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Almost Contra $\tilde{G}\alpha$-Continuous Functions

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Abstract

The concept of $\tilde{g}\alpha$-closed sets in a topological space are introduced by R. Devi et. al. [2]. In this paper, we introduce the notion of almost contra $\tilde{g}\alpha$-continuous functions utilizing $\tilde{g}\alpha$-open sets and study some of its applications.

Keywords. $\tilde{g}\alpha$-closed sets, almost contra $\tilde{g}\alpha$-continuous, almost contra pre-continuous and almost contra γ-continuous.

Introduction and Preliminaries

In 1996, Dontchev [4] introduced the notion of contra continuity in topological spaces. Also a new class of function called contra semi-continuous function is introduced and investigated by Dontchev and Noiri [6]. The concept of gα-open set was introduced by R. Devi et. al. [2]. Ekici [7] introduced and studied the notion of almost contra pre continuous functions and the concept of almost contra γ-continuous was introduced by A.A. Nasef [11]. In this direction, we introduce the notion of almost contra $\tilde{g}\alpha$-continuous functions via the concept of $\tilde{g}\alpha$-open set and study some of the applications of this function.

All through this paper, (X, τ) and (Y, σ) stand for topological spaces with no separation axioms assumed, unless otherwise stated. Let A ⊆ X, the closure of A and the interior of A will be denoted by cl(A) and int(A) respectively. A is regular open if A = int(cl(A)) and A is regular closed if its complement is regular open; equivalently A is regular closed if A = cl(int(A)), see [23].

Definition 1.1. A subset A of a space (X, τ) is called a

1. semi-open set [10] if A ⊆ cl(int(A)) and a semi-closed set [10] if int(cl(A)) ⊆ A,
2. α-open set [12] if A ⊆ int(cl(int(A))) and an α-closed set [12] if cl(int(cl(A))) ⊆ A.

The semi-closure (resp. α-closure) of a subset A of a space (X, τ) is the intersection of all semi-closed (resp. α-closed) sets that contain A and is denoted by scl(A) (resp. αcl(A)).

Definition 1.2. A subset A of a space (X, τ) is called a
1. g-closed set [20,21] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in (X, τ),
2. *g-closed set [19] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is g-open in (X,τ),
3. $^\#$gs-closed set [22] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is *g-open in (X,τ).

Let (X, τ) be a space and let A be a subset of X. A is called $\tilde{g}\alpha$-closed set [2] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is $^\#$gs-open set of (X, τ). The complement of an $\tilde{g}\alpha$-closed set is called $\tilde{g}\alpha$-open. The family of all regular open (resp. regular closed, $\tilde{g}\alpha$-open and $\tilde{g}\alpha$-closed) sets of X is denoted by RO(X) (resp. RC(X), $\tilde{g}\alpha O(X)$, $\tilde{g}\alpha C(X)$). We set $\tilde{g}\alpha O(X, x) = \{U : x \in U \text{ and } U \in g\alpha O(X)\}$. The set $\cup\{F \subset X : F \subseteq A, F$ is gα –open$\}$ is called $\tilde{g}\alpha$-interior of A and is denoted by int$\tilde{g}\alpha$ (A).

Definition 1.3. A function $f : (X, \tau) \to (Y, \sigma)$ is called a
1. perfectly continuous [13] if $f^{-1}(V)$ is clopen in (X, τ) for every open set V of (Y, σ),
2. almost continuous [15] if $f^{-1}(V)$ is open in (X, τ) for every regular open set V of (Y, σ),
3. contra continuous [4] if $f^{-1}(V)$ is closed in (X, τ) for every open set V of (Y, σ),
4. regular set connected [5] if $f^{-1}(V)$ is clopen in (X, τ) for every regular open set V of (Y, σ),
5. contra pre continuous [9] if $f^{-1}(V)$ is pre-closed in (X, τ) for every open set V of (Y, σ),
6. contra γ-continuous [11] if $f^{-1}(V)$ is γ-closed in (X, τ) for every open set V of (Y, σ),
7. $\tilde{g}\alpha$-continuous [3] if $f^{-1}(V)$ is $\tilde{g}\alpha$-closed in (X, τ) for every closed set V of (Y, σ),
8. contra $\tilde{g}\alpha$-continuous [1] if $f^{-1}(V)$ is $\tilde{g}\alpha$-closed in (X, τ) for every open set V of (Y, σ),
9. almost contra pre continuous [7] if $f^{-1}(V)$ is pre-closed in (X, τ) for every regular open set V of (Y, σ),
10. almost contra γ continuous [11] if $f^{-1}(V)$ is γ-closed in (X, τ) for every regular open set V of (Y, σ),

Definition 1.4. A space (X, τ) is called
1. an ultranormal [18] if each pair of non-empty disjoint closed sets can be separated by disjoint clopen sets.
2. a $\tilde{g}\alpha$-normal [1] if each pair of non-empty disjoint closed sets can be separated by disjoint $\tilde{g}\alpha$-open sets.
3. a $\tilde{g}\alpha$-connected [1] if X is not the union of two disjoint non-empty $\tilde{g}\alpha$-open

subsets of X.
4. $\tilde{g}\alpha$-T_1 [1] if for each pair of distinct points x and y in X, there exists $\tilde{g}\alpha$-open sets U and V containing x and y respectively, such that y ∈ U and x ∈ V .
5. $\tilde{g}\alpha$-T_2 [1] if for each pair of distinct points x and y in X, there exists $\tilde{g}\alpha$-open sets U and V containing x and y respectively, such that U ∩ V = φ.
6. $\tilde{g}\alpha T_{\frac{1}{2}}$ -space [3] if every $\tilde{g}\alpha$-closed set is closed.

Properties of almost contra $\tilde{g}\alpha$-continuous functions

Definition 2.1. A function f (X, τ) → (Y, σ) is called almost contra $\tilde{g}\alpha$-continuous if $f^{-1}(U) \in \tilde{g}\alpha C(X)$ for each U ∈ RO(Y).

Definition 2.2. [1] A function f : (X, τ) → (Y, σ) is called almost $\tilde{g}\alpha$-continuous if for each x ∈ X and each open set V of Y containing f(x), there exists U $\in\tilde{g}\alpha O(X,x)$ such that f(U)⊆int$\tilde{g}\alpha$ (cl(V)).

Theorem 2.3. Let (X, τ) and (Y, γ) be topological spaces. The following statements are equivalent for a function f : (X, τ) → (Y, γ).
1. f is almost contra $\tilde{g}\alpha$-continuous;
2. $f^{-1}(F) \in\tilde{g}\alpha C(X)$ for every F ∈ RO(Y);
3. for each x ∈ X and each regular open subset F in Y containing f (x), there exists a $\tilde{g}\alpha$ closed set U in X containing x such that f (U) ⊆ F ;
4. for each x ∈ X and each regular closed subset V in Y non-containing f (x), there exists a $\tilde{g}\alpha$ open set K in X non-containing x such that $f^{-1}(V) \subseteq K$;
5. $f^{-1}(int(cl(G))) \in\tilde{g}\alpha C(X)$ for every open subset G of Y ;
6. $f^{-1}(cl(int(F))) \in\tilde{g}\alpha O(X)$ for every closed subset F of Y .

Proof.
(1) ⇔ (2) Let F ∈ RO(Y). Then Y − F ∈ RC(Y). By (1) $f^{-1}(Y - F) = X - f^{-1}(F)$ $\in\tilde{g}\alpha O(X)$. We have $f^{-1}(F) \in\tilde{g}\alpha C(X)$. Reverse can be obtained similarly.
(2) ⇒ (3) Let F be any regular open set in Y containing f (x). By (2), $f^{-1}(F) \in\tilde{g}\alpha C(X)$ and $x \in f^{-1}(F)$. Take $U = f^{-1}(F)$. Then f (U) ⊆ F .
(3) ⇒ (2) Let F be any regular open set of Y and $x \in f^{-1}(F)$. From (3), there exists $\tilde{g}\alpha$-closed set U_x in X containing x such that $U \subseteq f^{-1}(F)$. We have $f^{-1}(F) = \cup_{x\in f^{-1}(F)} U_x$. Thus $f^{-1}(F)$ is $\tilde{g}\alpha$-closed.
(3) ⇔ (4) Let V be any regular closed in Y not containing f (x). Then Y − V is a regular open set containing f (x). By (3), there exists $\tilde{g}\alpha$-closed set U in X containing x such that f (U) ⊆ Y − V . Hence, $U \subseteq f^{-1}(Y - V) \subseteq X - f^{-1}(V)$ and then $f^{-1}(V) \subseteq$ X − U . Take H = X − U . We obtain that H is a $\tilde{g}\alpha$-open set in X non containing x. The converse can be solve easily.
(2) ⇔ (5) Let G be open subset of Y. Since int(cl(G)) is regular open, then by (2), it follows that $f^{-1}(int(cl(G))) \in\tilde{g}\alpha C(X)$. The converse can be shown easily.
(1) ⇔ (6) It can be obtained similar as (2) ⇔ (5).

Theorem 2.4. Every regular set connected is almost contra $\tilde{g}\alpha$-continuous.

Proof. Let V be any regular open in Y . Since f : X → Y is regular set-connected, $f^{-1}(V)$ is clopen in X. Hence $f^{-1}(V)$ is $\tilde{g}\alpha$-closed and $\tilde{g}\alpha$-open. Therefore f is almost contra gα-continuous.

The converse of the above Theorem need not be true by the following example.

Example 2.5. Let X = {a, b, c}, τ = {X, φ, {a}, {a, b}, {a, c}} and σ = {X, φ, {b}, {c}, {b, c}}. Then the identity function f : (X, τ) → (X, σ) is almost contra $\tilde{g}\alpha$-continuous. But it is not regular set connected.

Remark 2.6. The following diagram shows the relationships established between almost contra $\tilde{g}\alpha$-continuous functions and some other functions.

A G → H
↓ ↘ ↗ ↘ ↘
D B → C I → J
↑ ↘ ↙
F E

Notation 2.7. A = perfectly continuous, B = contra continuous, C = contra $\tilde{g}\alpha$-continuous, D = regular set connected, E = almost contra $\tilde{g}\alpha$-continuous, F = almost S-continuous, G = contra pre-continuous, H = almost contra precontinuous, I = contra γ-continuous, J = almost contra γ-continuous.

These implications are not reversible as shown by the examples stated below.

Example 2.8. Let X = {a, b, c}, τ = {X, φ, {a}, {a, b}, {a, c}} and σ = {X, φ, {a}, {a, b}}. Then the identity function f : (X, τ) → (X, σ) is regular set connected, but not perfectly continuous.

Example 2.9. Let X = {a, b, c}, τ = {X, φ, {a}, {a, b}, {a, c}} and σ = {X, φ, {a}, {a, b}}. Then the identity function f : (X, τ) → (X, σ) is almost contra $\tilde{g}\alpha$-continuous, but not contra $\tilde{g}\alpha$-continuous.

Example 2.10. Let X = {a, b, c}, τ = {X, φ, {a}, {b}, {a, b}} and Y = {1, 2} be the Sierpinski space with the topology σ = {Y, φ, {1}}. Let f : (X, τ) → (Y, σ) be defined by f(a) = 1,f(b) = f(c) = 2. Then f is contra γ-continuous, but not contra pre-continuous.

Example 2.11. Let X = {a, b, c} = Y , τ = {X, φ, {a}, {b, c}} and σ = {X, φ, {a}, {b}, {a, b}, {a, c}}. Let f : (X, τ) → (Y, σ) be defined by f (a) = b, f (b) = a, f (c) = c. Then f is almost contra γ-continuous, but not almost contra pre-continuous.

Theorem 2.12. If a function f : X → Y is almost contra $\tilde{g}\alpha$-continuous, al-most continuous and X is $\tilde{g}\alpha$T 1-space, then f is regular set connected.

Proof. Let V $\in$ RO(Y). Since f is almost contra $\tilde{g}\alpha$-continuous and almost continuous, then $f^{-1}(V)$ is $\tilde{g}\alpha$-closed and open. Since X is $\tilde{g}\alpha$T 1-space, $f-1(V)$ is closed and open. Hence $f^{-1}(V)$ is clopen. We obtained that f is regular set connected.

Theorem 2.13. If f : X → Y is almost contra $\tilde{g}\alpha$-continuous surjection and X is $\tilde{g}\alpha$-connected, then Y is connected.

Proof. Suppose that Y is not connected space. There exists non-empty disjoint open sets V_1 and V_2 such that $Y = V_1 \cup V_2$. Therefore, V_1 and V_2 are clopen in Y . Since f is almost contra $\tilde{g}\alpha$-continuous, $f^{-1}(V_1)$ and $f^{-1}(V_2)$ are $\tilde{g}\alpha$-open in X. Moreover, $f^{-1}(V_1)$ and $f^{-1}(V_2)$ are non-empty disjoint and $X = f^{-1}(V_1) \cup f^{-1}(V_2)$. This shows that X is not $\tilde{g}\alpha$-connected. This contradicts that Y is not connected assumed. Hence Y is connected.

Theorem 2.14. If f : X → Y is a almost contra $\tilde{g}\alpha$-continuous, closed injection and Y is ultranormal, then X is $\tilde{g}\alpha$-normal.

Proof. Let F_1 and F_2 be disjoint closed subsets of X. Since f is closed injective, $f(F_1)$ and $f(F_2)$ are disjoint closed subsets of Y . Since Y is ultranormal, $f(F_1)$ and $f(F_2)$ are separated by disjoint clopen sets V_1 and V_2, respectively. Hence $F_i \subset f^{-1}(V_i)$, $f^{-1}(V_i) \in \tilde{g}\alpha C(X)$ for i = 1, 2 and $f^{-1}(V_1) \cap f^{-1}(V_2) = \varphi$. Thus X is $\tilde{g}\alpha$-normal.

Theorem 2.15. Let X is a topological space and for each pair of distinct points x and y in X there exists a map f of X into a Urysohn topological space Y such that f (x) = f (y) and f is almost contra $\tilde{g}\alpha$-continuous at x and y, then X is $\tilde{g}\alpha$-T_2.

Proof. Let x and y be any distinct points in X. Then, there exists a Urysohn space Y and a function f : X → Y such that f (x) = f (y) and f is almost contra $\tilde{g}\alpha$-continuous at x and y. Let a = f (x) and b = f (y). Then a = b. Since Y is Urysohn space, there exists open sets V and W containing a and b, respectively, such that $cl(V) \cap cl(W) = \varphi$. Hence, $cl(int(V)) \cap cl(int(W)) = \varphi$. Since f is almost contra $\tilde{g}\alpha$continuous at x and y, there exist gα-open sets A and B containing a and b, respectively, such that $f(A) \subseteq cl(int(V))$ and $f(B) \subseteq cl(int(W))$. Then $f(A) \cap f(B) = \varphi$, so $A \cap B = \varphi$. Hence, X is $\tilde{g}\alpha$-T_2.

Corollary 2.16. Let f: X → Y be almost contra $\tilde{g}\alpha$-continuous injection.
If Y is an Urysohn space, then X is $\tilde{g}\alpha$-T_2.

Definition 2.17. A space X is said to be weakly Hausdorff [17] if each element of X is an intersection of regular closed sets.

Theorem 2.18. If f : X → Y is almost contra $\tilde{g}\alpha$-continuous injection and Y is weakly Hausdorff, then X is $\tilde{g}\alpha$-T_1.

Proof. Suppose that Y is weakly Hausdorff. For any distinct points x_1 and x_2 in X, there exists regular closed sets U and V in Y such that $f(x_1) \in U$, $f(x_2) \in U$, $f(x_1) \in V$ and $f(x_2) \in V$. Since f is almost contra $\tilde{g}\alpha$-continuous, $f^{-1}(U)$ and $f^{-1}(V)$ are $\tilde{g}\alpha$-open subsets of X such that $x_1 \in f^{-1}(U)$, $x_2 \in f^{-1}(U)$, $x_1 \in f^{-1}(V)$ and $x_2 \in f^{-1}(V)$. This shows that X is $\tilde{g}\alpha$-T_1.

Definition 2.19. A topological space X is said to be ultra Hausdorff [18] if for each pair of distinct points x and y in X there exist clopen sets A and B containing x and y, respectively such that $A \cap B = \varphi$.

Theorem 2.20. Let $f : X \to Y$ be almost contra $\tilde{g}\alpha$-continuous injection. If Y is ultra Hausdorff space, then X is $\tilde{g}\alpha$-T_2.

Proof. Let x_1 and x_2 be any distinct points in X, then $f(x_1) = f(x_2)$ and there exist clopen sets U and V containing $f(x_1)$ and $f(x_2)$ respectively such that $U \cap V = \varphi$. Since f is almost contra $\tilde{g}\alpha$-continuous, then$f^{-1}(U) \in \tilde{g}\alpha O(X)$and $f^{-1}(V) \in \tilde{g}\alpha O(X)$ such that $f^{-1}(U) \cap f^{-1}(V) = \varphi$. Hence, X is $\tilde{g}\alpha$-T_2.

Theorem 2.21. Let $f : X \to Y$ and $g : Y \to Z$ be functions. Then, the following properties hold:

1. If f is almost contra $\tilde{g}\alpha$-continuous and g is regular set connected, then $g \circ f : X \to Z$ is almost contra-$\tilde{g}\alpha$-continuous and almost $\tilde{g}\alpha$-continuous.
2. If f is almost contra $\tilde{g}\alpha$-continuous and g is perfect continuous, then $g \circ f : X \to Z$ is $\tilde{g}\alpha$-continuous and contra $\tilde{g}\alpha$-continuous.
3. If f is contra $\tilde{g}\alpha$-continuous and g is regular set connected, then $g \circ f : X \to Z$ is almost contra $\tilde{g}\alpha$-continuous and almost $\tilde{g}\alpha$-continuous.

Proof.

1. Let V be any regular open set in Z. Since g is regular set connected, $g^{-1}(V)$ is clopen. Since f is almost contra $\tilde{g}\alpha$-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\tilde{g}\alpha$-open and $\tilde{g}\alpha$-closed. Therefore, $g \circ f$ is almost contra $\tilde{g}\alpha$-continuous and almost $\tilde{g}\alpha$-continuous.
2. Let V be any regular open set in Z. Since g is perfectly continuous, $g^{-1}(V)$ is clopen. Since f is almost contra $\tilde{g}\alpha$-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\tilde{g}\alpha$-open and $\tilde{g}\alpha$-closed. Therefore, $g \circ f$ is $\tilde{g}\alpha$-continuous and contra $\tilde{g}\alpha$-continuous.
3. Let V be any regular open set in Z. Since g is regular set connected, $g^{-1}(V)$ is clopen. Since f is contra $\tilde{g}\alpha$-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\tilde{g}\alpha$-open and $\tilde{g}\alpha$closed. Therefore, $g \circ f$ is almost contra $\tilde{g}\alpha$-continuous and almost $\tilde{g}\alpha$-continuous.

Definition 2.22. A function $f : X \to Y$ is said to be pre $\tilde{g}\alpha$-open (pre $\tilde{g}\alpha$-closed) [1] if the image of each $\tilde{g}\alpha$-open set is $\tilde{g}\alpha$-open ($\tilde{g}\alpha$-closed).

Theorem 2.23. If $f : X \to Y$ is a surjective pre $\tilde{g}\alpha$-open and $g : Y \to Z$ is a function such that $g \circ f : X \to Z$ is almost contra $\tilde{g}\alpha$-continuous, then g is almost contra $\tilde{g}\alpha$-continuous.

Proof. Let V be any regular closed set in Z. Since $g \circ f$ is almost contra $\tilde{g}\alpha$-continuous, $(g \circ f)^{-1}(V) = f^{-1}(g^{-1}(V))$ is $\tilde{g}\alpha$-open. Since f is surjective pre $\tilde{g}\alpha$-open, $f(f^{-1}(g^{-1}(V))) = g^{-1}(V)$ is $\tilde{g}\alpha$-open. Therefore g is almost contra $\tilde{g}\alpha$-continuous.

Theorem 2.24. If $f : X \to Y$ is a surjective pre $\tilde{g}\alpha$-closed and $g : Y \to Z$ is a function such that $g \circ f : X \to Z$ is almost contra $\tilde{g}\alpha$-continuous, then g is almost contra $\tilde{g}\alpha$-continuous.

Proof. Let V be any regular open set in Z. Since $g \circ f$ is almost contra $\tilde{g}\alpha$-continuous, $(g \circ f)^{-1}(V) = f^{-1}(g^{-1}(V))$ is $\tilde{g}\alpha$-closed. Since f is surjective pre $\tilde{g}\alpha$-closed, $f(f^{-1}(g^{-1}(V))) = g^{-1}(V)$ is $\tilde{g}\alpha$-closed. Therefore g is almost contra $\tilde{g}\alpha$-continuous.

Definition 2.25. A space X is said to be
1. $\tilde{g}\alpha$-closed compact if every $\tilde{g}\alpha$-closed cover of X has a finite sub cover;
2. countably $\tilde{g}\alpha$-closed compact if every countable cover of X by $\tilde{g}\alpha$-closed sets has a finite sub cover;
3. $\tilde{g}\alpha$-closed Lindelof if every cover of X by $\tilde{g}\alpha$-closed sets has a countable sub cover;
4. nearly compact [16] if every regular open cover of X has a finite subcover;
5. nearly countably compact [8,14] if every countable cover of X by regular open sets has a finite subcover;
6. nearly Lindelof [7] if every cover of X by regular open sets has a countable subcover.

Theorem 2.26. Let $f : X \to Y$ be an almost contra $\tilde{g}\alpha$-continuous surjection. The following statements hold:
1. If X is $\tilde{g}\alpha$-closed compact, then Y is nearly compact.
2. If X is $\tilde{g}\alpha$-closed Lindelof, then Y is nearly Lindelof.
3. If X is countably $\tilde{g}\alpha$-closed compact, then Y is nearly countably compact.

Proof.
1. Let $\{V_\alpha : \alpha \in I\}$ be any regular open cover of Y . Since f is almost contra $\tilde{g}\alpha$-continuous, then $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is an $\tilde{g}\alpha$-closed cover of X. Since X is $\tilde{g}\alpha$-closed compact, there exists a finite subset I_0 of I such that $X = \cup\{f^{-1}(V_\alpha) : \alpha \in I_0\}$. Thus, we have $Y = \cup\{V_\alpha : \alpha \in I_0\}$ and Y is nearly compact.
2. Let $\{V_\alpha : \alpha \in I\}$ be any cover of Y by regular open sets. Since f is almost contra $\tilde{g}\alpha$-continuous, then $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is a $\tilde{g}\alpha$-closed cover of X. Since X is $\tilde{g}\alpha$-closed Lindelof, there exists an infinite subset I_0 of I such that $X = \cup\{f^{-1}(V_\alpha) : \alpha \in I_0\}$. Thus, we have $Y = \cup\{V_\alpha : \alpha \in I_0\}$ and Y is nearly

Lindelof.

3. Let $\{V_\alpha : \alpha \in I\}$ be a countable cover of Y by regular open sets. Since f is almost contra $\tilde{g}\alpha$-continuous, then $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is an $\tilde{g}\alpha$-closed cover of X. Since X is countably $\tilde{g}\alpha$-closed compact, there exists a finite subset I_0 of I such that $X = \cup\{f^{-1}(V_\alpha) : \alpha \in I_0\}$. Thus, we have $Y = \cup\{V_\alpha : \alpha \in I_0\}$ and Y is nearly countably compact.

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