B$ are $(NC\alpha^* - CMs)$ if and only if L is $(NC\alpha^* - CM)$.*

Proof . Necessity follows by using Theorem 4.3. Assume that G is (NCS) in Y. Since $L|_A$ and $L|_B$ are $(NC\alpha^* - CMs)$, $(L|_A)^{-1}(G)$ and $(L|_B)^{-1}(G)$ are $(N\alpha^* - OS)$ in X. So, their union is also, see Proposition 2.4. But $L^{-1}(G) = (L|_A)^{-1}(G) \cup (L|_B)^{-1}(G)$ and hence the proof is complete. □

Definition 4.6. *An (NTS) W is called:*

(i) an $N -_{a^*} T_2$ (resp., N-ultra-$_{a^*}T_2$) space if, for each $t \neq d \in W$, there exist two disjoint $(N\alpha^* - OSs)$ (resp., $(N\alpha^* - CSs)$) T, D satisfy $t \in T, d \in D$.

(ii) an$N - \alpha^*$-ultra normal space if for each pair nonempty (NDCSs) can be separated by disjoint $N\alpha^*$-clopen).

- *(iii) a neutrosophic α^*-compact space (Na^*C-space) if for each $N\alpha^*$-open cover of W has a finite subcover.*

Theorem 4.7. *Suppose that $h : W_1 \to W_2$ is injective $(NC\alpha^* - CM)$ and W_2 is $N - T_2-$ space. Then W_1 is N-ultra-$_\alpha \cdot T_2$ space.*

Proof . Assume that $t \neq d \in W_1$. Since h is injective, $h(t) \neq h(d)$ in W_2 and since W_2 is $N - T_2-$ space, there exist two (NDOSs) T, D satisfy $h(t) \in T, h(d) \in D$. Since h is $(NC\alpha^* - CM)$, $h^{-1}(T), h^{-1}(D)$ are $(N\alpha^* - CS)$ in W_1 containing t, d and $h^{-1}(T) \cap h^{-1}(D) = \varphi = h^{-1}(T \cap D)$. Hence W_1 is N-ultra-$_\alpha \cdot T_2$ space. □

Theorem 4.8. *Suppose that $L : X \to Y$ is injective $(NC\alpha^* - CM)$ and Y is an N-ultra T_2-space. Then X is an $N -_{\alpha^*} T_2$ space.*

Proof . Take $x \neq y$ in X. Since L is injective, $f(x) \neq f(y)$ in Y. Since Y is an N-ultra T_2- space, there exist two (NDCSs) A, B satisfy $L(x) \in A, L(y) \in B$. Moreover, from L is $(NCa^* - CM)$, we have $L^{-1}(A), L^{-1}(B)$ are $(N\alpha^* - OSs)$ in X containing x, y and $L^{-1}(A) \cap L^{-1}(B) = \emptyset$. Then X is an $N - a^*T_2$ space. □

Theorem 4.9. *Suppose that $h : W_1 \to W_2$ is a neutrosophic closed injective $(NC\alpha^* - CM)$ and W_2 is a neutrosophic ultra normal space. Then W_1 is $N - \alpha^*-$ is an ultra normal space.*

Proof . Assume that A_1, A_2 are two (NCSs) in W_1 with $A_1 \cap A_2 = \varphi$. Since h is a neutrosophic closed mapping, $h(A_1), h(A_2)$ are (NCSs) in W_2. Since, W_2 is a neutrosophic ultra normal space, there exist two disjoint neutrosophic clopen sets B_1, B_2 in W_2 satisfy $h(A_1) \subseteq B_1, h(A_2) \subseteq B_2$. Hence $A_1 \subseteq h^{-1}(B_1), A_2 \subseteq h^{-1}(B_2)$. From injectivity of h, we get $h^{-1}(B_1), h^{-1}(B_2)$ are disjoint neutrosophic α^*-clopen sets. Thus W_1 is a neutrosophic α^*-ultra normal space. □

Theorem 4.10. *Suppose that $h : W_1 \to W_2$ is a neutrosophic closed surjective $(NC\alpha^* - CM)$ and W_1 is $(N\alpha^*C-$ space$)$. Then W_2 is a neutrosophic strongly closed space.*

Proof . Assume that $\{V_i \mid i \in I\}$ is any neutrosophic closed cover of W_2. Since h is $(NC\alpha^* - CM)$, $\{h^{-1}(V_i) \mid i \in I\}$ is a neutrosophic α^*-open cover of W_1, but W_1 is ($N\alpha^*C-$ space), thus W_1 has finite subcover. This means that $W_1 = \bigcup_{i\in \mathrm{I}_0} h^{-1}(V_i)$, where $I_0 = \{1, \ldots, n\}$. Since h is neutrosophic surjective, we have

$$h(W_1) = h\left(\bigcup_{j=1}^{n} h^{-1}(V_i)\right) = \bigcup_{j=1}^{n} hh^{-1}(V_i).$$

Hence, $W_2 = \bigcup_{i\in \mathrm{I}_0} V_i$. Thus W_2 is a neutrosophic strongly closed space. □

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