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Almost Contra θgs-Continuous Functions

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Abstract

The aim of this paper is to introduce and study of a new class of function called almost contra θgs-continuous functions using θgs-open set.

Keywords: *Almost contra θgs-continuous, θgs-closed set*

1 Introduction

In 1996, Dontchev [6] introduced the notion of contra continuity and strong S-closedness in topological spaces. A new weaker form of this class of functions called contra semi continuous function is introduced and investigated by Dontchev and Noiri [7]. Recently in [10] the notion of of θ-generalized semi closed (briefly,θgs-closed)set was introduced. The aim of this paper is to introduce and study new generalization of contra continuity called Almost contra θgs-continuous functions utilising θgs-open set.

2 Preliminaries

Throughout this paper (X, τ), (Y, σ)(or simply X, Y)denote 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 *A subset A of a space X is called*
(1) a semi-open set [9] if $A \subset Cl(Int(A))$.
(2) a semi-closed set [3] if $Int(Cl(Int(A))) \subset A$.
(3) a regular open [23] if $A = Int(Cl(Int(A)))$

Definition 2.2 [4] *A point $x \in X$ is called a semi-θ-cluster point of A if $sCl(U) \cap A \neq \phi$, for each semi-open set U containing x. The set of all semi-θ-cluster point of A is called semi-θ-closure of A and is denoted by $sCl_\theta(A)$. A subset A is called semi-θ-closed set if $sCl_\theta(A) = A$. The complement of semi-θ-closed set is semi-θ-open set.*

Definition 2.3 [10] *A subset A of X is θgeneralized semi-closed(briefly, θgs-closed)set if $sCl_\theta(A) \subset U$ whenever $A \subset U$ and U is open in X. The complement of θgs-closed set is θgeneralized-semi open (briefly,θgs-open).The family of all θgs-closed sets of X is denoted by $\theta GSC(X,\tau)$ and θgs-open sets by $\theta GSO(X,\tau)$.*

Definition 2.4 [16] *A topological space X is called $T_{\theta gs}$-space if every θgs-closed set in it is closed set.*

Definition 2.5 *[13] A topological space X is said to be*
(i) θgs-T_1 space if for any pair of distinct points x and y, there exist θgs-open sets G and H such that $x \in G$, $y \notin G$ and $x \notin H$, $y \in H$.
(ii)θgs-T_2 if for each pair of distinct points x and y of X, there exist disjoint θgs-open sets, one containing x and the other containing y.

Definition 2.6 *A function $f\colon X \to Y$ is called:*
(i) θ-generalized semi-continuous (briefly,θgs-continuous)[11] if $f^{-1}(F)$ is θgs-closed set in X for every closed set F of Y.
(ii) contra θgs-continuous [19] if $f^{-1}(F)$ is θgs-closed set in X for every open set F of Y.

Definition 2.7 [12] *A function $f\colon X \to Y$ is said to be θgs-open (resp., θgs-closed) if $f(V)$ is θgs-open (resp., θgs-closed) in Y for every open set (resp., closed) V in X.*

Definition 2.8 [23] *(i)A topological space X is called Ultra Hausdroff space, if every pair of distinct points of x and y in X, there exist disjoint clopen sets U and V in X containing x and y respectively.*
(ii)A topological space X is called Ultra normal if each pair of disjoint closed sets can be separated by disjoint clopen sets.

Definition 2.9 *[19] A space X is called locally θgs-indiscrete if every θgs-open set is closed in X.*

Definition 2.10 [17] *A topological space X is said to be θgs-normal if each pair of disjoint closed sets can be separated by disjoint θgs-open sets.*

Definition 2.11 [18] *A topological space X is said to be*
(i)θgs-connected if X cannot be written as union of two non empty disjoint θgs-open sets.
(ii) θgs-compact if every θgs-open cover of X has a finite subcover.

Definition 2.12 *[14] A function $f : X \to Y$ is said to be almost continuous if $f^{-1}(V)$ is open in X for each regular open set V of Y.*

Definition 2.13 *[8] A topological space X is said to be hyperconnected if every open set is dense.*

Definition 2.14 *[2] A function $f : X \to Y$ is said to be R-map if $f^{-1}(V)$ is regular open in X for each regular open set V of Y.*

Definition 2.15 *[15] A function $f : X \to Y$ is said to perfectly continuous if $f^{-1}(V)$ is clopen in X for each open set V of Y.*

Definition 2.16 *[21] A space X is said to be weakly Hausdorff if each element of X is an intersection of regular closed sets.*

Definition 2.17 *A space X is said to be*
(i) Nearly compact [21] if every regular open cover of X has a finite subcover.
(ii) Nearly countably compact [21] if every countable cover of X by regular open sets has a finite subcover.
(iii) Nearly Lindelöf [21] if every regular open cover of X has a countable subcover.
(iv) S-Lindelöf [8] if every cover of X by regular closed sets has a countable subcover.
(v) Countably S-closed [5] if every countable cover of X by regular closed sets has a finite subcover.
(vi) S-closed [1] if every regular closed cover of x has a finite subcover.

3 Almost Contra θgs-Continuous Functions

In this section, new type of continuity called an almost contra θgs-continuity, which is weaker than contra θgs-continuity is introduced and studied some of their properties.

Definition 3.1 *A function $f : X \to Y$ is said to be almost contra θgs-continuous if $f^{-1}(V)$ is θgs-closed in X for each regular open set V in Y.*

Theorem 3.2 *If X is $T_{\theta gs}$-space and $f : X \to Y$ is almost contra θgs-continuous, then it is contra almost continuous.*

Proof. Let U be a regular open set in Y. Since f is almost contra θgs-continuous $f^{-1}(U)$ is θgs-closed set in X and X is $T_{\theta gs}$-space, which implies $f^{-1}(U)$ is closed set in X. Therefore f is contra almost continuous.

Theorem 3.3 *If a function $f : X \to Y$ is almost contra θgs-continuous and X is locally θgs-indiscrete space, then f is almost continuous.*

Proof. Let U be a regular open set in Y. Since f is almost contra θgs-continuous $f^{-1}(U)$ is θgs-closed set in X and X is locally θgs-indiscrete space, which implies $f^{-1}(U)$ is an open set in X. Therefore f is almost continuous.

Theorem 3.4 *If $f : X \to Y$ is contra θgs-continuous then it is almost contra θgs-continuous.*

Proof. Obvious, because every regular open set is open set.

Remark 3.5 *Converse of the above theorem need not be true in general as seen from the following example.*

Example 3.6 *Let $X = Y$=$\{a, b, c\}$, $\tau = \{X, \phi, \{a\}, \{b\}, \{a, b\}\}$ and $\sigma = \{Y, \phi, \{a\}, \ \{a, b\}\} \ \{b, c\}\}$be topologies on X and Y respectively. We have θgs-closed sets in X are $\{X, \phi, \{a\}, \{b\}, \{c\}, \{a, c\}, \ \{b, c\}\}$. Define a function $f : X \to Y$ by $f(a) = a$, $f(b) = b$ and $f(c) = c$. Then f is almost contra θgs-continuous function but not contra θgs-continuous, because for the open set $\{a, b\}$ in Y, $f^{-1}(\{a, b\})$ =$\{a, b\}$ is not θgs-closed in X.*

Theorem 3.7 *If $f : X \to Y$ is almost contra θgs-continuous and X is $T_{\theta gs}$-space then f is contra almost continuous.*

Proof. Let U be a regular open set in Y. Since f is almost contra θgs-continuous $f^{-1}(U)$ is θgs-closed set in X and X is $T_{\theta gs}$-space, which implies $f^{-1}(U)$ is an closed set in X. Therefore f is contra almost continuous.

Theorem 3.8 *For a function $f : X \to Y$ the followings are equivalent:*
(i) f is almost contra θgs-continuous.
(ii) for every regular closed set F of Y, $f^{-1}(F)$ is θgs-open set of X.

Proof. $(i) \Rightarrow (ii)$ Let F be a regular closed set in Y, then $Y - F$ is a regular open set in Y. By (i), $f^{-1}(Y - F)$=$X - f^{-1}(F)$ is θgs-closed set in X. This implies $f^{-1}(F)$ is θgs-open set in X. Therefore, (ii) holds.
$(ii) \Rightarrow (i)$ Let G be a regular open set of Y. Then $Y - G$ is a regular closed set in Y. By (ii), $f^{-1}(Y - G)$ is θ-open set in X. This implies $X - f^{-1}(G)$ is θgs-open set in X, which implies $f^{-1}(G)$ is θgs-closed set in X. Therefore, (i) holds.

Theorem 3.9 *For a function $f : X \to Y$ the followings are equivalent:*
(i) f is almost contra θgs-continuous.
(ii) $f^{-1}(Int(Cl(G)))$ is θgs-closed set in X for every open subset G of Y.
(iii) $f^{-1}(Cl(Int(F)))$ is θgs-open set in X for every closed subset F of Y.

Proof. $(i) \Rightarrow (ii)$ Let G be an open set in Y. Then $Int(Cl(G))$ is regular open set in Y. By (i), $f^{-1}(Int(Cl(G))) \in \theta GSC(X)$.
$(ii) \Rightarrow (i)$ Proof is obvious.
$(i) \Rightarrow (iii)$Let F be a closed set in Y. Then $Cl(Int(G))$ is regular closed set in Y. By (i), $f^{-1}(Cl(Int(G))) \in \theta GSO(X)$.
$(iii) \Rightarrow (i)$ Proof is obvious.

Theorem 3.10 *If $f : X \to Y$is an almost contra θgs-continuous injection and Y is weakly Hausdorff, then X is θgs-T_1.*

Proof. Suppose Y is weakly Hausdorff. For any distinct points x and y in X, there exist V and W regular closed sets in Y such that $f(x) \in V$, $f(y) \notin V$, $f(y) \in W$ and $f(x) \notin W$. Since f is almost contra θgs-continuous, $f^{-1}(V)$ and $f^{-1}(W)$ are θgs-open subsets of X such that $x \in f^{-1}(V)$, $y \notin f^{-1}(V)$, $y \in f^{-1}(W)$ and $x \notin f^{-1}(W)$. This shows that X is θgs-T_1.

Corollary 3.11 *If $f : X \to Y$ is a contra θgs-continuous injection and Y is weakly Hausdorff, then X is θgs-T_1.*

Theorem 3.12 *If $f : X \to Y$ is an almost contra θgs-continuous injective function from space X into a Ultra Hausdroff space Y, then X is θgs-T_2.*

Proof. Let x and y be any two distinct points in X. Since f is an injective $f(x) \neq f(y)$ and Y is Ultra Hausdroff space, there exist disjoint clopen sets U and V of Y containing $f(x)$ and $f(y)$ respectively. Then $x \in f^{-1}(U)$ and $y \in f^{-1}(V)$, where $f^{-1}(U)$ and $f^{-1}(V)$ are disjoint θgs-open sets in X. Therefore X is θgs-T_2.

Theorem 3.13 *If $f : X \to Y$ is an almost contra θgs-continuous closed injection and Y is ultra normal, then X is θgs-normal.*

Proof. Let E and F be disjoint 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 $f(E) \subset U$ and $f(F) \subset V$. This implies $E \subset f^{-1}(U)$ and $F \subset f^{-1}(V)$. Since f is an almost contra θgs-continuous injection, $f^{-1}(U)$ and $f^{-1}(V)$ are disjoint θgs-open sets in X. This shows X is θgs-normal.

Theorem 3.14 *If $f : X \to Y$ is an almost contra θgs-continuous surjection and X is θgs-connected space, then Y is connected.*

Proof. Let $f : X \to Y$ be an almost contra θgs-continuous surjection and X is θgs-connected space. Suppose Y is a not connected space. Then there exist disjoint open sets U and V such that $Y = U \cup V$. Therefore U and V are clopen in Y. Since f is almost contra θgs-continuous, $f^{-1}(U)$ and $f^{-1}(V)$ are θgs-open sets in X. Moreover $f^{-1}(U)$ 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 θgs-connected space. Therefore, Y is connected.

Theorem 3.15 *For two functions $f : X \to Y$ and $g : Y \to Z$, let $g \circ f : X \to Z$ is a composition function.Then, the following properties hold*
(i) If f is almost contra θgs-continuous and g is an R-map, then $g \circ f$ is almost contra θgs-continuous.
(ii) If f is almost contra θgs-continuous and g is perfectly continuous, then $g \circ f$ is θgs-continuous and contra θgs-continuous.
(iii) If f is contra θgs-continuous and g is almost continuous, then $g \circ f$ is almost contra θgs-continuous.

Proof. (i) Let V be any regular open set in Z. Since g is an R-map, $g^{-1}(V)$ is regular open in Y. Since f is an almost contra θgs-continuous $f^{-1}(g^{-1}(V))$= $(g \circ f)^{-1}(V)$ is θgs-closed set in X. Therefore, $g \circ f$ is almost contra θgs-continuous.
(ii) Let V be any open set in Z. Since g is perfectly continuous, $g^{-1}(V)$ is clopen in Y. Since f is an almost contra θgs-continuous $f^{-1}(g^{-1}(V))$=$(g \circ f)^{-1}(V)$ is θgs-open and θgs-closed set in X. Therefore, $g \circ f$ is θgs-continuous and contra θgs-continuous.
(iii) Let V be any regular open set in Z. Since g is almost continuous, $g^{-1}(V)$ is open in Y. Since f is contra θgs-continuous $f^{-1}(g^{-1}(V))$=$(g \circ f)^{-1}(V)$ is θgs-closed set in X. Therefore, $g \circ f$ is almost contra θgs-continuous.

Theorem 3.16 *Let $f : X \to Y$ is a contra θgs-continuous and $g : Y \to Z$ is θgs-continuous. If Y is $T_{\theta gs}$-space, then $g \circ f : X \to Z$ is an almost contra θgs-continuous.*

Proof. Let V be any regular open and hence open set in Z. Since g is θgs-continuous $g^{-1}(V)$ is θgs-open in Y and Y is $T_{\theta gs}$-space implies $g^{-1}(V)$ open in Y. Since f is contra θgs-continuous $f^{-1}(g^{-1}(V))$=$(g \circ f)^{-1}(V)$ is θgs-closed set in X. Therefore, $g \circ f$ is an almost contra θgs-continuous.

Definition 3.17 *A function $f : X \to Y$ is said to be strongly θgs-open (resp. strongly θgs-closed) if image of every θgs-open (resp. θgs-closed) set of X is θgs-open (resp. θgs-closed) set in Y.*

Theorem 3.18 *If $f : X \to Y$ is surjective strongly θgs-open (or strongly θgs-closed) and $g : Y \to Z$ is a function such that $g \circ f : X \to Z$ is an almost contra θgs-continuous, then g is an almost contra θgs-continuous.*

Proof. Let V be any regular closed (resp. regular open) set in Z. Since $g \circ f$ is an almost contra θgs-continuous, $(g \circ f)^{-1}(V)=f^{-1}(g^{-1}(V))$ is θgs-open (resp. θgs-closed) in X. Since f is surjective and strongly θgs-open (or strongly θgs-closed), $f(f^{-1}(g^{-1}(V)))=g^{-1}(V)$ is θgs-open(or θgs-closed). Therefore g is an almost contra θgs-continuous.

Definition 3.19 *A topological space X is said to be θgs-ultra-connected if every two non empty θgs-closed subsets of X intersect.*

Theorem 3.20 *If X is θgs-ultra-connected and $f : X \to Y$ is an almost contra θgs-continuous surjection, then Y is hyperconnected.*

Proof. Let X be a θgs-ultra-connected and $f : X \to Y$ is an almost contra θgs-continuous surjection. Suppose Y is not hyperconnected. Then there exists an open set V such that V is not dense in Y. Therefore, there exist nonempty regular open subsets $B_1 = Int(Cl(V))$ and $B_2 = Y - Cl(V)$ in Y. Since f is an almost contra θgs-continuous surjection, $f^{-1}(B_1)$ and $f^{-1}(B_2)$ are disjoint θgs-closed sets in X. This is contrary to the fact that X is θgs-ultra-connected. Therefore, Y is hyperconnected.

Definition 3.21 *A space X is said to be*
(i) Countably θgs-compact if every countable cover of X by θgs-open sets has a finite subcover.
(ii) θgs-Lindelöf if every θgs-open cover of X has a countable subcover.
(iii) mildly θgs-compact if every θgs-clopen cover of X has a finite subcover.
(iv) mildly countably θgs-compact if every countable cover of X by θgs-clopen sets has a finite subcover.
(v) mildly θgs-Lindelöf if every θgs-clopen cover of X has a countable subcover.

Theorem 3.22 *Let $f : X \to Y$ be an almost contra θgs-continuous surjection. Then, the following properties hold.*
(i) If X is θgs-compact, then Y is S-closed.
(ii) If X is countably θgs-closed, then Y is is countably S-closed.
(iii) If X is θgs-Lindelöf, then Y is S-Lindelöf.

Proof.(i) Let $\{V_\alpha : \alpha \in I\}$ be any regular closed cover of Y. Since f is almost contra θgs-continuous, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is θgs-open cover of X. Since X is θgs-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, $Y = \cup\{V_\alpha) : \alpha \in I_0\}$ is finite subcover for Y. Therefore, Y is S-closed.
(ii) Let $\{V_\alpha : \alpha \in I\}$ be any countable regular closed cover of Y. Since f is almost contra θgs-continuous, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is countable θgs-open cover of X. Since X is countably θgs-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, $Y = \cup\{V_\alpha) : \alpha \in I_0\}$ is finite subcover for Y. Therefore, Y is countably S-closed.
(iii) Let $\{V_\alpha : \alpha \in I\}$ be any regular closed cover of Y. Since f is almost contra θgs-continuous, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is θgs-open cover of X. Since X is θgs-Lindelöf, there exists a countable subset I_0 of I such that $X = \cup\{f^{-1}(V_\alpha) : \alpha \in I_0\}$. Since f is surjective, $Y = \cup\{V_\alpha) : \alpha \in I_0\}$ is finite subcover for Y. Therefore,Y is S-Lindelöf.

Definition 3.23 *A function $f : X \to Y$ is said to be almost θgs-continuous if $f^{-1}(V)$ is θgs-open in X for each regular open set V of Y.*

Theorem 3.24 *Let $f : X \to Y$ be an almost contra θgs-continuous and almost θgs-continuous surjection. Then, the following properties hold.*
(i) If X is mildly θgs-closed, then Y is nearly compact.
(ii) If X is mildly countably θgs-compact, then Y is nearly countabaly compact.
(iii) If X is mildly θgs-Lindelöf, then Y is nearly Lindelöf.

Proof.(i) Let $\{V_\alpha : \alpha \in I\}$ be any regular open cover of Y. Since f is almost contra θgs-continuous and almost θgs surjection, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is θgs-clopen cover of X. Since X is mildly θgs-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 nearly compact.
(ii) Let $\{V_\alpha : \alpha \in I\}$ be any countable regular open cover of Y. Since f is almost contra θgs-continuous and almost θgs surjection, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is countable θgs-closed cover of X. Since X is mildly countably θgs-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, $Y = \cup\{V_\alpha) : \alpha \in I_0\}$ is finite subcover for Y. Therefore, Y is nearly countably compact.
(iii) Let $\{V_\alpha : \alpha \in I\}$ be any regular open cover of Y. Since f is almost contra θgs-continuous and almost θgs surjection,, $\{f^{-1}(V_\alpha) : \alpha \in I\}$ is θgs-closed cover of X. Since X is mildly θgs-Lindelof, there exists a countable subset I_0 of I such that $X = \cup\{f^{-1}(V_\alpha) : \alpha \in I_0\}$. Since f is surjective, $Y = \cup\{V_\alpha) : \alpha \in I_0\}$ is finite subcover for Y. Therefore, Y is nearly Lindelöf.

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