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ON $\tilde{g}$ (1, 2)*-HOMEOMORPHISMS

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ABSTRACT

In this present paper, we introduce two new classes of bitopological functions called $\tilde{g}$ (1, 2)-homeomorphisms and strongly $\tilde{g}$ (1, 2)*-homeomorphisms by using $\tilde{g}$ (1, 2)*-closed sets.*

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1. INTRODUCTION

Njastad introduced α-open sets. Maki *et al.* [7] generalized the concepts of closed sets to α-generalized closed (briefly αg-closed) sets which are strictly weaker than α-closed sets. Veera Kumar [19] defined ĝ-closed sets in topological spaces. Thivagar *et al.* [20] introduced αĝ-closed sets which lie between α-closed sets and αg-closed sets in topological spaces.

Maki *et al.* introduced the notion of generalized homeomorphisms (briefly g-homeomorphism) which are generalizations of homeomorphisms in topological spaces. Subsequently, Devi *et al.* [2] introduced two classes of functions called generalized semi-homeomorphisms (briefly gs-homeomorphisms) and semi-generalized homeomorp-hisms (briefly sg-homeomorphisms). Quite recently, Zbigniew Duszynski [20] has introduced αĝ-homeomorphisms in topological spaces.

It is well-known that the above mentioned topological sets and functions have been generalized to bitopological settings due to the efforts of many modern topologists [see 1, 3, 4, 5, 6, 8, 9, 13, 14]. In this present paper, we introduce two new classes of bitopological functions called $\tilde{g}$ (1, 2)*-homeomorphisms and strongly $\tilde{g}$ (1,2)*-homeomorphisms by using $\tilde{g}$ (1,2)*-closed sets. Basic properties of these two functions are studied and the relation between these types and other existing ones are established.

2. PRELIMINARIES

Throughout this paper, (X, τ_1, τ_2) (briefly, X) will denote bitopological space.

Definition 2.1: 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 subsets of X need not necessarily form a topology.

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Definition 2.2 [11]: Let S be a subset of a bitopological space X. Then
(i) 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}.
(ii) 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 2.3: A subset A of a bitopological space X is called
(i) (1,2)*-semi-open set [10] if A $\subseteq$ $\tau_{1,2}$-cl($\tau_{1,2}$-int(A));
(ii) (1,2)*-α -open set [6] if A $\subseteq$ $\tau_{1,2}$-int($\tau_{1,2}$-cl($\tau_{1,2}$-int(A)));
(iii) (1,2)*-β-open set [12] if A $\subseteq$ $\tau_{1,2}$-cl($\tau_{1,2}$-int($\tau_{1,2}$-cl(A))).

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

The (1,2)*-semi-closure [8] (resp. (1,2)*-α -closure [8], (1,2)*-β-closure [12]) of a subset A of X, denoted by (1,2)*-scl(A) (resp. (1,2)*-α cl(A), (1,2)*- βcl(A)), is defined to be the intersection of all (1,2)*-semi-closed (resp. (1,2)*-α -closed, (1,2)*-β-closed) sets of (X, τ_1, τ_2) containing A. It is known that (1, 2)*-scl(A) (resp. (1, 2)*-α cl(A), (1,2)*- βcl(A)) is a (1,2)*-semi-closed (resp. (1,2)*-α -closed, (1,2)*-β-closed) set.

Definition 2.4: A subset A of a bitopological space (X, τ_1, τ_2) is called
(i) (1,2)*-g-closed set [18] if $\tau_{1,2}$-cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X. The complement of (1,2)*-g-closed set is called (1,2)*-g-open set;
(ii) (1,2)*-sg-closed set 10] if (1,2)*-scl(A) $\subseteq$ U whenever A$\subseteq$U and U is (1,2)*-semi-open in X. The complement of (1,2)*-sg-closed set is called (1,2)*-sg-open set;
(iii) (1,2)*-gs-closed set [10] if (1,2)*-scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X. The complement of (1,2)*-gs-closed set is called (1,2)*-gs-open set;
(iv) (1,2)*-α g-closed set [16] if (1,2)*-α cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X. The complement of (1,2)*-α g-closed set is called (1,2)*-α g-open set;
(v) (1,2)*-ĝ-closed set [3] or (1,2)*-ω-closed set [4] if $\tau_{1,2}$-cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is (1,2)*-semi-open in X. The complement of (1,2)*-ĝ-closed (or (1,2)*-ω-closed) set is called (1,2)*-ĝ-open (or (1,2)*-ω-open) set;
(vi) (1,2)*-ψ -closed set [9] if (1,2)*-scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is (1,2)*-sg-open in X. The complement of (1,2)*-ψ -closed set is called (1,2)*-ψ -open set;
(vii)(1,2)*-$\ddot{g}_\alpha$ -closed set [9] if (1,2)*-α cl(A)$\subseteq$U whenever A$\subseteq$U and U is (1,2)*-sg-open in X. The complement of (1,2)*-$\ddot{g}_\alpha$ -closed set is called (1,2)*-$\ddot{g}_\alpha$ -open set;
(viii) (1,2)*-gsp-closed set [12] if (1,2)*- βcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\tau_{1,2}$-open in X. The complement of (1,2)*-gsp-closed set is called (1,2)*-gsp-open set.

Remark 2.5: The collection of all (1,2)*-$\ddot{g}_\alpha$ -closed (resp. (1,2)*-ĝ-closed, (1,2)*-g-closed, (1,2)*-gs-closed, (1,2)*-α g-closed, (1,2)*-sg-closed, (1,2)*-ψ -closed, (1,2)*-α -closed, (1,2)*-semi-closed) sets is denoted by (1,2)*-$\ddot{G}_\alpha$ C(X) (resp. (1,2)*-$\hat{G}$ C(X), (1,2)*-G C(X), (1,2)*-GS C(X), (1,2)*-αG C(X), (1,2)*-SG C(X), (1,2)*-ψ C(X), (1,2)*-α C(X), (1,2)*-S C(X)).

We denote the power set of X by P(X).

Definition 2.6 [17]: A subset S of a bitopological space X is said to be locally (1,2)*-closed if S = U $\cap$ F, where U is $\tau_{1,2}$-open and F is $\tau_{1,2}$-closed in X.

Remark 2.7
(i) Every $\tau_{1,2}$-closed set is (1,2)*-semi-closed but not conversely [10].
(ii) Every $\tau_{1,2}$-closed set is (1,2)*-α -closed but not conversely [10].
(i) Every (1,2)*-semi-closed set is (1,2)*-ψ -closed but not conversely [9].
(ii) Every (1,2)*-semi-closed set is (1,2)*-sg-closed but not conversely [9].
(iv) Every (1,2)*-ĝ-closed set is (1,2)*-g-closed but not conversely [3].
(v) Every (1,2)*-sg-closed set is (1,2)*-gs-closed but not conversely [15].
(iii) Every (1,2)*-g-closed set is (1,2)*-α g-closed but not conversely [16].
(ix) Every (1,2)*-g-closed set is (1,2)*-gs-closed but not conversely [15].
(x) Every $\tau_{1,2}$-closed set is (1,2)*- $\hat{g}$ -closed but not conversely [3].
(xi) Every (1,2)*- $\hat{g}$ -closed set is (1,2)*-sg-closed but not conversely [3].

Definition 2.8: A subset A of a bitopological space X is called regular (1,2)*-open set [13] if A = $\tau_{1,2}$-int($\tau_{1,2}$-cl(A)).

The complement of regular (1,2)*-open set is called regular (1,2)*-closed.

Definition 2.9: A subset A of a bitopological space X is called

(i) (1,2)*-α$\hat{g}$-closed [4] or $\tilde{g}$ (1,2)*-closed if (1,2)*-αcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is (1,2)*-$\hat{g}$-open in X. The complement of $\tilde{g}$ (1,2)*-closed set is called $\tilde{g}$ (1,2)*-open.

(ii) $\tilde{g}$ (1,2)*-open if the image of every $\tau_{1,2}$-open set of X is $\tilde{g}$ (1,2)*-open in Y.

Definition 2.10: A function f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called (1,2)*-g-open [14] (resp. (1,2)*-$\hat{g}$-open [4], (1,2)*-open [4], (1,2)*-sg-open [10], (1,2)*-gs-open [5], (1,2)*-α-open [4], (1,2)*-αg-open [4], (1,2)*-α$\hat{g}$-open [4]) if the image of every $\tau_{1,2}$-open set in X is (1,2)*-g-open (resp. (1,2)*-$\hat{g}$-open, $\sigma_{1,2}$-open, (1,2)*-sg-open, (1,2)*-gs-open, (1,2)*-α-open, (1,2)*-αg-open, (1,2)*-α$\hat{g}$-open) in Y.

Definition 2.11: A function f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called

(i) (1,2)*-g-continuous [14] if f^{-1}(V) is (1,2)*-g-closed in X, for every $\sigma_{1,2}$-closed set V of Y.
(ii) (1,2)*-sg-continuous [10] if f^{-1}(V) is (1,2)*-sg-closed in X, for every $\sigma_{1,2}$-closed set V of Y.
(iii) (1,2)*-gs-continuous [15] if f^{-1}(V) is (1,2)*-gs-closed in X, for every $\sigma_{1,2}$-closed set V of Y.
(iv) (1,2)*-$\hat{g}$-continuous [14] if f^{-1}(V) is (1,2)*-$\hat{g}$-closed in X, for every $\sigma_{1,2}$-closed set V of Y.
(v) (1,2)*-continuous [14] if f^{-1}(V) is $\tau_{1,2}$-closed in X, for every $\sigma_{1,2}$-closed set V of Y.
(iii) $\tilde{g}$ (1,2)*-continuous or (1,2)*-α$\hat{g}$-continuous [4] if f^{-1}(V) is $\tilde{g}$ (1,2)*-closed in X, for every $\sigma_{1,2}$-closed set V of Y.

Definition 2.12 [15]: A function f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called

(i) (1,2)*-g-homeomorphism if f is bijection, (1,2)*-g-open and (1,2)*-g-continuous.
(ii) (1,2)*-sg-homeomorphism if f is bijection, (1,2)*-sg-open and (1,2)*-sg-continuous.
(iii) (1,2)*-gs-homeomorphism if f is bijection, (1,2)*-gs-open and (1,2)*-gs-continuous.
(iv) (1,2)*-homeomorphism if f is bijection, (1,2)*-open and (1,2)*-continuous.

Definition 2.13 [15]: A function f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called

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

Definition 2.14 [15]: A function f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called

(i) pre-(1,2)*-α-closed (resp. pre (1,2)*-α-open) if the image of every (1,2)*-α-closed (resp. (1,2)*-α-open) in X is (1,2)*-α-closed (resp. (1,2)*-α-open) in Y.
(ii) (1,2)*-α-irresolute if f^{-1}(V) is (1,2)*-α-open in X, for every (1,2)*-α-open set V of Y.
(iii) (1,2)*-gc-irresolute if f^{-1}(V) is (1,2)*-g-closed in X, for every (1,2)*-g-closed set V of Y.
(iv) (1,2)*-α-homeomorphism if f is bijection, (1,2)*-α-irresolute and pre-(1,2)*-α-closed.

Remark 2.15

(i) Every (1,2)*-α-closed set is $\tilde{g}$ (1,2)*-closed but not conversely.
(ii) Every $\tilde{g}$ (1,2)*-open set is (1,2)*-gs-open but not conversely.

3. $\tilde{g}$ (1, 2)*-HOMEOMORPHISMS

Definition 3.1

(i) A bijective function f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called a strongly $\tilde{g}$ (1,2)*-closed (resp. strongly $\tilde{g}$ (1,2)*-open) if the image of every $\tilde{g}$ (1,2)*-closed (resp. $\tilde{g}$ (1,2)*-open) set in X is $\tilde{g}$ (1,2)*-closed (resp. $\tilde{g}$ (1,2)*-open) of Y.
(ii) A bijective function f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called an $\tilde{g}$ (1,2)*-homeomorphism if f is both $\tilde{g}$ (1,2)*-open and $\tilde{g}$ (1,2)*-continuous.

Theorem 3.2: Every (1,2)*-homeomorphism is $\tilde{g}$ (1,2)*-homeomorphism.

Proof: Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be (1,2)*-homeomorphism. Then f is bijective, (1,2)*-open and (1,2)*-continuous function. Let U be an $\tau_{1,2}$-open set in X. Since f is (1,2)*-open function, f(U) is an $\sigma_{1,2}$-open set in Y. Every $\tau_{1,2}$-open set is $\tilde{g}$ (1,2)*-open and hence f(U) is $\tilde{g}$ (1,2)*-open in Y. This implies f is $\tilde{g}$ (1,2)*-open. Let V be a $\sigma_{1,2}$-closed set in Y. Since f is (1,2)*-continuous, $f^{-1}(V)$ is $\tau_{1,2}$-closed in X. Thus $f^{-1}(V)$ is $\tilde{g}$ (1,2)*-closed in X and therefore, f is $\tilde{g}$ (1,2)*-continuous. Hence, f is an $\tilde{g}$ (1,2)*-homeomorphism.

Remark 3.3: The converse of Theorem 3.2 need not be true as shown in the following example.

Example 3.4: Let X = {a, b, c}, τ_1 = {ϕ, X} and τ_2 = {ϕ, X, {a, b}}. Then the sets in {ϕ, X, {a, b}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}} are called $\tilde{g}$ (1,2)*-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y, {b}}. Then the sets in {ϕ, Y, {a}, {b}, {a, b}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {c}, {a, c}, {b, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {c}, {a, c},{b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b}, {a, b}} are called $\tilde{g}$ (1,2)*-open in Y. Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be the identity function. Then f is a $\tilde{g}$ (1,2)*-homeomorphism but f is not a (1,2)*-homeomorphism.

Proposition 3.5: For any bijective function f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ the following statements are equivalent.
(i) f^{-1}: $(Y, \sigma_1, \sigma_2) \to (X, \tau_1, \tau_2)$ is $\tilde{g}$ (1,2)*-continuous function.
(ii) f is a $\tilde{g}$ (1,2)*-open function.
(iii) f is a $\tilde{g}$ (1,2)*-closed function.

Proof
(i) ⇒ (ii): Let U be an $\tau_{1,2}$-open set in X. Then X – U is $\tau_{1,2}$-closed in X. Since f^{-1} is $\tilde{g}$ (1,2)*-continuous, $(f^{-1})^{-1}(X - U)$ is $\tilde{g}$ (1,2)*-closed in Y. That is f(X – U) = Y – f(U) is $\tilde{g}$ (1,2)*-closed in Y. This implies f(U) is $\tilde{g}$ (1,2)*-open in Y. Hence f is $\tilde{g}$ (1,2)*-open function.
(ii) ⇒ (iii): Let F be a $\tau_{1,2}$-closed set in X. Then X – F is $\tau_{1,2}$-open in X. Since f is $\tilde{g}$ (1,2)*-open, f(X – F) is $\tilde{g}$ (1,2)*-open set in Y. That is Y–f(F) is $\tilde{g}$ (1,2)*-open in Y. This implies that f(F) is $\tilde{g}$ (1,2)*-closed in Y. Hence f is $\tilde{g}$ (1,2)*-closed.

(iii) ⇒ (i): Let V be a $\tau_{1,2}$-closed set in X. Since f is $\tilde{g}$ (1,2)*-closed function, f(V) is $\tilde{g}$ (1,2)*-closed in Y. That is $(f^{-1})^{-1}(V)$ is $\tilde{g}$ (1,2)*-closed in Y. Hence f^{-1} is $\tilde{g}$ (1,2)*-continuous.

Proposition 3.6: Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be a bijective and $\tilde{g}$ (1,2)*-continuous function. Then the following statements are equivalent:
(i) f is a $\tilde{g}$ (1,2)*-open function.
(ii) f is a $\tilde{g}$ (1,2)*-homeomorphism.
(iii) f is a $\tilde{g}$ (1,2)*-closed function.

Proof:
(i) ⇒ (ii): Let f be a $\tilde{g}$ (1,2)*-open function. By hypothesis, f is bijective and $\tilde{g}$ (1,2)*-continuous. Hence f is a $\tilde{g}$ (1,2)*-homeomorphism.
(ii) ⇒ (iii): Let f be a $\tilde{g}$ (1,2)*-homeomorphism. Then f is $\tilde{g}$ (1,2)*-open. By Proposition 3.5, f is $\tilde{g}$ (1,2)*-closed function.
(iii) ⇒ (i): It is obtained from Proposition 3.5.

Theorem 3.7: Every (1,2)*-α-homeomorphism is $\tilde{g}$ (1,2)*-homeomorphism.

Proof: Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be a (1,2)*-α-homeomorphism. Then f is bijective, (1,2)*-α-irresolute and pre-(1,2)*-α-closed. Let F be $\tau_{1,2}$-closed in X. Then F is (1,2)*-α-closed in X. Since f is pre-(1,2)*-α-closed, f(F) is (1,2)*-α-closed in Y. Every (1,2)*-α-closed set is $\tilde{g}$ (1,2)*-closed and hence f(F) is $\tilde{g}$ (1,2)*-closed in Y. This implies f is $\tilde{g}$ (1,2)*-closed function. Let V be a $\sigma_{1,2}$-closed set of Y. Thus V is (1,2)*-α-closed in Y. Since f is (1,2)*-α-irresolute $f^{-1}(V)$ is (1,2)*-α-closed in X. Thus $f^{-1}(V)$ is $\tilde{g}$ (1,2)*-closed in X. Therefore f is $\tilde{g}$ (1,2)*-continuous. Hence f is a $\tilde{g}$ (1,2)*-homeomorphism.

Remark 3.8: The following Example shows that the converse of Theorem 3.7 need not be true.

Example 3.9: Let X = {a, b, c}, τ_1 = {ϕ, X} and τ_2 = {ϕ, X, {a}}. Then the sets in {ϕ, X, {a}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {a, b}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X, {a}, {b}, {c}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in X. Moreover, the sets in {ϕ, X, {a}, {a, b}, {a, c}} are called (1,2)*-α-open in X and the sets in {ϕ, X, {b}, {c}, {b, c}} are called (1,2)*-α-closed in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y} and σ_2 = {ϕ, Y, {a, b}}. Then the sets in {ϕ, Y, {a, b}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b}, {a, b}} are called $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {a, b}} are called (1,2)*-α-closed in Y and the sets in {ϕ, Y, {c}} are called (1,2)*-α-open in Y. Let f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) be the identity function. Then f is a $\tilde{g}$ (1,2)*-homeomorphism but f is not a (1,2)*-α-homeomorphism.

Remark 3.10: Next Example shows that the composition of two $\tilde{g}$ (1,2)*-homeomorphisms is not always a $\tilde{g}$ (1,2)*-homeomorphism.

Example 3.11: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {a, c}}. Then the sets in {ϕ, X, {a}, {a, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {b},{b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {a, b},{b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in{ϕ, X,{a},{c},{a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in X. Let Y= {a, b, c}, σ_1 = {ϕ, Y} and σ_2 = {ϕ, Y, {a}}. Then the sets in {ϕ, Y, {a}} are called $\sigma_{1,2}$-open and the sets in{ϕ, Y, {b, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {b}, {c}, {a, b}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y,{a}, {b}, {c}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in Y. Let Z = {a, b, c}, η_1 = {ϕ, Z} and η_2 = {ϕ, Z, {a, b}}. Then the sets in {ϕ, Z, {a, b}} are called $\eta_{1,2}$-open and the sets in {ϕ, Z, {c}} are called $\eta_{1,2}$-closed. Also the sets in {ϕ, Z, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Z and the sets in {ϕ, Z, {a}, {b},{a, b}} are called $\tilde{g}$ (1,2)*-open in Z. Let f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) and g : (Y, σ_1, σ_2) → (Z, η_1, η_2) be two identity functions. Then both f and g are $\tilde{g}$ (1,2)*-homeomorphisms. The set {a, c} is $\tau_{1,2}$-open in X, but (g o f)({a, c}) ={a, c} is not $\tilde{g}$ (1,2)*-open in Z. This implies that g o f is not $\tilde{g}$ (1,2)*-open and hence g o f is not $\tilde{g}$ (1,2)*-homeomorphism.

Theorem 3.12: Every $\tilde{g}$ (1,2)*-homeomorphism is (1,2)*-gs-homeomorphism but not conversely.

Proof: Let f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) be a $\tilde{g}$ (1,2)*-homeomorphism. Then f is a bijective, $\tilde{g}$ (1,2)*-open and $\tilde{g}$ (1,2)*-continuous function. Let U be an $\tau_{1,2}$-open set in X. Then f(U) is $\tilde{g}$ (1,2)*-open in Y. Every $\tilde{g}$ (1,2)*-open set is (1,2)*-gs-open and hence, f(U) is (1,2)*-gs-open in Y. This implies f is (1,2)*-gs-open function. Let V be $\sigma_{1,2}$-closed set in Y. Then $f^{-1}(V)$ is $\tilde{g}$ (1,2)*-closed in X. Hence $f^{-1}(V)$ is (1,2)*-gs-closed in X. This implies f is (1,2)*-gs-continuous. Hence f is (1,2)*-gs-homeomorphism.

Remark 3.13: The following Example shows that the converse of Theorem 3.12 need not be true.

Example 3.14: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {c}, {a, c}, {b, c}}are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X,{a}, {b}, {a, b}} are called $\tilde{g}$ (1,2)*-open in X. Moreover, the sets in {ϕ, X, {a}, {b}, {c}, {a, c}, {b, c}} are called (1,2)*-gs-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}, {a, c}, {b, c}} are called (1,2)*-gs-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y, {b, c}}. Moreover, the sets in{ϕ, Y, {a}, {b, c}} are called $\sigma_{1,2}$-open and $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {a}, {b, c}} are called $\tilde{g}$ (1,2)*-closed and $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {a}, {b}, {c}, {a, b}, {a, c}, {b, c}} are called (1,2)*-g-closed and (1,2)*-g-open in Y. Let f: (X, τ_1, τ_2) → (Y, σ_1, σ_2) be the identity function. Then f is a (1,2)*-gs-homeomorphism but f is not a $\tilde{g}$ (1,2)*-homeomorphism.

Remark 3.15: The following Examples show that the concepts of $\tilde{g}$ (1,2)*-homeomorphisms and (1,2)*-g-homeomorphisms are independent of each other.

Example 3.16: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}, {a, b}} and τ_2 = {ϕ, X, {a, c}}. Then the sets in {ϕ, X, {a}, {a, b}, {a, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {b}, {c}, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed and (1,2)*-g-closed in X. Moreover, the sets in {ϕ, X, {a}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open and (1,2)*-ĝ-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {b}} and σ_2 = {ϕ, Y, {a, b}}. Then the sets in {ϕ, Y, {b}, {a, b}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {c}, {a, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {a}, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b}, {a, b}, {b, c}} are called $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {c}, {a, c}, {b, c}} are called (1,2)*-g-closed in Y and the sets in {ϕ, Y, {a}, {b}, {a, b}} are called (1,2)*-g-open in Y. Define a function f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ by f(a) = b, f(b) = a and f(c) = c. Then f is a $\tilde{g}$ (1,2)*-homeomorphism but f is not a (1,2)*-g-homeomorphism.

Example 3.17: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X}. Then the sets in {ϕ, X, {a}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {a, b}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed and (1,2)*-g-closed in X. Moreover, the sets in {ϕ, X, {a}, {b}, {c}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open and (1,2)*-g-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y, {b, c}}. Then the sets in {ϕ, Y, {a}, {b, c}} are called $\sigma_{1,2}$-open and $\sigma_{1,2}$-closed. Also the sets in{ϕ, Y, {a}, {b, c}} are called $\tilde{g}$ (1,2)*-closed and $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {a}, {b}, {c}, {a, b}, {a, c}, {b, c}} are called (1,2)*-gs-closed and (1,2)*-gs-open in Y. Define a function f : $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ by f(a) = b, f(b) = c, f(c) = a. Then f is a (1,2)*-g-homeomorphism but f is not a $\tilde{g}$ (1,2)*-homeomorphism.

Remark 3.18: $\tilde{g}$ (1,2)*-homeomorphisms and (1,2)*-sg-homeomorphisms are independent of each other as shown below.

Example 3.19: The function f defined in Example 3.16 is $\tilde{g}$ (1,2)*-homeomorphism but not (1,2)*-sg-homeomorphism.

Example 3.20: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}} are called $\tau_{1,2}$-open and $\tilde{g}$ (1,2)*-open in X; the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called $\tau_{1,2}$-closed and $\tilde{g}$ (1,2)*-closed in X. Also, the sets in {ϕ, X, {a}, {b}, {c}, {a, c}, {b, c}} are called (1,2)*-sg-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}, {a, c}, {b, c}} are called (1,2)*-sg-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y, {b, c}}. Then the sets in {ϕ, Y, {a}, {b, c}} are called $\sigma_{1,2}$-open and $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {a}, {b, c}} are called $\tilde{g}$ (1,2)*-closed and $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {a}, {b}, {c}, {a, b}, {a, c}, {b, c}} are called (1,2)*-sg-closed and (1,2)*-sg-open in Y. Define a function f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ by f(a) = b, f(b) = a and f(c) = c. Then f is (1,2)*-sg-homeomorphism but not $\tilde{g}$ (1,2)*-homeomorphism.

4. STRONGLY $\tilde{g}$ (1, 2)*-HOMEOMORPHISMS

Definition 4.1: A bijection f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ is said to be strongly $\tilde{g}$ (1,2)*-homeomorphism if f is $\tilde{g}$ (1,2)*-irresolute and its inverse f^{-1} is also $\tilde{g}$ (1,2)*-irresolute.

Theorem 4.2: Every strongly $\tilde{g}$ (1,2)*-homeomorphism is $\tilde{g}$ (1,2)*-homeo-morphism.

Proof: Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be strongly $\tilde{g}$ (1,2)*-homeomorphism. Let U be $\tau_{1,2}$-open in X. Then U is $\tilde{g}$ (1,2)*-open in X. Since f^{-1} is $\tilde{g}$ (1,2)*-irresolute, $(f^{-1})^{-1}(U)$ is $\tilde{g}$ (1,2)*-open in Y. That is f(U) is $\tilde{g}$ (1,2)*-open in Y. This implies f is $\tilde{g}$ (1,2)*-open function. Let F be a $\sigma_{1,2}$-closed in Y. Then F is $\tilde{g}$ (1,2)*-closed in Y. Since f is $\tilde{g}$ (1,2)*-irresolute, $f^{-1}(F)$ is $\tilde{g}$ (1,2)*-closed in X. This implies f is $\tilde{g}$ (1,2)*-continuous function. Hence f is $\tilde{g}$ (1,2)*-homeomorphism.

Remark 4.3: The following Example shows that the converse of Theorem 4.2 need not be true.

Example 4.4: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {a, c}}. Then the sets in {ϕ, X, {a}, {a, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {b}, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {a, b}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X, {a}, {c}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y}. Then the sets in {ϕ, Y, {a}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {b, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {b}, {c}, {a, b}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b}, {c}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in Y. Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be the identity function. Then f is a $\tilde{g}$ (1,2)*-homeomorphism but f is not a strongly $\tilde{g}$ (1,2)*-homeomorphism.

Theorem 4.5: The composition of two strongly $\tilde{g}$ (1,2)*-homeomorphisms is a strongly $\tilde{g}$ (1,2)*-homeomorphism.

Proof: Let f : $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ and g : $(Y, \sigma_1, \sigma_2) \to (Z, \eta_1, \eta_2)$ be two strongly $\tilde{g}$ (1,2)*-homeomorphisms. Let F be a $\tilde{g}$ (1,2)*-closed set in Z. Since g is $\tilde{g}$ (1,2)*-irresolute, $g^{-1}(F)$ is $\tilde{g}$ (1,2)*-closed in Y. Since f is a $\tilde{g}$ (1,2)*-irresolute, $f^{-1}(g^{-1}(F))$ is $\tilde{g}$ (1,2)*-closed in X. That is $(g \circ f)^{-1}(F)$ is $\tilde{g}$ (1,2)*-closed in X. This implies that g o f: $(X, \tau_1, \tau_2) \to (Z, \eta_1, \eta_2)$ is $\tilde{g}$ (1,2)*-irresolute. Let V be a $\tilde{g}$ (1,2)*-closed in X. Since f^{-1} is a $\tilde{g}$ (1,2)*-irresolute, $(f^{-1})^{-1}(V)$ is $\tilde{g}$ (1,2)*-closed in Y. That is f(V) is $\tilde{g}$ (1,2)*-closed in Y. Since g^{-1} is a $\tilde{g}$ (1,2)*-irresolute, $(g^{-1})^{-1}(f(V))$ is $\tilde{g}$ (1,2)*-closed in Z. That is g(f(V)) is $\tilde{g}$ (1,2)*-closed in Z. So, (g o f)(V) is $\tilde{g}$ (1,2)*-closed in Z. This implies that $((g \circ f)^{-1})^{-1}(V)$ is $\tilde{g}$ (1,2)*-closed in Z. This shows that $(g \circ f)^{-1} : (Z, \eta_1, \eta_2) \to (X, \tau_1, \tau_2)$ is $\tilde{g}$ (1,2)*-irresolute. Hence g o f is a strongly $\tilde{g}$ (1,2)*-homeomorphism**.**

Remark 4.6: The concepts of strongly $\tilde{g}$ (1,2)*-homeomorphisms and (1,2)*-α-homeomorphisms are independent notions as shown in the following examples.

Example 4.7: Let X = {a, b, c}, τ_1 = {ϕ, X} and τ_2 = {ϕ, X, {a, b}}. Then the sets in {ϕ, X, {a, b}} are called $\tau_{1,2}$-open and (1,2)*-α-open; and the sets in{ϕ, X, {c}} are called $\tau_{1,2}$-closed and (1,2)*-α-closed. Also the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b}} are called $\tilde{g}$ (1,2)*-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y, {b}}. Then the sets in {ϕ, Y, {a}, {b}, {a, b}} are called $\sigma_{1,2}$-open and (1,2)*-α-open; and the sets in{ϕ, Y, {c}, {a, c}, {b, c}} are called $\sigma_{1,2}$-closed and (1,2)*-α-closed in Y. Also the sets in {ϕ, Y, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b}, {a, b}} are called $\tilde{g}$ (1,2)*-open in Y. Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be the identity function. Then f is a strongly $\tilde{g}$ (1,2)*-homeomorphism but f is not (1,2)*-α-homeomorphism.

Example 4.8: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {a, b}}. Then the sets in {ϕ, X, {a}, {a, b}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {c}, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in X. Moreover, the sets in {ϕ, X, {b}, {c}, {b, c}} are called (1,2)*-α-closed in X and the sets in {ϕ, X, {a}, {a, b}, {a, c}} are called (1,2)*-α-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y} and σ_2 = {ϕ, Y, {a}}. Then the sets in {ϕ, Y, {a}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {b, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {b}, {c}, {a, b}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b}, {c}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {b}, {c}, {b, c}} are called (1,2)*-α-closed in Y and the sets in {ϕ, Y, {a}, {a, b}, {a, c}} are called (1,2)*-α-open in Y.Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be the identity function. Then f is a (1,2)*-α-homeomorphism but not strongly $\tilde{g}$ (1,2)*-homeomorphism.

Definition 4.9: A bijective function f : $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ is called (1,2)*-gc-homeomorphism if f is (1,2)*-gc-irresolute and f^{-1} is (1,2)*-gc-irresolute.

Remark 4.10: The concepts of strongly $\tilde{g}$ (1,2)*-homeomorphisms and (1,2)*-gc-homeomorphisms are independent of each other as the following examples show.

Example 4.11: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {a, b}}. Then the sets in {ϕ, X, {a}, {a, b}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {c}, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {b}, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in X. Moreover, the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called (1,2)*-g-closed in X and the sets in {ϕ, X, {a}, {b}, {a, b}} are called (1,2)*-g-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {b}, {a, b}} and σ_2 = {ϕ, Y, {a}, {a, c}}. Then the sets in {ϕ, Y, {a}, {b}, {a, b}, {a, c}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {b}, {c}, {a, c}, {b, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {b}, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed, the sets in {ϕ, Y, {b}, {c}, {b, c}} are called (1,2)*-g-closed in Y and the sets in {ϕ, Y, {a}, {b}, {a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open, the sets in {ϕ, Y, {a}, {a, b}, {a, c}} are called (1,2)*-g-open in Y. Let f: $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be the identity function. Then f is a strongly $\tilde{g}$ (1,2)*-homeomorphism but not (1,2)*-gc-homeomorphism.

Example 4.12: Let X = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called $\tau_{1,2}$-closed. Also the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed and (1,2)*-g-closed in X, and the sets in {ϕ, X, {a}, {b}, {a, b}} are called $\tilde{g}$ (1,2)*-open and (1,2)*-g-open in X. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}} and σ_2 = {ϕ, Y, {a, b}}. Then the sets in {ϕ, Y, {a}, {a, b}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {b}, {c}, {a, c}, {b, c}} are called $\sigma_{1,2}$-closed. Also the sets in {ϕ, Y, {b}, {c}, {a, c}, {b, c}} are called $\tilde{g}$ (1,2)*-closed in Y and the sets in {ϕ, Y, {a}, {b},{a, b}, {a, c}} are called $\tilde{g}$ (1,2)*-open in Y. Moreover, the sets in {ϕ, Y, {c}, {a, c}, {b, c}} are called (1,2)*-g-closed in Y and the sets in{ϕ, Y, {a}, {b}, {a, b}} are called (1,2)*-g-open in Y. Let f: (X, τ_1, τ_2) $\rightarrow$ (Y, σ_1, σ_2) be the identity function. Then f is a (1,2)*-gc-homeomorphism but not strongly $\tilde{g}$ (1,2)*-homeomorphism.

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