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Characterization of Contra sgα-Continuous Functions In Topological Spaces

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ABSTRACT

In this paper, we introduce and investigate the notion of Characterization of Contra sgα-Continuous Functions in Topological Spaces. We obtain separation axiom of contra sgα-continuous functions and discuss the relationships between contra-sgα-continuity and other related functions.

Subject Classification: *54C05, 54C08, 54C10.*

Keywords: *contra sgα-continuous functions, sgα-graph, sgα-dense, sgα-clopen, sgα- T-spaces, sgα-Normal, sgα-lindeloff.*

1. INTRODUCTION

N. Levine [16] introduced generalized closed sets (briefly g-closed set) in 1970. N. Levine [15] introduced the concepts of semi-open sets in 1963. Bhattacharya and Lahiri [6] introduced and investigated semi-generalized closed (briefly sg- closed) sets in 1987. Arya and Nour [3] defined generalized semi-closed (briefly gs-closed) sets for obtaining some characterization of s-normal spaces in 1990. O.Njastad in 1965 defined α-open sets [23].

In 1996, Dontchev [11] introduced a new class of functions called contra- continuous functions. A new weaker form of this class of functions called contra semi-continuous function is introduced and investigated by Dontchev and Noiri [12].

In this paper, the notion of sgα-closed sets [9] and contra sgα- continuous Space in topological spaces [8] is applied to introduce and study a new class of functions called characterization of contra sgα-continuous functions, as a new generalization of contra continuity, separation axioms, also the relationships with some other functions are discussed.

2. PRELIMINARIES

Throught this paper (X, τ), (Y, σ) and (Z, η) always mean topological spaces on which no separation axioms are assumed unless explicity stated. Let A be a subset of a space X. The closure of A and the interior of A are denoted by cl (A) and int (A) respectively. (X, τ) will be replaced by X if there is no chance of confusion. Let us recall the following definitions as pre requests.

A subset A of a topological space X is said to be open if $A \in \tau$. A subset A of a topological space X is said to be closed if the set X−A is open. The interior of a subset A of a topological space X is defined as the union of all open sets contained in A. It is denoted by int(A). The closure of a subset A of a topological space X is defined as the intersection of all closed sets containing A. It is denoted by cl(A).

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Definitions 2.1: A subset A of a space (X, τ) is said to be

1. semi open [15] if $A \subseteq cl(int(A))$ and semi closed if $int(cl(A)) \subseteq A$.
2. α-open [23] if $A \subseteq int(cl(int(A)))$ and α-closed if $cl(int(cl(A))) \subseteq A$.
3. β-open or semi pre-open [1] if $A \subseteq cl(int(cl(A)))$ and β-closed or semi pre-closed if $int(cl(int(A))) \subseteq A$.
4. pre-open [11] if $A \subseteq int(cl(A))$ and pre-closed if $cl(int(A)) \subseteq A$.

The complement of a semi-open (resp.pre-open, α-open, β-open) set is called semi-closed (resp.pre-closed, α-closed, β-closed). The intersec- tion of all semi-closed (resp.pre-closed, α-closed, β-closed) sets containing A is called the semi-closure (resp.pre-closure, α-closure, β-closure) of A and is denoted by scl(A)(resp. pcl(A), α-cl(A), β-cl(A)). The union of all semi-open (resp.pre-open, α-open, β-open) sets contained in A is called the semi-interior(resp.pre-interior, α-interior, β-interior) of A and is denoted by sint(A)(resp. pint(A), α-int(A), β-int(A)). The family of all semi- open (resp.pre-open, α-open, β-open) sets is denoted by SO(X)(resp. PO(X), $\alpha-O(X)$, $\beta-O(X)$). The family of all semi-closed (resp.pre-closed, α-closed, β-closed) sets is denoted by SCl(X) (resp. PCl(X), α-Cl(X), β-Cl(X)).

Definitions 2.2: A subset A of a space (X, τ) is called

1. g-closed[16] if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in (X, τ). The complement of a g-closed set is called g-open set.
2. gs-closed set[7] if $scl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in (X, τ).
3. sg-closed set[6] if $scl(A) \subseteq U$, whenever $A \subseteq U$ and U is semi-open in (X, τ).
4. 4. αg-closed[17] if $\alpha(cl(A)) \subseteq U$, whenever $A \subseteq U$ and U is open in (X, τ).
5. gα-closed [18] if $\alpha(cl(A)) \subseteq U$, whenever $A \subseteq U$ and U is α-open in (X, τ).
6. gp-closed [19] if $pcl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in (X, τ).

Definition 2.3: Let X and Y be topological spaces. A function $f: X \to Y$ is said to be
1. continuous [14] if for each open set V of Y the set $f^{-1}(V)$ is an open subset of X.
2. α-continuous [23] if $f^{-1}(V)$ is a α-closed set of (X, τ) for every closed set V of (Y, σ).
3. β-continuous [1] if $f^{-1}(V)$ is a β-closed set of (X, τ) for every closed set V of (Y, σ).
4. pre-continuous [21] if $f^{-1}(V)$ is a pre-closed set of (X, τ) for every closed set V of (Y, σ).
5. semi-continuous [15] if $f^{-1}(V)$ is a semi-closed set of (X, τ) for every closed set V of (Y, σ).

Definition 2.4: A function $f: (X, \tau) \to (Y, \sigma)$ is said to be
1. g-continuous [16] if $f^{-1}(V)$ is a g-closed set of (X, τ) for every closed set V of (Y, σ).
2. gs-continuous[7] if $f^{-1}(V)$ is a gs-closed set of (X, τ) for every closed set V of (Y, σ).
3. sg-continuous [6] if $f^{-1}(V)$ is a sg-closed set of (X, τ) for every closed set V of (Y, σ).
4. αg-continuous [17] if $f^{-1}(V)$ is a αg-closed set of (X, τ) for every closed set V of (Y, σ).
5. gα-continuous [18] if $f^{-1}(V)$ is a gα-closed set of (X, τ) for every closed set V of (Y, σ).
6. gp-continuous [19] if $f^{-1}(V)$ is a gp-closed set of (X, τ) for every closed set V of (Y, σ).

Definitions 2.5[22]: A function $f: (X, \tau) \to (Y, \sigma)$ is said to be almost continuous if for every open set V of Y, $f^{-1}(V)$ is regular open in X.

Definitions 2.6[9]: A subset A of space (X, τ) is called sgα-closed if $scl(A) \subseteq U$, whenever $A \subseteq U$ and U is α-open in X. The family of all sgα-closed subsets of the space X is denoted by SGαC (X).

Definitions 2.7[9]: The intersection of all sgα-closed sets containing a set A is called sgα-closure of A and is denoted by sgα-cl(A). A set A is sgα-closed set if and only if sgα Cl(A) = A.

Definitions 2.8[9]: A subset A in X is called sgα-open in X if A^c is sgα-closed in X. The family of a sgα-open sets is denoted by SGαO(X).

Definitions 2.9[9]: The union of all sgα-open sets containing a set A is called sgα-interior of A and is denoted by sgα-Int(A). A set A is sgα-open set if and only if sgα Int (A) = A.

Definition 2.10[8]: A function $f:(X, \tau) \to (Y, \sigma)$ is called sgα-continuous if $f^{-1}(V)$ is sgα-closed in (X, τ) for every closed set V of (Y, σ).

Definition 2.11[8]: A function $f: X \to Y$ is said to be Contra sgα-Continuous if $f^{-1}(V)$ is sgα-closed in X for each open set V of Y.

Definition 2.12[8]: A space X is called locally sgα-indiscrete if every sgα-open set is closed in X.

Definition 2.13 [8]: If a function $f : X \to Y$ is called almost sgα-continuous if for each $x \in X$ and each open set V of Y containing $f(x)$, there exists $U \in SG\alpha O(X, x)$ such that $f(U) \subset Int(cl(V))$.

Definition 2.14[8]: If a function $f: X \to Y$ is called quasi sgα-open if image of every sgα-open set of X is open set in Y.

Definition 2.15[8]: If a function $f : X \to Y$ is called weakly sgα-continuous if for each $x \in X$ and each open set V of Y containing $f(x)$, there exists $U \in SG\alpha O(X, x)$ such that $f(U) \subset scl(V)$.

Definition 2.16 [8]: Let A be a subset of X. Then sgα-Cl(A)-sgα-Int(A) is called sgα-frontier of A and is denoted by sgα-Fr(A).

Lemma 2.17[13]: The following properties hold for subsets A and B of a space X.
1. $x \in \ker(A)$ if and only if $A \cap F = \varphi$ for any closed set F of X containing x.
2. $A \subset \ker(A)$ and $A = \ker(A)$ if A is open in X.
3. if $A \subset B$, then $\ker(A) \subset \ker(B)$

3. Characterization of Contra− sgα Continuous Functions in Topological Spaces

Definition 3.1: The graph $G(f)$ of a function $f: X \to Y$ is said to be contra sgα-graph if for each $(x, y) \in (X \times Y) \mid G(f)$, there exists a sgα- open set U in X containing x and a closed set V in Y containing y such that $U \times Y \cap G(f) = \varphi$.

Theorem 3.2: Let $f: X \to Y$ be a function and let $g: X \times X \to Y$ be the graph function of f defined by $g(x) = (x, f(x))$ for every $x \in X$. If g is contra sgα-continuous, then f is contra sgα-continuous.

Proof: Let U be an open set in Y. Then $X \times U$ is an open set in $X \times Y$. Since g is contra sgα-continuous, it follows that $f^{-1}(U) = g^{-1}(X \times U)$ is a sgα- closed set in X. Therefore f is contra sgα-continuous.

Theorem 3.3: Assume SGαO(X) is closed under any intersection. If $f : X \to Y$ and $g : X \to Y$ are contra sgα-continuous and Y is Urysohn, then $E = \{x \in X : f(x) = g(x)\}$ is sgα-closed in X.

Proof: Let $x \in X - E$. Then $f(x) = g(x)$. Since Y is Urysohn, there exists open sets V and W such that $f(x) \in V$, $g(x) \in W$ and $Cl(V) \cap Cl(W) = \varphi$. Since f and g are contra sgα-continuous, $f^{-1}(Cl(V))$ and $g^{-1}(Cl(W))$ are sgα-open sets in X. Let $U = f^{-1}(Cl(V))$ and $G = g^{-1}(Cl(W))$. Then U and G are sgα-open sets containing x, set $A = U \cap G$, thus A is sgα-open set in X. Hence $f(A) \cap g(A) = f(U \cap G) \cap g(U \cap G) \subset f(U) \cap g(G) = Cl(V) \cap Cl(W) = \varphi$. Therefore, $A \cap E = \varphi$. This implies $x \not\in sg\alpha - Cl(E)$. Hence E is sgα-closed set in X.

Definition 3.4: A subset A of a topological space X is said to be sgα-dense in X if $sg\alpha - Cl(A) = X$.

Theorem 3.5: Assume $SG\alpha O(X)$ is closed under any intersection. If $f: X \to Y$ and $g: X \to Y$ are contra sgα-continuous, Y is Urysohn, and $f = g$ on sgα-dense set $A \subset X$, then $f = g$ on X.

Proof: Since f and g are contra sgα-continuous. Y is Urysohn, by the theorem 3.3, $E = \{x \in X; f(x) = g(x)\}$ is sgα-closed in X. By assumption, $f = g$ on sgα-dense set A subset of X. Since $A \subset E$ and A is sgα-dense set in X, then $X = sg\alpha - Cl(A) \subset sg\alpha - Cl(E) = E$. Hence $f = g$ on X.

Definition 3.6: A space X is called sgα-connected provided that X is not the union of two disjoint non-empty sgα-open sets.

Theorem 3.7: If $f: X \to Y$ is a contra sgα-continuous from a sgα- connected space X onto any space Y, then Y is not a discrete space.

Proof: Let $f: X \to Y$ is a contra sgα-continuous and X is sgα-connected space. Suppose Y is a discrete space. Let A be a proper non empty open and closed subset of Y. Then $f^{-1}(A)$ is a proper non empty sgα-open and sgα- closed subset of X, which is a contradiction to the fact that X is sgα-connected space. Therefore, Y is not a discrete space.

Definition 3.8: A subset A of a space (x, τ) is said to be sgα-clopen if A is both sgα-open and sgα-closed.

Theorem 3.9: If $f: X \to Y$ is a contra sgα-continuous surjection and X is sgα-connected space, then Y is connected.

Proof: Let $f: X \to Y$ is a contra sgα-continuous and X is sgα-connected space. Suppose Y is not connected space. Then there exists disjoint open sets U and V such that $Y = U \cap V$. Therefore U and V are clopen in Y Since f is contra sgα-continuous, $f^{-1}(U)$ and $f^{-1}(V)$ are sgα-open sets in X. Further f is surjective implies, $f^{-1}(U)$ and $f^{-1}(V)$ are non empty disjoint and $X = f^{-1}(U) \cup f^{-1}(V)$. This is contradiction to the fact that X is sgα- connected space. Therefore Y is connected.

Definition 3.10: A topological space X is said to be sgα-T_1-space if for any pair of disjoint points x and y, there exist disjoint sgα-open sets G and H such that $x \in G$ and $y \in H$.

Definition 3.11: A topological space X is said to be sgα-T_2-space if for any pair of disjoint points x and y, there exist disjoint sgα-open sets G and H such that $x \in G$ and $y \in H$.

Theorem 3.12: Let X be a sgα-connected and Y be T_1-space, if $f: X \to Y$ is a contra sgα-continuous, then f is constant.

Proof: Let $f: X \to Y$ is contra sgα-continuous, X be a sgα-connected and Y is T_1. Since Y is T_1-space, $\Delta = \{f^{-1}(y): y \in Y\}$ is a disjoint sgα-open partition of X. If $|\Delta| \geq 2$, then there exists a proper sgα-open and sgα-closed set W. This is contradiction to the fact that X is sgα-connected. Therefore $|\Delta| = 1$, and hence f is constant.

Theorem 3.13: Let X be Y be topological spaces. If

1. For each pair of distinct points x and y in X, there exists a function $f: X \to Y$ such that $f(x) = f(y)$.
2. Y is an Urysohn space.
3. f is contra sgα-continuous at x and y. Then X is sgα-T_2.

Proof: Let x and y be any distinct points in X and f: X → Y is a function such that f (x) = f (y). Let a = f (x) and b = f (y), then a = b. Since Y is an Urysohn space , there exists open sets V and W in Y containing a and b respectively, such that Cl (V) ∩ Cl (W) = φ. Since f is contra sgα- continuous at x and y , then there exists sgα-open sets A and B in X containing x and y, respectively, such that f (A) ⊂ Cl (V) and f (B) ⊂ Cl (W). Then f (A) ∩ f (B) ⊂ Cl (V) ∩ Cl (W) = φ. Therefore A ∩ B = φ. Hence X is sgα-T_2.

Corollary 3.14: Let f: X → Y be contra sgα-continuous injective function from space X into an Urysohn space Y, then X is sgα-T_2.

Proof: For each pair of distinct points x and y in X, f is contra sgα-continuous function from a space X into a Urysohn space such that f(x) = f(y) because f is injective. Hence by theorem 3.13, X is sgα-T_2.

Definition 3.15 [25]: A topological space X is said to be Ultra Hausdorff space if for every each pair of disjoint points x and y in X, there exist disjoint clopen sets U and V in X containing x and y respectively.

Theorem 3.16: If f: X →Y be contra sgα-continuous injective function from space X into a Ultra Hausdorff space Y, then X is sgα-T_2.

Proof: Let x and y be any distinct points in X .Since f is injective f (x) = f (y) and Y is Ultra Hausdorff space, implies there exists disjoint clopen sets U and V of Y containing f (x) and f (y) respectively. Then x ∈ f^{-1}(U) and y ∈ f^{-1} (V), where f^{-1}(U) and f^{-1}(V) are disjoint sgα-open sets in X. Therefore X is sgα-T_2.

Definition 3.17 [25]: A topological space X is said to be Ultra Normal space if for each pair of disjoint closed sets can be separated by disjoint clopen sets.

Definition 3.18: A topological space X is said to be sgα-Normal if each pair of disjoint closed sets can be separated by disjoint sgα-open sets.

Theorem 3.19: If f: X → Y be contra sgα-continuous closed injection and Y is Ultra Normal, then X is sgα-normal.

Proof: Let E and F be distinct closed subsets of X .Since f is closed and injective f (E) and f (F) are disjoint closed sets in Y. Since Y is Ultra normal there exists disjoint clopen sets U and V in Y such that f (E) ⊂ U and f (F) ⊂ V. This implies E ⊂ f^{-1}(U) and F ⊂ f^{-1}(V). Since f is contra sgα- continuous injection, f^{-1}(U) and f^{-1}(V) are disjoint sgα-open sets in X. This shows X is sgα-normal.

Theorem 3.20: If f: X → Y is contra sgα-continuous and g: Y →Z is continuous. Then gof: X → Z is contra sgα-continuous.

Proof: Let V be any open set in Z. Since g is continuous g^{-1}(V) is open in Y. Since f is contra sgα-continuous $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is sgα-closed set in X. Therefore, gof is contra sgα-continuous.

Theorem 3.21: If f: X →Y be contra sgα-continuous and g: Y →Z be sgα- continuous. If Y is Tsgα-space, then gof: X → Z is contra sgα- continuous.

Proof: Let V be any open set in Z. Since g is sgα-continuous, g^{-1}(V) is sgα- open in Y and since Y is Tsgα-space g^{-1}(V) is open in Y. Since f is contra sgα-continuous $f^{-1}(g^{-1}(V)) = (gof)^{-1}(V)$ is sgα-closed set in X. Therefore, gof is contra sgα-continuous.

Definition 3.22: A function f: X → Y is said to be strongly sgα-open (resp. strongly sgα-closed) if image of every sgα-open(resp.sgα-closed) set of X is sgα-open (resp.sgα-closed) set in Y.

Theorem 3.23: If f: X →Y is surjective strongly sgα-open or strongly sgα- closed and g: Y → Z is a function such that gof: X → Z is contra sgα- continuous. then g is contra sgα-continuous.

Proof: Let V be any closed (resp. open) set in Z. Since gof is contra sgα- continuous, $(gof)^{-1}(V) = f^{-1}(g^{-1}(V))$ is sgα-open (resp.sgα-closed). Since f is surjective and strongly sgα-open or strongly sgα-closed, $f(f^{-1}(g^{-1}(V))) = g^{-1}(V)$ is sgα-open or sgα-closed. Therefore g is contra sgα-continuous.

Definition 3.24: A space X is said to be
1. SGα-closed compact if every sgα-closed cover of X has a finite subcover.
2. Countably SGα-closed compact if every countable cover of X by sgα- closed sets has a finite subcover.
3. SGα-Lindeloff if every sgα-closed cover of X has countable subcover.

Theorem 3.25: Let f: X →Y be a contra sgα-continuous surjection, then the following properties hold:
1. If X is SGα-closed compact, then Y is compact.
2. If X is countably SGα-closed compact, then Y is countably compact.
3. If X is SGα-Lindeloff then Y is Lindeloff.

Proof:

1. Let $\{V\alpha: \alpha\in I\}$ be an open cover of Y. Since f is contra sgα-continuous, then $\{f^{-1}(V\alpha): \alpha\in I\}$ is sgα-closed cover of X. Since X is SGα-closed compact, there exists a finite subset I_0 of I such that $X = \cup \{f^{-1}(V\alpha): \alpha\in I_0\}$. Since f is surjective, $Y = \cup \{(V\alpha): \alpha\in I_0$, which is finite subcover for Y. Therefore, Y is compact.

2. Let $\{V\alpha: \alpha\in I\}$ be any countable open cover of Y. Since f is contra sgα-continuous, then $f^{-1}(V\alpha): \alpha\in I\}$ is countable sgα-closed cover of X. Since X is countably SGα-closed compact, there exists a finite subsetI_0 of I such that $X = \cup \{f^{-1}(v\alpha) : \alpha \in I_0\}$. Since f is surjective, $Y = \cup \{(V\alpha) : \alpha \in I_0\}$ is finite subcover for Y. Therefore, Y is countably compact.

3. Let $\{V\alpha: \alpha \in I\}$ be an open cover of Y. Since f is contra sgα-continuous, then $\{f^{-1}(V\alpha) : \alpha \in I\}$ is sgα-closed cover of X. Since X is SGα- Lindeloff,, there exists a finite countable subsetI_0 of I such that $X = \cup \{f^{-1}(V\alpha): \alpha\in I_0\}$. Since f is surjective, $Y = \cup \{(V\alpha): \alpha \in I_0\}$ is finite subcover for Y. Therefore, Y is Lindeloff.

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