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RESEARCH ARTICLE

Characterization of Contra Continuous Functions

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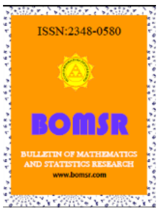

ABSTRACT

In this paper, weaker forms of continuous functions called contra αg*s-continuous functions are introduced. Also, a new form of contra continuity called almost contra αg*s-continuous functions which are weaker than contra αg*s-continuity is introduced and studied their basic properties relating to them.

Keywords and Phrases: αg*s-closed sets, αg*s-continuous functions, contra αg*s-continuous functions.

AMS Subject Classification: 54C08, 54C10

1. Introduction

Dontchev [4] introduced a new class of functions called contra-continuous functions in topological spaces. New weaker forms of functions called contra-semi continuous functions were introduced and investigated by Dontchev and Noiri [5]. Jafari and Noiri [8], [9] introduced other new weaker forms of this class of functions called contra-α-continuous and contra-pre continuous functions. Also, Contra super continuity is a continuation of research done by Dontchev [4] and Jafari and Noiri [7].

In this paper, we introduce and investigate the properties of new class of functions called contra αg*s-continuous functions as a generalization of contra continuity. Also, almost contra αg*s-continuous functions are introduced and obtained some of their properties in topological spaces.

2. Preliminaries

Throughout this paper (X, τ), (Y, μ) and (Z, σ) (or simply X, Y and Z) always mean topological spaces on which no separation axioms are assumed unless explicitly stated. For a subset A of a space X, the closure and interior of A with respect to τ are denoted by cl(A) and int(A) respectively.

Definition 2.1. [10] A subset A of X is αg*s-closed if αcl(A) ⊂ U whenever A ⊂ U

and U is gs-open in X.

Definition 2.2. [10] The intersection of all αg*s-closed sets containing a set A is called αg*s-closure of A and is denoted by αg*s-cl(A).

A set A is αg*s-closed set if and only if αg*s-cl(A) = A.

Definition 2.3. [10] The union of all αg*s-open sets contained in A is called αg*s- interior of A and is denoted by αg*s-int(A).

A set A is αg*s-open if and only if αg*s-int(A) = A.

Definition 2.4. In a space X,

(i) If every αg*s-closed set is closed in X, then X is called $T_{\alpha g^*s}$ space [10].

Definition 2.5. A function f : X →Y is called a

(i) αg*s-continuous [10], if the inverse image of every closed set in Y is αg*s-closed in X.

(ii) pre αg*s-continuous [10], the image of every αg*s-closed set in X is αg*s- closed in Y.

(iii) αg*s-irresolute [10], if the inverse image of every αg*s-closed set in Y is αg*s-closed in X.

(iv) contra continuous [4], for every open set V in Y, $f^{-1}(V)$ is closed in X.

3. Contra αg*s -continuous functions

In this section, a new class of functions called contra αg*s-continuous functions is introduced and obtains some of their properties and relationships with some other related functions are discussed.

Definition 3.1. A function f: X → Y is said to be contra αg*s-continuous if

$f^{-1}(V)$ ∈ sgωα-C(X) for every V ∈ O(Y).

Remark 3.1. We can observe that contra αg*s-continuous and αg*s-continuous are independent of each other.

Example 3.1. Let X = Y = {a, b, c} , τ ={X, ϕ, {a}, {b}, {a, b}} and μ = {Y, ϕ, {a, b}} be topologies on X and Y respectively. Let f: X→Y be the identity function. Then f is αg*s-continuous function but not contra αg*s-continuous, since for the open set {a, b} in Y, f^{-1}({a, b}) = {a, b} is not αg*s-closed in X.

Example 3.2. Let X = Y = {a, b, c}, τ = {X, ϕ, {c}} and μ = {Y, ϕ, {a, b}} be topologies on X and Y respectively. Define the identity function f : X → Y . Then f is contra αg*s-continuous but not αg*s-continuous, for the open set {a, b} in Y, f^{-1}({a, b}) = {a, b} is not αg*s-open in X.

Remark 3.2. Every contra continuous is contra αg*s-continuous.

Theorem 3.1. If a function $f : X \to Y$ is αg*s-irresolute, $g : Y \to Z$ is contra continuous then $g \circ f : X \to Z$ is contra αg*s-continuous.

Proof: Let $G \in O(Z)$. Since g is contra continuous, $g^{-1}(G) \in C(Y)$. Thus $g^{-1}(G) \in$ αg*s-C(Y). Since f is αg*s-irresolute, $f^{-1}(g^{-1}(G)) = (g \circ f)^{-1}(G) \in$ αg*s-C(X). Thus $g \circ f$ is contra αg*s-continuous.

Theorem 3.2. Composition of contra αg*s -continuous and continuous functions is again contra αg*s -continuous.

Proof. Let $V \in O(Z)$. As g is continuous, $g^{-1}(V) \in O(Y)$. Then by contra αg*s-continuity, $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V) \in$ αg*s-C(X). Thus gof is contra αg*s-continuous.

Lemma 3.1. [7] The following properties holds for $A, B \subset X$:

(i) $x \in ker(A)$ if and only if $A \cap F \neq \phi$ for any $F \in C(X, x)$

(ii) $A \subset ker(A)$ and $A = ker(A)$ if $A \in O(X)$.

(iii) if $A \subset B$, then $ker(A) \subset ker(B)$

Theorem 3.3. The followings conditions are equivalent for a function $f: X \to Y$:

(i) f is contra αg*s-continuous.

(ii) for every $F \in C(Y)$, $f^{-1}(F) \in$ αg*s-O(X).

(iii) for each $x \in X$ and each $F \in C(Y, f(x))$, there exists $U \in$ αg*s-O(X, x) such that $f(U) \subset F$.

(iv) for each $x \in X$ and $V \in O(Y)$ not containing f (x), there exists $K \in$ αg*s-C(X) not containing x such that $f^{-1}(V) \subset K$.

(v) f(αg*s-cl(A)) ⊂ ker(f (A)) holds for $A \subset X$

(vi) αg*s-cl($f^{-1}(B)$) ⊂ $f^{-1}(ker(B))$ holds for $B \subset Y$.

Proof. (i) → (ii) Let $F \in C(Y)$ and so $Y-F \in O(Y)$. From (i), $f^{-1}(Y-F) = X-f^{-1}(F) \in$ αg*s-C(X). Thus $f^{-1}(F) \in$ s αg*s-O(X). Hence (ii) holds.

(ii) → (i): Let $G \in O(Y)$ and so $Y-G \in C(Y)$. From (ii), $f^{-1}(Y-G) = X-f^{-1}(G) \in$ αg*s-O(X), which shows that $f^{-1}(G) \in$ αg*s-C(X). Thus (i) hold.

(iii) → (ii) Let $F \in C(Y, f(x))$. Then $x \in f^{-1}(F)$. By (ii), $f^{-1}(F) \in$ αg*s-O(X, x). Let $U = f^{-1}(F)$. Then $f(U) = f(f^{-1}(F)) \subseteq F$. Therefore (iii) holds.

(ii) → (iii) Let $F \in C(Y, f(x))$. Then $x \in f^{-1}(F)$. From (iii), $Ux \in$ αg*s-O(X, x) with $f(Ux) \subseteq F$, that is $Ux \in f^{-1}(F)$. Thus $f^{-1}(F) = \cup\{Ux : x \in f^{-1}(F)\}$, which is the union of αg*s-open sets. Thus $f^{-1}(F) \in$ αg*s-O(X).

(iv)→ (iii) Let $V \in O(Y)$ not containing f (x). Then $Y-V \in C(Y, f(x))$. By (iii), $U \in$ αg*s-O(X, x) such that $f(U) \subseteq Y-V$ and so $U - f^{-1}(Y-V) = X-f^{-1}(V)$. Hence $f^{-1}(V) \subseteq X - U$. Put $K = X - U$ and so $K \in$ αg*s-C(Y) not containing x such that $f^{-1}(V) \subseteq K$.

(iii) → (iv) Let $F \in C(Y, f(x))$ and so $Y- F \in O(Y)$ not containing f (x). From (iv), $K \in$ αg*s-C(X) not containing x with $f^{-1}(Y-F) \subseteq K$ and so $X-f^{-1}(F) \in K$. Thus $X-K \in f^{-1}(F)$, that is $f(X-K) \subseteq F$. Put $U = X - K$, then $U \in$ αg*s-O(X, x) with $f(U) \subseteq F$.

(ii) $\rightarrow$ (v) Let $A \subseteq X$. Assume that $y \notin ker(f(A))$. From lemma 3.1, $F \in C(Y, y)$ with $f(A) \cap F = \phi$. Thus, $A - f^{-1}(F) = \phi$ and so $A\text{-}X \subseteq f^{-1}(F)$. But from (ii), $f^{-1}(F) \in$ αg*-O(X) and hence $X\text{-}f^{-1}(F) \in$ αg*s-C(X). Thus αg*s-cl($X\text{-}f^{-1}(F)$) = $X\text{-}f^{-1}(F)$. Now $A\text{-}X \subseteq f^{-1}(F)$, that is αg*s-cl(A) $\in$ αg*s-cl($X - f^{-1}(F)$) = $X\text{-}f^{-1}(F)$. Therefore αg*s-cl(A) $\in f^{-1}(F) = \phi$, which implies f (αg*s-cl(A)) $\cap F = \phi$ and hence $y \notin$ αg*s-cl(A). Thus f (αg*s-cl(A)) $\in$ ker(f (A)) holds for every $A \subseteq X$.

(v) $\rightarrow$ (vi) Let $B \subset Y$. Then $f^{-1}(B) \subset X$. From (iv) and by Lemma 3.1, f (αg*s- cl($f^{-1}(B)$)) $\subset$ ker(f($f^{-1}(B)$)) $\subset$ ker(B). Thus, for every $B \subseteq Y$, we have

αg*s- cl($f^{-1}(B)$) $\subseteq f^{-1}$(ker(B)) .

(vi) $\rightarrow$ (i) Let $V \in O(Y)$. Then from (vi) and Lemma 3.1, αg*s-cl($f^{-1}(V)$ $\subseteq f^{-1}$(ker(V)) = $f^{-1}(V)$ and αg*s-cl($f^{-1}(V)$) = $f^{-1}(V)$. Thus $f^{-1}(V) \subseteq$ αg*s-C(X). Hence f is contra αg*s-continuous.

Theorem 3.4. Let f: X $\rightarrow$ Y be contra αg*s-continuous with Y is regular space. Then f is αg*s-continuous.

Proof. Let $x \in X$ and $V \in O(Y, f(x))$. Then by regularity of Y, $W \in O(Y, f(x)$ with $cl(W) \subseteq V$. As f is contra αg*s-continuous and from **Theorem** 3.3 (iii), U $\in$ αg*s-O(X, x) such that $f(U) \subset cl(W)$. Then $f(U) \subset cl(W) \subset V$. Thus f is αg*s-continuous.

Definition 3.2. A space X is called locally αg*s-indiscrete if V $\in$ αg*s-O(X) then $V \in C(X)$.

Theorem 3.5. If a function f: X $\rightarrow$ Y is contra αg*s-continuous with X is locally αg*s-indiscrete then f is continuous.

Proof. Let $U \in O(Y)$. As f is contra αg*s-continuous and X is locally αg*s- indiscrete space, $f^{-1}(U) \in O(X)$. Thus f is continuous.

Definition 3.3. A function f is said to be weakly αg*s-continuous, if for each $x \in X$

and $V \in O(Y, f(x))$, there exists U $\in$ αg*s -O(X, x) with $f(U) \subset cl(V)$.

Theorem 3.6. Every contra αg*s-continuous function is weakly αg*s-continuous function.

Proof. Let $V \in O(Y)$. Since $cl(V) \in C(X)$ and from **Theorem** 3.3(ii), $f^{-1}(cl(V)) \in$ αg*s-O(X). Let $U = f^{-1}(cl(V))$, then $f(U) \subset f(f^{-1}(cl(V))) \subset cl(V)$. Thus f is almost weakly αg*s-continuous.

Definition 3.4. For any $A \subset X$, αg*s-frontier of A defined as αg*s-cl(A)-αg*s- int(A) and is denoted by αg*s-Fr(A).

Theorem 3.7. The set of all points x of X at which the function f : X $\rightarrow$ Y is not contra αg*s-continuous is identical with the union of αg*s-frontier of the inverse images of closed sets of Y containing f (x).

Proof. Suppose f is not contra αg*s-continuous at $x \in X$. From **Theorem** 3.3 (iii), for every U $\in$ αg*s-O(X, x), $F \in C(Y, f(x))$ such that $f(U) \cap (Y\text{-}F) = \phi$, that is $U \cap f^{-1}(Y\text{-}F) = \phi$. Therefore, $x \in$ αg*s-cl($f^{-1}(Y\text{-}F)$) = αg*s-cl($X\text{-}f^{-1}(F)$). Also, $x \in f^{-1}(F) \in$ αg*s-cl($f^{-1}(F)$). Thus, $x \in$ αg*s-cl($f^{-1}(F)$) - αg*s-cl($X\text{-}f^{-1}(F)$), that is $x \in$ αg*s-cl($f^{-1}(F)$) - αg*s-int($f^{-1}(F)$). Hence $x \in$ αg*-Fr($f^{-1}(F)$).

On the other hand, for some $F \in C(Y, f(x))$, $x \in$ αg*s-Fr($f^{-1}(F)$). As f is contra αg*s-continuous, U $\in$ αg*s-O(X, x) such that $f(U) \subset F$. Therefore, $x \in U \subseteq f^{-1}(F)$ and hence $x \in$ αg*s-int($f^{-1}(F)$) $\subseteq X$ - αg*s-Fr($f^{-1}(F)$), which is contradiction to the fact that $x \in$ αg*s-Fr($f^{-1}(F)$). Hence f is not contra αg*s-continuous.

Definition 3.5. If X cannot be expressed as the union of two disjoint nonempty αg*s-open sets, then X is said to be αg*s-connected.

Theorem 3.8. Let f: X → Y be contra αg*s-continuous from a αg*s-connected space X onto any space Y. Then Y is not a discrete space.

Proof. Let f be contra αg*s-continuous with X is αg*s-connected. On the contrary, let Y be a discrete space. Let A ∈ O(Y), C(Y) and so $f^{-1}(A)$ ∈ αg*s-O(X), αg*s- C(X), which shows that X is αg*s-connected. Thus Y is not a discrete space.

Theorem 3.9. Every contra αg*s-continuous surjective space with αg*s-connected space is connected.

Proof. Let f be contra αg*s-continuous with X is αg*s-connected. Suppose Y is not connected. Then U, V ∈ O(Y) with U∩V = ϕ such that Y = U ∪ V. Thus U and V are clopen sets in Y. By contra αg*s-continuity of f, $f^{-1}(U)$, $f^{-1}(V)$ ∈ αg*s-O(X). As f is surjective, $f^{-1}(U)$ and $f^{-1}(V)$ are non-empty disjoint and X = $f^{-1}(U) \cup f^{-1}(V)$, which shows that X is αg*s-connected. Thus Y must be connected.

Theorem 3.10. Let X be αg*s-connected with Y is T1-space. Then f is constant, if f is contra αg*s-continuous.

Proof. Let f: X → Y is contra αg*s-continuous with X is αg*s-connected and Y is T1-space. Then by T1-space, ∇ = {$f^{-1}(y)$: y ∈ Y} which is the disjoint αg*s-open partition of X. If |∇| ≥ 2, there exists a proper αg*s-open and αg*s-closed set, which is contradiction to the hypothesis. Thus ∇ = 1 and so f is a constant map.

Definition 3.8 [10]: A space X is said to be αg*s-T_2, if for any x, y ∈ X with x ≠y, there exist U, V ∈ αg*s-O(X) with U ∩ V = ϕ such that x ∈U and y ∈ V.

Definition 3.9. [11] A space X is called Ultra Hausdroff space, if for every pair of distinct points x and y in X, there exist disjoint clopen sets U and V in X containing x and y respectively.

Theorem 3.12. Let f : X → Y be contra αg*s-continuous injective function. If Y is Ultra Hausdroff, then X is αg*s-T_2.

Proof. Let x, y ∈ X with x ≠ y. Then f (x) ≠ f (y). By Ultra Hausdroff space there exists disjoint clopen sets U and V containing f (x) and f (y) respectively. Then x∈ $f^{-1}(U)$ and y ∈ $f^{-1}(V)$, where $f^{-1}(U)$, $f^{-1}(V)$ ∈ αg*s-O(X) with $f^{-1}(U) \cap f^{-1}(V)$ = ϕ. Thus X is αg*s-T_2.

Definition 3.10. [10] (i) if every αg*s-closed cover has a finite subcover, then X is said to be αg*s-closed compact.

(ii) if every countable cover of X by αg*s-closed sets has a finite subcover, then X is said to be countably αg*s-closed compact.

(iii) if every αg*s-closed cover has a countable subcover, then X is said to be αg*s- Lindelof.

Theorem 3.13. The following properties holds for a contra αg*s-continuous surjection function f : X → Y :

(i) Y is compact, if X is αg*s-closed compact.

(ii) Y is countabaly compact, if X is countably αg*s-closed compact.

(iii) Y is Lindelof, if X is αg*s-Lindelof.

4. Almost Contra αg*s-Continuous Functions inTopological spaces

In this section, a new type of continuous functions called an almost contra αg*s-continuous functions, which are weaker than contra αg*s-continuous functions are introduced and studied some of their properties.

Definition 4.1. A function f: X ⟶ Y is said to be almost contra αg*s continuous if $f^{-1}(V)$ is αg*s-closed in X for each regular-open set V in Y.

Theorem 4.1: For the function f: X → Y, following statements are equivalent:

(i) f is almost contra αg*s-continuous

(ii) for every F ∈ RO(Y), f−1(F) ∈ αg*sO(X)

(iii) for each x ∈ X and for each F ∈ RC(Y, f (x)) there exists U∈αg*sO(X, x) such that f(U) ⊆ F.

(iv) for each x ∈ X and for each V ∈ RO(Y) such that f(x) ∉ there exists K ∈ αg*sC(X) not containing x such that f−1(V) ⊆ K.

Proof: (i) ⇒ (ii) Let F ∈ RO(Y) then Y − F ∈ RC(Y). From (i), $f^{-1}(Y - F) = X - f^{-1}(F)$ ∈ αg*sC(X) and hence $f^{-1}(F)$ ∈ αg*sO(X).

(ii) ⇒ (i) Let G ∈ RC(Y) then Y − G ∈ RC(Y). By (ii), $f^{-1}(Y - G) = X - f^{-1}(G)$ ∈ αg*sO(X), this implies that $f^{-1}(G)$ ∈ αg*sC(X).

(ii) ⇒ (iii) Let F ∈ RC(Y, f (x)) such that x ∈ $f^{-1}(F)$. By (ii), U ∈ αg*sO(X, x) such that f(Ux) ⊆ F, so Ux ⊆ $f^{-1}(F)$. Thus $f^{-1}(F)$ = ∪{Ux : x ∈ $f^{-1}(F)$}.

(iii) ⇒ (ii) Let F ∈ RC(Y, f (x)) and x ∈ $f^{-1}(F)$. By (iii), there exists U ⊆ αg*sO(X,x) such that f(Ux) ⊆ F, that implies Ux ⊆ $f^{-1}(F)$. Thus, $f^{-1}(F)$ = ∪{Ux: x ∈ $f^{-1}(F)$}. Hence $f^{-1}(F)$ ∈ αg*sO(X).

(iii) ⇒ (iv) Let V ∈ RO(Y) such that f (x) ∉ V then Y − V ∈ RC(Y, f (x)). By (iii) there exists U ∈ αg*sO(X, x) such that f (U) ⊆ Y − V , that is U ⊆ $f^{-1}(Y - V) = X - f^{-1}(V)$ and hence $f^{-1}(V) \subseteq X - U$. Take K = X − U then K ∈ αg*sC(X) such that $f^{-1}(V)$ ⊆ K.

(iv) ⇒ (iii): Let F ∈ RC(Y, f (x)) then Y − F ∈RO(Y). From (iv), there exists K ∈ αg*sC(X) not containing x such that $f^{-1}(Y - F)$ ⊆ K, that is X − $f^{-1}(F)$ ⊆ K. Hence X − K ⊆ $f^{-1}(F)$ this implies f (X − K) ⊆ F. Take U = X − K then U ∈ αg*s O(X, x) such that f (U) ⊆ F.

Theorem 4.2. If f: X → Y is an almost contra αg*s-continuous injective and Y is Weakly Hausdorff then X is αg*s-T_1- space.

Proof: Let x, y ∈ X with x ≠ y. Then there exist V, W ∈ RC(Y) such that f (x) ∈V and f(y) ∈W as Y Weakly Hausdroff. Since f is almost contra αg*s-continuous then $f^{-1}(V)$, $f^{-1}(W)$ ∈ αg*sO(X) such that x ∈ $f^{-1}(V)$, y ∉ $f^{-1}(V)$ and y ∈ $f^{-1}(W)$, x ∉ $f^{-1}(W)$. Hence X is αg*s-T_1- space.

Theorem 4.3. If f : X → Y is almost contra αg*s-continuous injective function from a space X into an Ultra Hausdorff space Y then X is αg*s-T_2.

Proof: Let x, y ∈ X with x ≠ y then f (x) ≠ f (y) as f is injective. As Y is Ultra Hausdorff there exist U ∈ CO(Y, f (x)) and V ∈ CO(Y, f (y)) such that U ∩ V = ϕ. Since f is almost contra αg*s-continuous, $x \in f^{-1}(U)$ and $y \in f^{-1}(V)$ where $f^{-1}(U) \in$ αg*sO(X, x) and $f^{-1}(V) \in$ αg*sO(X, y) such that $f^{-1}(U) \cap f^{-1}(V) = \phi$. Hence X is αg*s-$T_2$.

Theorem 4.4. Let f: X → Y be almost contra αg*s-continuous closed and injection function. If Y is Ultra Normal then X is αg*s-normal.

Theorem 4.5. If a function f : X → Y is almost contra αg*s-continuous from a αg*s-connected space X on to a topological space Y, then Y is also connected space.

Proof: If Y is not connected then U, V ∈ O(Y) such that Y = U ∪ V and hence U, V ∈ CO(Y). Then $f^{-1}(U), f^{-1}(V) \in$ αg*sO(X) since f is almost contra αg*s-continuous function and $f^{-1}(U) \cap f^{-1}(V) = \phi$ such that $X = f^{-1}(U) \cup f^{-1}(V)$ which is a contradiction to the fact that X is αg*s-connected. Hence Y must be connected space.

Theorem 4.6. Let f: X → Y and g : Y → Z are any two functions. Then we have the following:

(i) gof is almost contra αg*s-continuous if f is almost contra αg*s-continuous and g is an R-map.

(ii) gof is αg*s-continuous and contra αg*s-continuous if f is almost contra αg*s-continuous and g is perfectly-continuous.

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