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STRONG FORMS OF CONTRA (1,2)*-g*-CONTINUITY

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Abstract

This paper devotes to introduce and investigate a new class of maps called contra-(1,2)*-g*-continuous maps which are weaker than contra-(1,2)*-continuity and stronger than contra-(1,2)*-g-continuity, contra-(1,2)*-αg-continuity, contra-(1,2)*-gs-continuity, contra-(1,2)*-gsp-continuity, contra-(1,2)*-gp-continuity, contra-(1,2)*-rg-continuity, contra-(1,2)*-α**g-continuity and contra-(1,2)*-gpr-continuity. The main results of the paper are that several properties concerning contra-(1,2)*-g*-continuous maps. Furthermore, the relationships between the contra-(1,2)*-g*-continuity and some bitopological maps as well as separation axioms are also investigated

Keywords: - contra-(1,2)*-g*-continuous maps; contra-(1,2)*-gs-bitopological maps.

Introduction

In the literature there are many types of continuities introduced by various authors. Quite recently, Noiri et.al [2,4,5,6,7] introduced and investigated the notions of contra-precontinuity, contra-α-continuity, contra-g-continuity and contra-super-continuity as a continuation of research done by Dontchev [3], and Dontchev and Noiri [4] on the interesting notions of contra-continuity and contra-semi-continuity.

This paper devotes to introduce and investigate a new class of maps called contra-(1,2)*-g*-continuous maps which are weaker than contra-(1,2)*-continuity and stronger than contra-(1,2)*-g-continuity, contra-(1,2)*-αg-continuity, contra-(1,2)*-gs-continuity, contra-(1,2)*-gsp-continuity, contra-(1,2)*-gp-continuity, contra-(1,2)*-rg-continuity, contra-(1,2)*-α**g-continuity and contra-(1,2)*-gpr-continuity. The main results of the paper are that several properties concerning contra-(1,2)*-g*-continuous maps. Furthermore, the relationships between the contra-(1,2)*-g*-continuity and some bitopological maps as well as separation axioms are also investigated.

Throughout this paper, (X, τ_1, τ_2), (Y, σ_1, σ_2) and (Z, η_1, η_2) (briefly, X, Y and Z) will denote bitopological spaces.

We recall the following definitions which are useful in the sequel.

Definition 1.1

Let S be a subset of X. Then S is said to be $\tau_{1,2}$-open [11] if $S = A \cup B$ where $A \in \tau_1$ and $B \in \tau_2$.

The complement of $\tau_{1,2}$-open set is called $\tau_{1,2}$-closed.

Notice that $\tau_{1,2}$-open sets need not necessarily form a topology.

Definition 1.2 [11]

Let S be a subset of a bitopological space X. Then

(1) the $\tau_{1,2}$-closure of S, denoted by $\tau_{1,2}$-cl(S), is defined as $\cap$ {F : S $\subseteq$ F and F is $\tau_{1,2}$-closed }.

(2)the $\tau_{1,2}$-interior of S, denoted by $\tau_{1,2}$-int(S), is defined as $\cup$ {F : F $\subseteq$ S and F is $\tau_{1,2}$-open }.

Definition 1.3

A subset A of a bitopological space X is called

(i) (1,2)*-α-open [11] if A $\subseteq \tau_{1,2}$-int($\tau_{1,2}$-cl($\tau_{1,2}$-int(A)));

(ii) (1,2)*-β-open [8] if A $\subseteq \tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(A));

(iii) (1,2)*-preopen [11] if A $\subseteq \tau_{1,2}$-int($\tau_{1,2}$-cl(A).

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

The intersection of all (1,2)*-pre-closed (resp. (1,2)*-β-closed and (1,2)*-α-closed) sets containing a subset A of X is called the (1,2)*-preclosure (resp. (1,2)*-β-closure and (1,2)*-α-closure) of A and is denoted by (1,2)*-pcl(A)(resp. (1,2)*-spcl(A) and (1,2)*-αcl(A)).

PROPERTIES OF CONTRA (1,2)*-g^*-CONTINUOUS MAPS

We introduce the following definition.

Definition 2.1

A subset A of a bitopological space X is called

(i) (1,2)*-g-closed [9] if $\tau_{1,2}$-cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X;

(ii) (1,2)*-gs-closed if (1,2)*-scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X;

(iii) (1,2)*-αg-closed if (1,2)*-αcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X;

(iv) (1,2)*-α^{**}g-closed if (1,2)*-αcl(A) $\subseteq \tau_{1,2}$-int($\tau_{1,2}$-cl (U)) whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X;

(v) (1,2)*-gsp-closed if (1,2)*-spcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X;

(vi) (1,2)*-rg-closed [8] if $\tau_{1,2}$-cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is regular (1,2)*-open in X;

(vii) (1,2)*-gp-closed if (1,2)*-pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X;

(viii) (1,2)*-gpr-closed if (1,2)*-pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is regular (1,2)*-open in X and

(ix) (1,2)*-g^*-closed if $\tau_{1,2}$-cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is (1,2)*-g-open in X.

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

Remark 2.2

(i) Every $\tau_{1,2}$-closed set is (1,2)*-g^*-closed.

(ii) Every (1,2)*-g^*-closed set is (1,2)*-g-closed and hence an (1,2)*-αg-closed, (1,2)*-gs-closed, (1,2)*-gsp-closed, (1,2)*-gp-closed, (1,2)*-gpr-closed, (1,2)*-α^{**}g-closed and (1,2)*-rg-closed.

Definition 2.3

A bitopological space X is called

(i) a (1,2)*-$T_{½}$*space if every (1,2)*-g^*-closed set in it is $\tau_{1,2}$-closed.

(ii) a (1,2)*-*$T_{½}$ space if every (1,2)*-g-closed set in it is (1,2)*-g^*-closed.

(iii) a (1,2)*-Tc space if every (1,2)*-gs-closed set in it is (1,2)*-g^*-closed.

(iv) an (1,2)*-αTc space if every (1,2)*-αg-closed set in it is (1,2)*-g^*-closed.

(v) (1,2)*- locally indiscrete if each $\tau_{1,2}$-open subset of X is $\tau_{1,2}$-closed in X.

Definition 2.4

A map f: X → Y is called

(i) contra-(1,2)*-g-continuous if f^{-1}(V) is (1,2)*-g-closed set of X for every $\sigma_{1,2}$-open set V of Y;

(ii) contra-(1,2)*-αg-continuous if f^{-1}(V) is (1,2)*-αg-closed set of X for every $\sigma_{1,2}$-open set V of Y;

(iii) contra-(1,2)*-gs-continuous if f^{-1}(V) is (1,2)*-gs-closed set of X for every $\sigma_{1,2}$-open set V of Y;

(iv) contra-(1,2)*-rg-continuous if f^{-1}(V) is (1,2)*-rg-closed set of X for every $\sigma_{1,2}$-open set V of Y;

(v) contra-(1,2)*-gp-continuous if f^{-1}(V) is (1,2)*-gp-closed set of X for every $\sigma_{1,2}$-open set V of Y;

(vi) contra-(1,2)*-gpr-continuous if f^{-1}(V) is (1,2)*-gpr-closed set of X for every $\sigma_{1,2}$-open set V of Y;

(vii) (1,2)*-g^*-continuous if f^{-1}(V) is (1,2)*-g^*-closed set of X for every $\sigma_{1,2}$-closed set V of Y;

(viii) (1,2)*-g^*-irresolute if $f^{-1}(V)$ is (1,2)*-g^*-closed set of X for every (1,2)*-g^*-closed set V of Y ;

(ix) pre (1,2)*-g^*-closed if f(A) is a (1,2)*-g^*-closed set of Y for every (1,2)*-g^*-closed set of X and

(x) (1,2)*-preclosed if f(V) is (1,2)*-preclosed in Y for every $\tau_{1,2}$-closed set V of X.

Definition 2.5

A map f: X $\rightarrow$ Y is called contra-(1,2)*-g^*-continuous if $f^{-1}(V)$ is a (1,2)*-g^*-closed set of X for every $\sigma_{1,2}$-open set V of Y.

Theorem 2.6

Every contra-(1,2)*-continuous map is contra (1,2)*-g^*-continuous.

The following example supports that the converse of the above theorem is not true in general.

Example 2.7

Let X = Y = {a, b, c}, τ_1 = {ϕ, X, {a}, {a, c}}, τ_2 = {ϕ, X, {a}}, σ_1 {ϕ, Y, {b}} and σ_2 = {ϕ, Y, {b}, {a, b}, {b, c}}. Define f: X → Y as the identity map. Then f is contra-(1,2)*-g^*-continuous map but it is not contra-(1,2)*-continuous.

Definition 2.8

A map f: X → Y is called

(i) contra -(1,2)*-α^{**}g-continuous if $f^{-1}(V)$ is (1,2)*-α^{**}g-closed set of X for every $\sigma_{1,2}$-open set V of Y.

(ii) contra-(1,2)*-gsp-continuous if $f^{-1}(V)$ is (1,2)*-gsp-closed set of X for every $\sigma_{1,2}$-open set V of Y.

Theorem 2.9

Every contra-(1,2)*-g^*-continuous map is contra-(1,2)*-g-continuous and hence contra-(1,2)*-αg-continuous, contra-(1,2)*- α^{**}g-continuous, contra-(1,2)*-gs-continuous, contra-(1,2)*-gsp-continuous, contra-(1,2)*-gp-continuous, contra-(1,2)*-rg-continuous and contra-(1,2)*-gpr-continuous.

The following example shows that the converse of the above theorem is not true in general.

Example 2.10

Let X =Y = {a,b,c}. Let τ_1 = {ϕ, X, {a}, {b,c}}, τ_2 = {ϕ, X, {a}}, σ_1 = {ϕ, Y} and σ_2 = {ϕ,Y,{b}}. Define f: X $\rightarrow$ Y as the identity map. Then f is contra-(1,2)*-g-continuous map and hence contra-(1,2)*-αg-continuous map and contra-(1,2)*-α^{**}g-continuous map, contra-(1,2)*-gs-continuous map, contra-(1,2)*-gsp-continuous map, contra-(1,2)*-gp-continuous map, contra-(1,2)*-rg-continuous map and contra-(1,2)*-gpr-continuous map but it is not contra-(1,2)*-g^*-continuous.

The following example supports that the composition of two contra-(1,2)*-g^*-continuous maps need not be a contra-(1,2)*-g^*-continuous map.

Example 2.11

Let X = Y = Z = {a, b, c}, τ_1 = {ϕ, X, {a}, {a, c}}, τ_2 = {ϕ, X, {a}}, σ_1 = {ϕ, Y}, σ_2 = {ϕ, Y, {b}}, η_1 = {ϕ, Z } and η_2 = {ϕ, Z, {a, c}}. Let f: X $\rightarrow$ Y be the identity map and g: Y $\rightarrow$ Z be the identity map. Then f is contra-(1,2)*-g^*-continuous map and g is contra-(1,2)*-g^*-continuous map. But their composition g o f is not contra-(1,2)*-g^*-continuous.

Theorem 2.12

Let f: X $\rightarrow$ Y be a map. Then the following statements are equivalent.

(i) f is contra-(1,2)*-g^*-continuous .

(ii) The inverse image of each $\sigma_{1,2}$-open set of Y is (1,2)*-g^*-closed in X.

(iii) The inverse image of each $\sigma_{1,2}$-closed set of Y is (1,2)*-g^*-open in X.

Proof

(i) ⇒ (ii): Let V be any $\sigma_{1,2}$-open set in Y. By the assumption of (i), $f^{-1}(V)$ is (1,2)*-g^*-closed in X.

(ii) ⇒ (iii) : Let V be a $\sigma_{1,2}$-closed set in Y. Then Y−V is $\sigma_{1,2}$-open in Y. By the assumption of (ii), $f^{-1}(Y-V) = X-f^{-1}(V)$ is (1,2)*-g^*-closed in X. Thus, $f^{-1}(V)$ is (1,2)*-g^*-open in X.

(iii) ⇒ (i) : Let V be an $\sigma_{1,2}$-open set in Y. Then Y−V is $\sigma_{1,2}$-closed in Y. By the assumption of (iii), $f^{-1}(Y-V) = X-f^{-1}(V)$ is (1,2)*-g^*-open in X. Therefore $f^{-1}(V)$ is (1,2)*-g^*-closed in X. Hence f is contra-(1,2)*-g^*-continuous map.

SEPARATION AXIOMS

Theorem 3.1

Let f: X → Y be a contra-(1,2)*-g^*-continuous map. If X is (1,2)*-$T_{½}$* space, then f is contra-(1,2)*-continuous map.

Proof

Let V be an $\sigma_{1,2}$-open set in Y. Since f is contra-(1,2)*-g^*-continuous, $f^{-1}(V)$ is (1,2)*-g^*-closed in X. But X is (1,2)*-$T_{½}^*$ space, $f^{-1}(V)$ is $\tau_{1,2}$-closed in X. Therefore f is contra-(1,2)*-continuous map.

Theorem 3.2

Let f: X → Y be contra-(1,2)*-αg-continuous map. If X is (1,2)*-αTc space, then f is contra-(1,2)*-g^*-continuous map.

Proof

Let V be an $\sigma_{1,2}$-open set in Y. Since f is contra-(1,2)*-αg-continuous, $f^{-1}(V)$ is (1,2)*-αg-closed in X. But X is (1,2)*-αTc space, $f^{-1}(V)$ is (1,2)*-g^*-closed in X. Therefore f is contra-(1,2)*-g^*-continuous map.

Theorem 3.3

Let f: X → Y be contra-(1,2)*-g-continuous map. If X is (1,2)*-*$T_{½}$ space, then f is contra-(1,2)*-g^*-continuous map.

Proof

Let V be an $\sigma_{1,2}$-open set in Y. Since f is contra-(1,2)*-g-continuous, $f^{-1}(V)$ is (1,2)*-g-closed in X. But X is (1,2)*-*$T_{½}$ space, $f^{-1}(V)$ is (1,2)*-g^*-closed in X. Therefore f is contra-(1,2)*-g^*-continuous map.

Theorem 3.4

Let f: X → Y be contra-(1,2)*-gs-continuous map. If X is (1,2)*-Tc space, then f is contra-(1,2)*-g^*-continuous map.

Proof

Let V be an $\sigma_{1,2}$-open set in Y. Since f is contra-(1,2)*-gs-continuous, $f^{-1}(V)$ is (1,2)*-gs-closed in X. But X is (1,2)*-Tc space, $f^{-1}(V)$ is (1,2)*-g^*-closed in X. Therefore f is contra-(1,2)*-g^*-continuous map.

Theorem 3.5

Let f: X → Y be a surjective, (1,2)*-preclosed, contra-(1,2)*-g^*-continuous map and X be (1,2)*-$T_{½}$* space. Then Y is (1,2)*-locally indiscrete.

Proof

Suppose V is $\sigma_{1,2}$-open set in Y. By hypothesis, f is contra-(1,2)*-g^*-continuous, $f^{-1}(V)$ is (1,2)*-g^*-closed in X. Since X is (1,2)*-$T_{½}$* space, $f^{-1}(V)$ is $\tau_{1,2}$-closed in X. Since f is (1,2)*-preclosed, V is (1,2)*-preclosed in Y. Now we have $\sigma_{1,2}$-cl(V) = $\sigma_{1,2}$-cl($\sigma_{1,2}$-int(V)) ⊆ V. This means that V is $\sigma_{1,2}$-closed in Y. Thus, Y is (1,2)*-locally indiscrete.

Theorem 3.6

If f: X → Y and g: Y → Z are contra-(1,2)*-g^*-continuous maps with Y as a (1,2)*-$T_{½}$* space, then g o f: X → Z is (1,2)*-g^*-continuous map.

Proof

Let G be an $\eta_{1,2}$-open set in Z. Since g is contra-(1,2)*-g^*-continuous, $g^{-1}(G)$ is (1,2)*-g^*-closed in Y. Since Y is (1,2)*-$T_{½}$* space, $g^{-1}(G)$ is $\sigma_{1,2}$-closed in Y. Since f is contra-(1,2)*-g^*-continuous, $f^{-1}(g^{-1}(G))$ = $(g \circ f)^{-1}(G)$ is (1,2)*-g^*-open in X. Therefore g o f is (1,2)*-g^*-continuous map.

Theorem 3.7

Let X and Z be any bitopological spaces and Y be a (1,2)*-$T_{½}$* space. Then the composition g o f: X → Z is contra-(1,2)*-g^*-continuous map if f: X → Y is (1,2)*-g^*-continuous map and g: Y → Z is contra-(1,2)*-g^*-continuous.

Proof

Let G be any $\eta_{1,2}$-open set in Z. Since g is contra-(1,2)*-g^*-continuous, $g^{-1}(G)$ is (1,2)*-g^*-closed in Y. But Y is a (1,2)*-$T_{½}$* space, $g^{-1}(G)$ is $\sigma_{1,2}$-closed in Y. Since f is (1,2)*-g^*-continuous, $f^{-1}(g^{-1}(G))$ = $(g \circ f)^{-1}(G)$ is (1,2)*-g^*-closed in X. Therefore g o f is contra (1,2)*-g^*-continuous map.

Theorem 3.8

Let X and Z be any bitopological spaces and Y be a (1,2)*-*$T_{½}$ space. Then g o f: X → Z is contra-(1,2)*-g^*-continuous map if f: X → Y is (1,2)*-g^*-irresolute map and g: Y → Z is contra-(1,2)*-g-continuous map.

Proof

Let G be an $\eta_{1,2}$-open set in Z. Since g is contra-(1,2)*-g-continuous, $g^{-1}(G)$ is (1,2)*-g-closed in Y. But Y is (1,2)*-*$T_{½}$ space, $g^{-1}(G)$ is (1,2)*-g^*-closed in Y. Since f is (1,2)*-g^*-irresolute, $f^{-1}(g^{-1}(G)) = (g \circ f)^{-1}(G)$ is (1,2)*-g^*-closed in X. Therefore g o f is contra-(1,2)*-g^*-continuous map.

Theorem 3.9

Let X and Z be any bitopological spaces and Y be a (1,2)*-$T_{½}$* space. Then g o f: X → Z is contra-(1,2)*-g^*-continuous map if f: X → Y is contra-(1,2)*-g^*-continuous map and g: Y → Z is (1,2)*-g^*-irresolute map.

Proof

Let G be any $\eta_{1,2}$-closed set in Z. Then G is (1,2)*-g^*-closed in Z. Since g is (1,2)*-g^*-irresolute, $g^{-1}(G)$ is (1,2)*-g^*-closed in Y. But Y is a (1,2)*-$T_{½}$*space, $g^{-1}(G)$ is $\sigma_{1,2}$-closed in Y. Since f is contra-(1,2)*-g^*-continuous, $f^{-1}(g^{-1}(G)) = (g \circ f)^{-1}(G)$ is (1,2)*-g^*-open in X. Therefore g o f is contra-(1,2)*-g^*-continuous map.

RELATIONS WITH OTHER MAPS

Theorem 4.1

Let f: X → Y and g: Y → Z be any two maps. Then g o f is contra-(1,2)*-g^*-continuous map if g is contra-(1,2)*-continuous map and f is (1,2)*-g^*-continuous map.

Proof

Let V be an $\eta_{1,2}$-open set in Z. Since g is contra-(1,2)*-continuous, $g^{-1}(V)$ is $\sigma_{1,2}$-closed in Y. Since f is (1,2)*-g^*-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is (1,2)*-g^*-closed in X. Therefore g o f is contra-(1,2)*-g^*-continuous map.

Theorem 4.2

Let f: X → Y be surjective, (1,2)*-g^*-irresolute and pre (1,2)*-g^*-closed and g: Y → Z be any map. Then g o f: X→ Z is contra-(1,2)*-g^*-continuous if and only if g is contra-(1,2)*-g^*-continuous.

Proof

Let g o f: X → Z be contra-(1,2)*-g^*-continuous map. Let F be an $\eta_{1,2}$-open subset of Z. Then $(g \circ f)^{-1}(F) = f^{-1}(g^{-1}(F))$ is a (1,2)*-g^*-closed subset of X. Since f is pre (1,2)*-g^*-closed, $f(f^{-1}(g^{-1}(F))) = g^{-1}(F)$ is (1,2)*-g^*-closed in Y. Thus g is contra-(1,2)*-g^*-continuous map.

Conversely, let g: Y → Z be contra-(1,2)*-g^*-continuous. Let G be an o$\eta_{1,2}$-pen subset of Z. Since g is contra-(1,2)*-g^*-continuous, $g^{-1}(G)$ is (1,2)*-g^*-closed in Y. Since f is (1,2)*-g^*-irresolute, $f^{-1}(g^{-1}(G)) = (g \circ f)^{-1}(G)$ is (1,2)*-g^*-closed in X. Hence g o f is contra-(1,2)*-g^*-continuous map.

Theorem 4.3

Let f: X → Y be (1,2)*-g^*-irresolute map and g: Y → Z be contra-(1,2)*-g^*-continuous map. Then g o f: X → Z is contra-(1,2)*-g^*-continuous map.

Proof

Let F be an $\eta_{1,2}$-open set in Z. Since g is contra-(1,2)*-g^*-continuous, $g^{-1}(F)$ is (1,2)*-g^*-closed in Y. Since f is (1,2)*-g^*-irresolute, $f^{-1}(g^{-1}(F)) = (g \circ f)^{-1}(F)$ is (1,2)*-g^*-closed in X. Thus, g o f is contra-(1,2)*-g^*-continuous map.

Corollary 4.4

Let f: X → Y be (1,2)*-g^*-irresolute map and g: Y → Z be contra-(1,2)*-g^*-continuous map. Then g o f: X → Z is contra-(1,2)*-g-continuous map.

Corollary 4.5

Let f: X → Y be (1,2)*-g^*-irresolute map and g: Y → Z be contra-(1,2)*-g^*-continuous map. Then g o f: X → Z is contra-(1,2)*-αg-continuous map.

Corollary 4.6

Let f: X → Y be (1,2)*-g^*-irresolute map and g: Y → Z be contra-(1,2)*-g^*-continuous map. Then g o f: X → Z is contra-(1,2)*-gs-continuous map.

Corollary 4.7

Let f: X → Y be (1,2)*-g*-irresolute map and g: Y → Z be contra-(1,2)*-g*-continuous map. Then g o f: X → Z is contra-(1,2)*-gsp-continuous map.

Corollary 4.8

Let f: X → Y be (1,2)*-g*-irresolute map and g: Y → Z be contra-(1,2)*-g*-continuous map. Then g o f: X → Z is contra-(1,2)*-gp-continuous map.

Corollary 4.9

Let f: X → Y be (1,2)*-g*-irresolute map and g: Y → Z be contra-(1,2)*-g*-continuous map. Then g o f: X → Z is contra-(1,2)*-gpr-continuous map.

Corollary 4.10

Let f: X → Y be (1,2)*-g*-irresolute map and g: Y → Z be contra-(1,2)*-g*-continuous map. Then g o f: X → Z is contra-(1,2)*-α^{**}g-continuous map.

Corollary 4.11

Let f: X → Y be (1,2)*-g*-irresolute map and g: Y → Z be contra-(1,2)*-g*-continuous map. Then g o f: X → Z is contra-(1,2)*-rg-continuous map.

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