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On Contra Delta Generalized Pre-Continuous Functions

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Abstract- In this paper, the notion of contra δgp-continuous functions is introduced by utilizing δgp-closed sets in topological spaces. Some of their fundamental properties are studied the relationships of contra δgp-continuous functions with other related functions are discussed.

Keywords- δgp-open set, contra continuoud function, contra pre-continuous function, contra δgp-continuous function.

I. INTRODUCTION

In 1996,Dontchev[8] initiated the study of contra continuous functions. Subsequently, Jafari and Noiri [15, 16] exhibited contra α-continuous and contra pre-continuous functions in topological spaces. In this paper, a new class of generalized contra continuous functions by using δgp-closed sets, called contra δgp-continuous functions is introduced and study some of their basic properties. Relationships between contra δgp-contin- uous functions and other related functions are investigated.

II. PRELIMINARIES

Definition 2.1 A subset A of a topological space X is called pre-closed[19](resp, b-closed [1],regular closed [26],semi-closed[18] and α-closed[21]) if cl(int(A))⊆A (resp,cl(int(A))∩int(cl(A))⊆A, A=cl(int(A)),int(cl(A))⊆A and int(cl(int(A)))⊆A).

Definition 2.2 A subset A of a topological space X is called δ-closed[28] if $A = cl_\delta(A)$ where
$cl_\delta(A) = \{x \in X: int(cl(U)) \cap A = \varphi, U \in \tau \text{ and } x \in U\}$

Definition 2.3 A subset A of a topological space X is called ,
(i)δgp-closed[5](resp,gpr-closed[13] and gp-closed[17]) if pcl(A) ⊆ U whenever A ⊆ U and U is δ-open (resp, regular open and open) in X.
(ii) gδs-closed[3] if scl(A) ⊆ U whenever A⊆ U and U is δ-open in X.

The complements of the above mentioned closed sets are their respective open sets.

Definition 2.4 A function f:X→Y from a topological space X into a topological space Y is called,
(i) contra continuous[8] (resp,contra pre-continuous[15], contra-α-continuous[16], contra gp-continuous[7] and contra gpr-continuous) if $f^{-1}(G)$ is closed (resp, pre-closed, α-closed,gp-closed and gpr-closed) in X for every open set G of Y.
(ii)perfectly-continuous[23] if $f^{-1}(G)$ is clopen in X for every open set G of Y.
(iii)pre-closed[10] if for every closed subset A of X, f(A) is pre-closed in Y.
(iv) δgp-continuous[27](resp,comletely-continuous[2] and super continuous[20]) if $f^{-1}(G)$ is δgp-open (resp, regular-open and δ-open)in X for every open set G of Y.

Definition 2.5 A space X is called,
(a) extremely disconnected[12] if the closure of every open subset of X is open.
(b)strongly irresolvable[11] if every open subspace of X is irresolvable.
(c)semi-regular[6] if every open set is δ-open in X.
(d)Urysohn[29] if for each pair of distinct points x and y of X, there exist open sets U and V containing x and y respectively such that cl(U) ∩ cl(V) = φ.
(e)regular[29] if U is open in X and x∈ U, then there is an open set V containing x such that cl(V) ⊆ U.

Definition 2.5 A space X is said to be:
(i) $T_{\delta gp}$–space if every δgp-closed subset of X is closed.
(ii) $\delta gpT_{1/2}$-space space if every δgp-closed subset of X is pre-closed.

3 .Contra δgp-Continuous Functions.

Definition 3.1 A function f:X→Y is called contra delta generalized pre-continuous (briefly, contra δgp-continuous) if the inverse image of every open set of Y is δgp-closed in X.

Theorem 3.2 A function f:X→Y is contra δgp-continuous if and only if f^{-1}(U) is δgp-open in X for every closed set U of Y.

Remark 3.3 From Definitions 2.4 and 3.1, we have the following diagram of implications for a function f:X→Y

Perfectly continuity
↓
contra pre-continuity ←contra continuity
↓
contra gp-continuity → contra δgp-continuity
↓
contra gpr-continuity

None of the implications in above diagram is reversible.

Example 3.4 Consider X={a,b,c,d} with the topologies T = { X,Φ,{a},{b},{a},{b},{a,b,c}} and σ ={X,φ,{a},{b},{a,b}, {a,c},{a,b,c}}. Define f:(X,τ)→(X,σ)by f(a)=f(b)=a, f(c)=b and f(d)=c. Then f is contra gpr-continuous but not contra δgp-continuous, since {a} is open in Y but
$f^{-1}(\{a\})=\{a,b\}$ is not δgp-closed in X.
Define g:(X,τ)→(X,σ) by g(a)=g(c)=a, g(b)=b and g(d)=d. Then g is contra δgp-continuous but not contra gp-continuous, since {a} is open in Y but
$g^{-1}(\{a\})=\{a,c\}$ is not gp-closed in X.

Remark 3.5 (a) contra δgp-continuity and δgp-contin- uity are independent each other.
(b) contra δgp-continuity and contra gδs-continuity are independent each other.
Example 3.6 In Example 3.4,f is δgp-continuous but not contra δgp-continuous.

Example 3.7 Consider X,_ and _ as in Example in 3.4.
Define h:(X,τ)→(X,σ) by h(a)=d, h(b)=c, h(c)=a and h(d)=b. Then h is contra δgp-continuous but not δgp-continuous, since {a,b} is open in Y but h^{-1}({a,b})={c,d} is not δgp-open in X .

Definition 3.8 A space X is called locally δgp-indiscrete if every δgp-open set is δgp-closed in X.

Theorem 3.9 If f:X→Y is a contra δgp-continuous and X is locally δgp-indiscrete space, then f is δgp-continuous.
Proof: Let V be a closed set in Y. Since f is contra δgp-continuous and X is locally δgp-indiscrete space, then f^{-1}(V) is δgp-closed in X. Hence f is δgp-continuous.

Definition 3.10 [22] A space X is called locally indiscrete if every open set is closed in X.

Theorem 3.11 If f:X→Y is a _gp-continuous and Y is locally indiscrete space, then f is contra δgp-continuous.
Proof: Let G be any open set of Y. Since Y is locally indiscrete space and f is δgp-continuous, then f^{-1}(G) is δgp-closed in X. Hence f is contra δgp-continuous.

Theorem 3.12 [27] (a)In extremely disconnected space X, every gδs-closed set is δgp-closed.
(b)In strongly irresolvable space X, every δgp-closed set is gδs-closed.

As a consequence of Theorem 3.12, we have the following Theorem 3.13 and Theorem 3.14.

Theorem 3.13 If f:X→Y is a contra gδs-continuous and X is extremely disconnected space, then f is contra δgp-continuous.

Theorem 3.14 If f:X→Y is a contra δgp-continuous and X is strongly irresolvable space, then f is contra gδs-continuous.

Theorem 3.15 If f:X→Y is contra δgp-continuous and X is Tδgp-space,then f is contra continuous.
Proof: Suppose X is $T_{\delta gp}$-space and f is contra δgp-continuous. Let G be an open set in Y,by hypothesis f^{-1}(G) is δgp-closed in X and hence f^{-1}(G) is closed in X. Therefore f is contra continuous.

Theorem 3.16 If f:X→Y is contra δgp-continuous and X is $\delta gpT_{1/2}$-space,then f is contra pre-continuous.

Proof: Suppose X is $\delta gpT_{1/2}$-space and f is contra δgp-continuous. Let G be an open set in Y,by hypothesis f^{-1}(G) is δgp-closed in X and hence f^{-1}(G) is pre-closed in X. Therefore f is contra pre-continuous.

Theorem 3.17 If f:X→Y is contra δgp-continuous and X is semi regular, then f is contra gp-continuous.
Proof: Follows from the fact that every open set is δ-open in semi-regular space.

Lemma 3.18 [27] For a subset A of a space X, the following are equivalent:
(a)A is clopen;
(b)A is open and pre-closed;
(c)A is open and gp-closed;

(d)A is δ-open and δgp-closed;
(e)A is regular-open and gpr-closed.

Lemma 3.19 For a subset A of a space X, the following are equivalent:
(a)A is clopen .
(b) A is regular-open and pre-closed.
(c)A is δ-open and pre-closed.

Following Theorem is immediate from Lemma 3.18 and Lemma 3.19:

Theorem 3.20 The following statements are equivalent for a function f:X→Y:
(a)f is perfectly continuous.
(b)f is continuous and contra pre-continuous.
(c)f is continuous and contra gp-continuous.
(d)f is super-continuous and contra δgp-continuous.
(e)f is r-continuous contra gpr-continuous.
(f)f is r-continuous and contra pre-continuous.
(g)f is super-continuous and contra pre-continuous.

Theorem 3.21 If f:X→Y is contra δgp-continuous, then the following equivalent statements hold:
(i) For each x ∈ X and each closed set B of Y containing f(x),there exists an δgp-open set A in X containing x such that f(A)⊂B.
(ii)For each x ∈ X and each open set G of Y not containing f(x),there exists a δgp-closed set H in X not containing x such that f^{-1}(G)⊂H.

Proof: Let B be a closed set in Y such that f(x)∈B, then x ∈ f^{-1}(B). By hypothesis, f^{-1}(B) is δgp-open set in X containing x. Let A = f^{-1}(F), then f(A) = f(f^{-1}(B))⊂B.

Theorem 3.22 [5] Let A⊂X.Then x∈ δgpcl(A) if and only if U∩A= Φ, for every δgp-open set U containing x.

Recall that for a subset A of a space (X,τ), the set ∩{U∈τ /A⊆U} is called the kernel of A and is denoted by ker(A).

Lemma 3.23 [14] The following properties hold for subsets A and B of a space X :
(i) x ∈ ker(A) if and only if A∩F=φ for any closed set F of X containing x.
(ii) A ⊂ ker(A) and A = ker(A) if A is open in X.
(iii) If A ⊂ B, then ker(A) ⊂ ker(B).

Definition 3.24 A space X is said to be δgp- additive if δGPC(X) is closed under arbitrary intersections.

Theorem 3.25 Let X be δgp-additive, then the following are equivalent for a function f:X→Y.
(i) f is contra δgp-continuous.
(ii) For each x ∈ X and each closed set D of Y containing f(x), there exists an δgp-open set C in X containing x such that f(C)⊂D.
(iii) f(δgpcl(C))⊂ker(f(C)) for every subset C of X.
(iv) δgpcl(f^{-1}(D))⊂ f^{-1}(ker(D))for every subset D of Y.

Proof: (i)→(ii)It follows from Theorem 3.21
(ii)→(i) Let G be a closed set in Y containing f(x),then x ∈ f^{-1}(G). From (ii), there exists δgp-open set U_X in X containing x such that f(U_X)⊂D, U_X⊂ f^{-1}(G).
Thus f^{-1}(G)=∪{Ux : x ∈ f^{-1}(G)} is δgp-open in X .
(i)→(iii)Let C be any subset of X. Suppose y∉ker(f(C)), then by Lemma 3.23, there exists a closed set D in Y containing y such that f(C) ∩ D = φ. Hence we have, C ∩ f^{-1}(D)=φ and δgp-cl(C) ∩ f^{-1}(D)=φ which implies f(δgpcl(C)) ∩ D=φ and hence y∉f(δgpcl(C)). Therefore f(δgpcl(C)) ⊂ ker(f(C)).
(iii)→(iv)Let D ⊂ Y, then f^{-1}(D) ⊂ X. By (iii) and Lemma3.23, f (δgpcl(f^{-1}(D))) ⊂ ker(f (f^{-1}(D))) ⊂ ker(D). Thus δgpcl(f^{-1}(D)) ⊂ f^{-1}(ker(D)).
(iv)→(i) Let U be any open subset of Y. Then by (iv) and Lemma 3.23, δgpcl(f^{-1}(U) ⊂ f^{-1}(ker(U)) = f^{-1}(U) and δgpcl(f^{-1}(U)) = f^{-1}(U). Therefore f^{-1}(V) is δgp-closed set in X.

Theorem 3.26 If a surjective function f:(X,τ)→(Y,σ) is contra δgp-continuous and preclosed with X as a $T_{\delta gp}$ -space, then Y is locally indiscrete.

Proof: Let H be any open set in Y. Since f is contra δgp-continuous and X is $T_{\delta gp}$-space, then f^{-1}(H) is closed in X. Since f is preclosed, then H is preclosed in Y. Thus we have cl(H) = cl(int(H))⊂H and hence H is closed in Y.

Theorem 3.27 If f:(X,τ)→(Y,σ) is contra δgp-continuous, X is δgp-additive and Y is regular, then f is δgp-continuous.

Proof: Let x ∈ X and N be any open set of Y containing f(x). As Y is regular, there exists an open set M in Y containing f(x) such that cl(M) ⊂ N. Since f is contra δgp-continuous, there exists an δgp-open set U in X containing x such that f(U) ⊂ cl(M). Then f(U) ⊂ cl(M) ⊂ N. Hence by Theorem 3.25, f is δgp- contin- uous.

Recall that, for a function f:X→Y,the subset {(x,f(x)):x∈X}⊂X×Y is called the graph of f and is denoted by G(f).

Definition 3.28 The graph G(f) of a function f:(X,τ)→(Y,σ) is said to be contra δgp-closed if for each (x,y)∈(X×Y)-G(f) there exist δgp-open set U in X containing x and closed set V in Y containing y such that (U×V)∩G(f)=φ.

Theorem 3.29 The graph G(f) of a function f:(X,τ)→(Y,σ) is contra δgp-closed in X×Y if and only for each (x,y)∈(X×Y)-G(f) there exist δgp-open set U in X containing x and closed set V in Y containing y such that f(U)∩V=φ.

Theorem 3.30 If f:(X,τ)→(Y,σ) is contra δgp-continuous and Y is Urysohn, then G(f) is contra δgp-closed in the product space X×Y.

Proof:Let (x,y)∈(X×Y)-G(f),then y=f(x) and there exist open sets U and V such that f(x)∈U,y∈V and cl(U)∩cl(V)=φ. Since f is contra δgp-continuous, then there exists a δgp-open set G such that x∈G and f(G)⊂cl(U) and hence we obtain f(G)∩cl(V)=φ.This shows that G(f) is contra δgp-closed.

Theorem 3.31 Let g:X→X×Y be the graph function of f:X→Y,defined by g(x)=(x,f(x)) for each x∈X. Then f is contra δgp-continuous,if g is contra δgp- continuous.

Proof: Let V be any open set in Y, then X×V is an open set in X×Y.It follows that f^{-1}(U)=g^{-1}(X×U) is δgp-closed in X since g is contra δgp-continuous. Hence f is contra δgp-continuous.

Definition 3.32 **[24]** A space X is submaximal if every pre-open set is open in X.

Theorem 3.33 If M and N are δgp-closed sets in a submaximal space X, then M∪N is δgp-closed in X.

Proof: Let U be δ-open set in X such that M∪N⊂U. Then pcl(M)⊂U and pcl(N)⊂U since M and N are δgp-closed sets. As X is submaximal, pcl(A)=cl(A) for any subset A of X. Therefore pcl(M∪N)=pcl(M)∪pcl(N)⊂U and hence M∪N is δgp-closed.

Corollary 3.34 If A and B are δgp-open sets in submaximal space X, then A∩B is δgp-open in X.

Theorem 3.35 **[5]** If A⊂X is δgp-closed,then A=δgpcl(A)

Remark 3.36 Converse of above theorem is true if X is δgp-additive.

Theorem 3.37 Assume that X is δgp-additive. If f:X→Y and g:X→Y are contra δgp-continuous, X is submaximal and Y is Urysohn. Then F={x∈X:f(x)=g(x)} is δgp-closed in X.

Proof: Let x∈X-F, then f(x)=g(x). Therefore,there exist open sets U and V such that f(x)∈U,g(x)∈V and cl(U)∩cl(V)=φ because Y is Urysohn. Since f and g are contra δgp-continuous , f^{-1}(cl(U)) and g^{-1}(cl(V)) are δgp-open sets in X . Let M= f^{-1}(cl(U)) and N = g^{-1}(cl(V)), then M and N are δgp-open sets containing x. Set O=M∩N, then O is δgp-open set in X. Hence f(O)∩g(O)=f(M∩N)∩g(M∩N)⊂f(M)∩g(N)=cl(U)∩cl(V) =φ and so O∩F=φ. From Theorem 3.22, x ∉δgpcl(F). Hence by above remark, F is δgp-closed in X.

Definition 3.38 A space X is called δgp-connected provided that X is not the union of two disjoint nonempty δgp-open sets.

Theorem 3.39 For a space X the following are equivalent: (a) X is δgp-connected.
(b) φ and X are the only subsets of X which are both δgp-open and δgp-closed. (c) Every contra δgp-contin- uous function of X into a discrete space Y with at least two points is a constant function.

Proof: (a)→(b): Suppose A is any proper δgp-open and δgp-closed subset of X. Then X-A is both δgp-closed and δgp-open in X. Then X=A∪(X-A) and A∩(X-A)=φ which contradicts the fact that X is δgp-connec- ted. Hence A=φ or X.

(b)→(a): Suppose X=A∪B where A and B are disjoint δgp-open subsets of X. Since A=X-B, A is both δgp-closed and δgp-open but by assumption A=φ or X which is a contradiction. Hence (a) holds.

(b)→(c): Let f:X→Y be a contra δgp-continuous function where Y is a discrete space with at least two points. Then f^{-1}({y}) is δgp-closed and δgp-open for each y ∈ Y and X = ∪{f^{-1}({y}): y ∈ Y}.By hypothesis, f^{-1}({y}) = φ or X. If f^{-1}({y})=φ for all y ∈ Y, then f is fails to be a function. Then there exists only one point y ∈ Y such that f^{-1}({y})=φ and hence f^{-1}({y})=X. This shows that f is constant

(c)→(b): Let N be a nonempty proper δgp-open and δgp-closed subset of X. Let f:X→Y be a contra δgp-continuous function defined by f(N)={y} and f(X-N)={z} for some distinct points in Y. By (c), f is constant it follows that N=X.

Theorem 3.40 If f:X→Y is a contra δgp-continuous function and X is δgp-connected space, then Y is not a discrete space.

Proof: If possible,let Y be a discrete space. Let A be a proper non empty open and closed subset of Y. Since f is contra δgp-continuous, then f^{-1}(A) is proper nonempty δgp-open and δgp-closed subset of X which contradicts the fact that X is δgp-connected space. Hence Y is not discrete.

Theorem 3.41 If a surjective function f:X→Y is contra δgp-continuous and X is δgp-connected space, then Y is connected.

Proof: Suppose that Y is not a connected space. Then there exist disjoint open sets U and V in Y such that Y=U∪V. Therefore U and V are closed sets in Y. Since f is contra δgp-continuous, f^{-1}(U) and f^{-1}(V) are δgp-open sets in X . Also f is surjective , f^{-1}(U) and f^{-1}(V) are non empty disjoint and X = f^{-1}(U) ∪ f^{-1}(V) which contradicts the fact that X is δgp-connected space. Hence Y is connected.

Theorem 3.42 Let X be a δgp-connected and Y be T_1 -space. If f:X→Y is contra δgp-continuous, then f is constant.

Proof: By hypothesis Y is T_1 -space, K={ f^{-1}(y): y∈Y} is a disjoint δgp-open partition of X. If |K|≥2, then X is the union of two nonempty δgp-open sets. This is contradiction to the fact that X is δgp-connected. Therefore |K|=1 and hence f is constant.

Definition 3.43 A topological space X is said to be δgp-Hausdorff space if for any pair of distinct points x and y, there exist disjoint δgp-open sets G and H such that x ∈ G and y ∈ H.

Theorem 3.44 If an injective function f:X→Y is contra δgp-continuous and Y is an Urysohn space. Then X is δgp-Hausdorff.

Proof: Let x and y be any two distinct points in X and f is injective,then f(x)=f(y). Since Y is an Urysohn space, there exist open sets A and B in Y containing f(x) and f(y) respectively,such that cl(A)∩cl(B)=φ.Then f(x) ∈ cl(A) and f(y) ∈ cl(B). Since f is contra δgp-continuous, then by Theorem 3.8, there exist δgp-open sets C and D in X containing x and y,respectively,such that f(C) ⊆ cl(A) and f(D) ⊆ cl(B). We have C ∩ D ⊆ f^{-1}(cl(A)) ∩ f^{-1}(cl(B)) = f^{-1}(φ) = φ. Hence X is δgp-Hausdorff.

Definition 3.45 [25] A space X is called Ultra normal space, if each pair of disjoint closed sets can be separated by disjoint clopen sets.

Definition 3.46 A topological space X is said to be δgp-normal if each pair of disjoint closed sets can be separated by disjoint δgp-open sets.

Theorem 3.47 If f:X→Y be contra δgp-continuous closed injection and Y is ultra normal, then X is δgp-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 exist disjoint clopen sets U and V in Y such that f(E)⊂U and f(F)⊂V. This im- plies E⊂ f^{-1}(U) and F⊂ f^{-1}(V). Since f is contra δgp-continuous injection, f^{-1}(U) and f^{-1}(V) are disjoint δgp-open sets in X. This shows X is δgp-normal.

Remark 3.48 The composition of two contra δgp-continuous functions need not be contra δgp-continuous as seen from the following examples.

Example 3.49 let X=Y=Z={a,b,c}, τ ={X,φ,{a},{b},{a,b}},σ={Y,φ,{a}} and η={Z,φ,{b,c}} be topologies on X,Y and Z respectively. Define a function f:X→Y as f(a)=a,f(b)=b and f(c)=c and a function g:Y→Z as g(a)=b,g(b)=c and g(c)=a. Then f and g are contra δgp-continuous but g⋆f:X→Z is not contra δgp-continuous, since there exists an open set {b,c} in Z such that$(g\star f)^{-1}${b,c}={a,b} is not δgp-closed in X.

Theorem 3.50 For any two functions f:X→Y and g:Y→Z,the following hold:

(i)g⋆f is contra δgp-continuous if f is contra δgp-continuous and g is contra continuous.

(ii)g⋆f is contra δgp-continuous if f is δgp-continuous and g is contra continuous.

(iii)g⋆f is contra δgp-continuous f is δgp-irresolute and g is contra δgp-continuous.

Proof:(i) Let U be an open set in Z. Then g^{-1}(V) is open in Y since g is continuous.

Therefore $f^{-1}[g^{-1}(U)]=(g\star f)^{-1}(U)$ is δgp-closed in X because f is contra δgp-continuous. Hence g⋆f is contra δgp-continuous.

The proofs of (ii) and (iii) are analogous to (i) with the obvious changes.

Theorem 3.51 Let f:X→Y be contra δgp-continuous and g:Y→Z be δgp- continuous with Y is $T_{\delta gp}$ -space, then g⋆f:X→Z is contra δgp-continuous.

Proof: Let V be any open set in Z . Since g is δgp-continuous, g^{-1}(V) is δgp- open in Y and since Y is $T_{\delta gp}$ -space, g^{-1}(V) open in Y . Since f is contra δgp-continuous, $f^{-1}(g^{-1}(V))=(g\star f)^{-1}(V)$ is δgp-closed set in X. Therefore g⋆f is contra δgp-continuous.

Definition 3.52 A function f:X→Y is called pre δgp-closed if the image of every δgp-closed set of X is δgp-closed in Y.

Theorem 3.53 Let f:X→Y be pre δgp-closed surjec- t ion and g:Y→Z be a function such that g⋆f:X→Z is contra δgp-continuous,then g is contra δgp- contin- uous.

Proof: Let U be any open set in Z.Then $(g\star f)^{-1}(U)= f^{-1}(g^{-1}(U))$ is δgp-closed in X. Since f is a pre δgp-closed surjection, $f(f^{-1}(g^{-1}(U)))= g^{-1}(U)$ is δgp-closed set in Y. Therefore, g is contra δgp-continuous.

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