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REMARKS ON BITOPOLOGICAL (1, 2)*-rω-HOMEOMORPHISMS

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ABSTRACT

The aim of this paper is to introduce the concepts of (1, 2)-rω- continuous mappings and study some of its properties. Their corresponding (1,2)*-rω-irresolute mappings and (1,2)*-rω-homeomorphisms are also defined and investigated in this paper.*

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1. INTRODUCTION:

Regular open sets have been introduced and investigated by Stone [32]. Levine [16, 17], Cameron [3], Sundaram and Sheik John [34], and Gnanambal [7] introduced and investigated semi-open sets, regular semiopen sets, weakly closed sets and generalized pre-regular closed sets respectively. Regular ω-closed sets have been introduced and investigated by Benchalli and Wali [2] respectively, which is properly placed in between the class of ω-closed sets [33] and the class of regular-generalized closed sets [19]. Recently Ravi, Lellis Thivagar, Ekici and Many others [20-31] defined different weak forms of semi-open sets, preopen sets, regular open sets, regular semi open sets etc., in bitopological spaces.

In this paper, we introduce the notions of (1,2)*-rω-continuous mappings, (1,2)*-rω-irresolute mappings and (1,2)*-rω-homeomorphisms in bitopological spaces and study some of their basic properties. In most of the occasions our ideas are illustrated and substantiated by some suitable examples.

2. PRELIMINARIES:

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

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Definition: 2.1
Let S be a subset of a bitopological space X. Then S is called $\tau_{1,2}$-open [11] if S = $A \bigcup B$, where $A \in \tau_1$ $B \in \tau_2$ .The complement of $\tau_{1,2}$-open set is called $\tau_{1,2}$-closed. The family of all $\tau_{1,2}$-open sets of X is denoted by (1,2)*-O(X).

Definition: 2.2
Let S be a subset of a bitopological space X. Then

(i) the $\tau_{1,2}$-closure of S [11], denoted by $\tau_{1,2}$-cl(S), is defined by $\cap$ {U: $S \subseteq U$ and U is $\tau_{1,2}$-closed };

(ii) the $\tau_{1,2}$-interior of S [11], denoted by $\tau_{1,2}$-int(S), is defined by $\cup$ {U: $U \subseteq S$ and U is $\tau_{1,2}$-open}.

Remark: 2.3
Notice that $\tau_{1,2}$-open subsets of X need not necessarily form a topology.

Now we recall some definitions and results, which are used in this paper.

Definition: 2.4
A subset S of a bitopological space X is said to be

(i) (1, 2)*-α-open [13] if $S \subseteq \tau_{1,2}$-int($\tau_{1,2}$-cl($\tau_{1,2}$-int(S)));

(ii) (1, 2)*-semi-open [13] if $S \subseteq \tau_{1,2}$-cl($\tau_{1,2}$-int(S));

(iii) regular (1,2)*-open [20] if S = $\tau_{1,2}$-int($\tau_{1,2}$-cl(S));

(iv) (1, 2)*-preopen [13] if $S \subseteq \tau_{1,2}$-int($\tau_{1,2}$ -cl(S));

(v) (1, 2)*-π-open [15] if S is the finite union of regular (1, 2)*-open sets.

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

The family of all (1,2)*-α-open (resp. (1,2)*-semi-open, (1,2)*-preopen, regular (1,2)*-open, (1,2)*-π-open) sets of X will be denoted by (1,2)*-αO(X) (resp. (1,2)*-SO(X), (1,2)*-PO(X), (1,2)*-RO(X), (1,2)*-πO(X)).

The (1,2)*-semi-closure [25](resp. (1,2)*-preclosure [21], (1,2)*-α-closure [21]) of a subset S of X is, denoted by (1,2)*-scl(S) (resp. (1,2)*-pcl(S) (1,2)*-αcl(S)), defined as the intersection of all (1,2)*-semi-closed (resp. (1,2)*-preclosed, (1,2)*-α-closed) sets containing S.

Definition: 2.5

A subset S of a bitopological space X is said to be

(i) a regular (1,2)*-generalized closed (briefly, (1,2)*-rg-closed [22]) if $\tau_{1,2}$-cl(S) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-RO(X).

(ii) a (1,2)*-ω-closed or (1,2)*- $\hat{g}$ -closed [9] if $\tau_{1,2}$-cl(S) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-SO(X).

(iii) a (1,2)*-gpr-closed [28] if (1,2)*-pcl(S) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-RO(X).

(iv) a (1,2)*-generalized closed (briefly, (1,2)*-g-closed [23]) if $\tau_{1,2}$-cl(S) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-O(X).

(v) a weakly (1,2)*-generalized closed (briefly, (1,2)*-wg-closed [29]) if $\tau_{1,2}$-cl($\tau_{1,2}$-int(S)) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-O(X).

(vi) a (1,2)*-πg-closed [15] if $\tau_{1,2}$-cl(S) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-πO(X).

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

Definition: 2.6[27]
A subset S of a bitopological space X is called

(i) regular (1,2)*-semiopen if there is a regular (1,2)*-open set U such that $U \subset S \subset \tau_{1,2}$-cl(U).

(ii) regular (1,2)*-α-open (briefly, (1,2)*-rα-open) if there is a regular (1,2)*-open set U such that $U \subset S \subset$ (1,2)*-αcl(U).

The family of all regular (1, 2)*-semiopen(resp. regular (1,2)*-α-open) sets of X is denoted by (1,2)*-RSO(X) (resp. RαO(X)).

Definition: 2.7 [31]
A subset A of a bitopological space X is called a regular generalized-(1,2)*-α-closed set (briefly, (1,2)*-rgα-closed) if (1,2)*-α-cl(A) $\subset$ U whenever $A \subset U$ and $U \in$ RαO(X).

We denote the set of all (1,2)*-rgα-closed sets in X by (1,2)*-RGαC(X).

Definition: 2.8 [27]
A subset S of a bitopological space X is called regular (1, 2)*-ω-closed (briefly (1,2)*-rω-closed) if $\tau_{1,2}$-cl(S) $\subset$ U whenever $S \subset U$ and $U \in$ (1,2)*-RSO(X).

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

We denote the family of all (1,2)*-rω-closed (resp. (1,2)*-rω-open) sets in X by (1,2)*-RωC(X)(resp. (1,2)*-RωO(X)).

Definition: 2.9

A map $f : X \rightarrow Y$ is said to be

(i) (1, 2)*-continuous [20] if $f^{-1}(V)$ is $\tau_{1,2}$-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(ii) (1, 2)*-semi-continuous [25] if $f^{-1}(V)$ is (1, 2)*-semi-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(iii) (1, 2)*-ω-continuous [28] if $f^{-1}(V)$ is (1, 2)*- ω-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(iv) (1, 2)*-rg-continuous [22] if $f^{-1}(V)$ is (1, 2)*-rg-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(v) (1, 2)*-πg-continuous [15] if $f^{-1}(V)$ is (1, 2)*-πg-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(vi) (1, 2)*-g-continuous [24] if $f^{-1}(V)$ is (1, 2)*-g-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(vii)(1, 2)*-gpr-continuous [12] if $f^{-1}(V)$ is (1, 2)*-gpr-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

(viii) (1, 2)*-wg-continuous [29] if $f^{-1}(V)$ is (1, 2)*-wg-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

Definition: 2.10
A map $f : X \rightarrow Y$ is said to be

(i) (1, 2)*-semi-irresolute [13] if $f^{-1}(V)$ is (1, 2)*-semi-open in X, for every (1, 2)*-semi-open V in Y.

(ii) (1, 2)*-ω-irresolute [28] if $f^{-1}(V)$ is (1, 2)*-ω-closed in X, for every (1, 2)*- ω-closed V in Y.

Definition 2.11
A bijective $f : X \rightarrow Y$ is said to be

(i) (1, 2)*-g-homeomorphism [26] if both f and f^{-1} are (1,2)*-g continuous

(ii) (1, 2)*-ω-homeomorphism [28] if both f and f^{-1} are (1,2)*-ω-continuous

(iii) (1, 2)*-homeomorphism [26] if both f and $f^{-1}$are (1,2)*- continuous

Remark: 2.12
Every $\tau_{1,2}$-closed set is (1,2)*-rω-closed set but not conversely [27].

3. (1, 2)*-rω-CONTINUOUS MAPPINGS:

Definition: 3.1
A subset A of a bitopological space X is called a regular weakly generalized-(1,2)*-closed set (briefly, (1,2)*-rwg-closed) if $\tau_{1,2}$-cl($\tau_{1,2}$-int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is regular (1,2)*-open in X.

Definition: 3.2
A map f : X → Y is said to be

(i) (1, 2)*-rω-continuous if $f^{-1}(V)$ is (1,2)*-rω-closed in X, for every $\sigma_{1,2}$-closed set V in Y.

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

Theorem: 3.3
Every (1, 2)*-continuous map is (1,2)*-rω-continuous.

Proof:
Let f : X → Y be (1,2)*-continuous and V be any $\sigma_{1,2}$-closed set in Y. Then $f^{-1}(V)$ is $\tau_{1,2}$-closed set in X. By Remark 2.12, $f^{-1}(V)$ is (1, 2)*-rω-closed in X. Therefore, f is (1, 2)*-rω-continuous.

Remark: 3.4
The converse of Theorem 3.3 need not be true as shown in the following example.

Example: 3.5
Let X = {a, b, c}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {a, c}}. Then the sets in {ϕ, X, {b}, {a, c}} are called $\tau_{1,2}$-open and $\tau_{1,2}$-closed. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {b, c}} and σ_2 = {ϕ, Y, {c}}. Then the sets in {ϕ, Y, {c}, {b, c}} are called $\sigma_{1,2}$-open and the sets in{ϕ, Y, {a}, {a, b}} are called $\sigma_{1,2}$-closed. The map f : X → Y defined by f(a) = a, f(b) = b, f(c) = c is (1,2)*-rω-continuous but not (1,2)*-continuous.

Theorem: 3.6
If f : X → Y is (1,2)*-ω-continuous map then it is (1,2)*-rω-continuous.

Proof:
Let V be any $\sigma_{1,2}$-closed set of Y. Then by hypothesis $f^{-1}(V)$ is (1, 2)*-ω-closed set in X. But every (1, 2)*-ω-closed set is (1, 2)*-rω-closed, by Theorem 3.3[27]. Therefore, f is (1, 2)*-rω-continuous.

Remark: 3.7
The converse of Theorem 3.6 need not be true as shown in the following example.

Example: 3.8
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {c}, {b, c, d}}. Then the sets in {ϕ, X, {b}, {c}, {b, c}, {b, c, d}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {a}, {a, d}, {a, b, d}, {a, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, σ_1 = {ϕ, Y, {a, b, c}} and σ_2 = {ϕ, Y, {a, c}}. Then the sets in{ϕ, Y, {a, c}, {a, b, c}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {d}, {b, d}} are called $\sigma_{1,2}$-closed. The map f : X → Y defined by f(a) = a, f(b) = b, f(c) = c and f(d) = d is (1,2)*-rω-continuous but not (1,2)*-ω-continuous.

Theorem: 3.9
If f : X → Y is (1,2)*-rω-continuous map then it is (1,2)*-rg-continuous.

Proof:
Let V be any $\sigma_{1,2}$-closed set of Y. Then by hypothesis $f^{-1}(V)$ is (1, 2)*-rω-closed set in X. But every (1, 2)*-rω-closed set is (1, 2)*-rg-closed, by Theorem 3.6[27]. Therefore f is (1, 2)*-rg-continuous.

Remark: 3.10:
The converse of Theorem 3.9 need not be true as shown in the following example.

Example: 3.11
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d}, {c, d}, {a, c, d}, {b, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, σ_1 = {ϕ, Y, {a, b, c}} and σ_2 = {ϕ, Y}. Then the sets in {ϕ, Y, {a, b, c}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {d}} are called $\sigma_{1,2}$-closed. The map f : X → Y defined by f(a) = b, f(b) = a, f(c) = c and f(d) = d is (1,2)*-rg-continuous but not (1,2)*-rω-continuous.

Theorem: 3.12
If f : X → Y is (1,2)*-rω-continuous map then it is (1,2)*-gpr-continuous.

Proof:
Let V be any $\sigma_{1,2}$-closed set of Y. Then by hypothesis $f^{-1}(V)$ is (1, 2)*-rω-closed set in X. But every (1, 2)*-rω-closed set is (1, 2)*-gpr-closed, by Theorem 3.12[27]. Therefore, f is (1, 2)*-gpr-continuous.

Remark: 3.13
The converse of Theorem 3.12 need not be true as shown in the following example.

Example: 3.14
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {c}, {b, c, d}}. Then the sets in {ϕ, X, {b}, {c}, {b, c}, {b, c, d}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {a}, {a, d}, {a, b, d}, {a, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, σ_1 = {ϕ, Y, {a, b, c}} and σ_2 = {ϕ, Y, {a, c}}. Then the sets in {ϕ, Y, {a, c}, {a, b, c}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {d}, {b, d}} are called $\sigma_{1,2}$-closed. The map f : X → Y defined by f(a) = a, f(b) = b, f(c) = c and f(d) = d is (1,2)*-gpr-continuous but not (1,2)*-rω-continuous.

Remark: 3.15
The concepts of

(i) (1, 2)*-rω-continuous and (1, 2)*-g-continuous are independent.

(ii) (1, 2)*-rω-continuous and (1, 2)*-semi-continuous are independent.

(iii) (1, 2)*-rω-continuous and (1, 2)*-wg-continuous are independent.

(iv) (1, 2)*-rω-continuous and (1, 2)*-πg-continuous are independent.

Example: 3.16
Let X = Y = {a, b, c}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {c}}. Then the sets in {ϕ, X, {b}, {c}, {b, c}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {a},{a, b}, {a, c}}are called $\tau_{1,2}$-closed. Let 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 the sets in {ϕ, Y, {a},{b, c}}are $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {a},{a, b}, {a, c}, {b, c}} are called (1,2)*-rω-closed and the sets in {ϕ, X, {a},{a, b}, {a, c}} are called (1,2)*-g-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b and f(c) = c. Then f is (1, 2)*-rω-continuous but not (1, 2)*-g-continuous.

Example: 3.17
Let X = Y = {a, b, c, d}, τ_1 = {ϕ, X} and τ_2 = {ϕ, X, {a}, {b}, {a, b}, {a, b, c}}. Then the sets in {ϕ, X, {a},{b}, {a, b}, {a, b, c}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d},{c, d}, {a, c, d}, {b, c, d}}are called $\tau_{1,2}$-closed. Let σ_1 = {ϕ, Y} and σ_2 = {ϕ, Y, {c}, {a, c}, {b, c}, {a, b, c}}. Then the sets in {ϕ, Y, {c},{a, c}, {b, c}, {a, b, c}}are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {d},{a, d}, {b, d}, {a, b, d}} are called $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {d},{a, b}, {c, d}, {a, b, c}, {a, b, d}, {a, c, d}, {b, c, d}} are called (1, 2)*-rω-closed and the sets in {ϕ, X, {d}, {b, d}, {c, d}, {a, d}, {b, d}, {a, b, d}, {a, c, d}, {b, c, d}} are called (1, 2)*-g-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b, f(c) = c and f(d) = d. Then f is (1, 2)*-g-continuous but not (1, 2)*-rω-continuous.

Example: 3.18
Let X = Y = {a, b, c}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {c}}. Then the sets in {ϕ, X, {b}, {c}, {b, c}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {a},{a, b}, {a, c}}are called $\tau_{1,2}$-closed. Let 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 the sets in {ϕ, Y, {a},{b, c}}are $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {a},{a, b}, {a, c}, {b, c}} are called (1,2)*-rω-closed and the sets in {ϕ, X, {a}, {b}, {c}, {a, b}, {a, c}} are called (1,2)*-semi-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b and f(c) = c. Then f is (1, 2)*-rω-continuous but not (1, 2)*-semi-continuous.

Example: 3.19
Let X = Y = {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. Let σ_1= {ϕ, Y} and σ_2 = {ϕ, Y, {b}, {a, b}, {b, c}}. Then the sets in {ϕ, Y, {b}, {a, b}, {b, c}} are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {a}, {c},{a, c}} are called $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called (1, 2)*-rω-closed and the sets in {ϕ, X, {a},{b}, {c}, {a, c}, {b, c}} are called (1, 2)*-semi-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b and f(c) = c. Then f is (1, 2)*-semi-continuous but not (1, 2)*-rω-continuous.

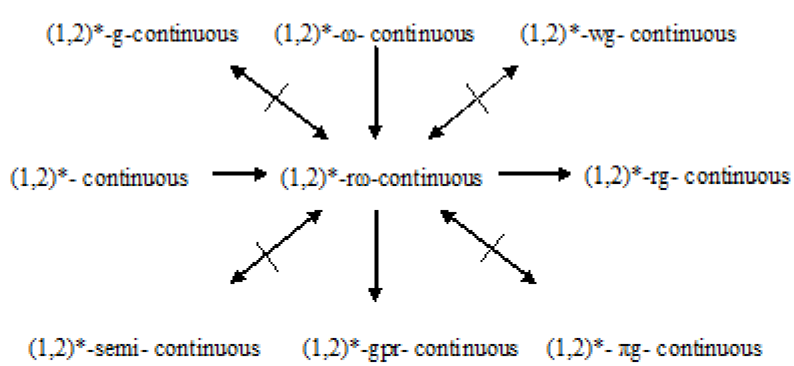
Example: 3.20
Let X = Y = {a, b, c}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}}. Then the sets in {ϕ, X, {a},{b}, {a, b}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {c},{a, c}, {b, c}}are called $\tau_{1,2}$-closed. Let σ_1 = {ϕ, Y, {c}} and σ_2 = {ϕ, Y, {a, b}}. Then the sets in {ϕ, Y, {c}, {a, b}}are called $\sigma_{1,2}$-open and $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {c},{a, b}, {a, c}, {b, c}} are called (1, 2)*-rω-closed and the sets in {ϕ, X, {c}, {a, c}, {b, c}} are called (1, 2)*-wg-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b and f(c) = c. Then f is (1, 2)*-rω-continuous but not (1, 2)*-wg-continuous.

Example: 3.21
Let X = Y = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a},{b}, {a, b}, {a, b, c}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d},{c, d}, {a, c, d}, {b, c, d}}are called $\tau_{1,2}$-closed. Let σ_1 = {ϕ, Y, {b, c}} and σ_2 = {ϕ, Y, {c}, {a, c}, {a, b, c}}. Then the sets in {ϕ, Y, {c},{a, c}, {b, c}, {a, b, c}}are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {d},{a, d}, {b, d}, {a, b, d}} are called $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {d},{a, b}, {c, d}, {a, b, c}, {a, b, d}, {a, c, d}, {b, c, d}} are called (1, 2)*-rω-closed and the sets in {ϕ, X, {c},{d}, {c, d}, {a, d}, {b, d}, {a, c}, {a, b, d}, {a, c, d}, {b, c, d}} are called (1, 2)*-wg-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b, f(c) = c and f(d) = d. Then f is (1, 2)*-wg-continuous but not (1, 2)*-rω-continuous.

Example: 3.22
Let X = Y = {a, b, c}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {c}}. Then the sets in {ϕ, X, {b}, {c}, {b, c}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {a},{a, b}, {a, c}}are called $\tau_{1,2}$-closed. Let 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 the sets in {ϕ, Y, {a},{b, c}}are $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {a},{a, b}, {a, c}, {b, c}} are called (1,2)*-rω-closed and the sets in {ϕ, X, {a},{b}, {c} {a, b}, {a, c}, {b, c}} are called (1,2)*- πg -closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b and f(c) = c. Then f is (1, 2)*-rω-continuous but not (1, 2)*-πg-continuous.

Example: 3.23
Let X = Y = {a, b, c, d}, τ_1 = {ϕ, X, {b}} and τ_2 = {ϕ, X, {a}, {a, b, c}}. Then the sets in {ϕ, X, {a},{b}, {a, b}, {a, b, c}}are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d},{c, d}, {a, c, d}, {b, c, d}}are called $\tau_{1,2}$-closed. Let σ_1 = {ϕ, Y, {a, d}} and σ_2 = {ϕ, Y, {a, b, d}}. Then the sets in {ϕ, Y, {a, d}, {a, b, d}}are called $\sigma_{1,2}$-open and the sets in {ϕ, Y, {c},{b, c}} are called $\sigma_{1,2}$-closed. Also, the sets in {ϕ, X, {d},{a, b}, {c, d}, {a, b, c}, {a, b, d}, {a, c, d}, {b, c, d}} are called (1, 2)*-rω-closed and the sets in {ϕ, X, {c},{d}, {a, c}, {b, c}, {c, d}, {a, d}, {b, d}, {a, b, c}, {a, b, d}, {a, c, d}, {b, c, d}} are called (1, 2)*- πg-closed in X. Define f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) by f(a) = a, f(b) = b, f(c) = c and f(d) = d. Then f is (1, 2)*- πg-continuous but not (1, 2)*-rω-continuous.

Remark: 3.24
The following diagram summarizes the above discussions.



Remark: 3.25
The following Example shows that the composition of two (1, 2)*-rω-continuous maps need not be a (1, 2)*-rω-continuous.

Example: 3.26
Let X = Y = Z= {a, b, c}, τ_1 = {ϕ, X, {b}}, τ_2 = {ϕ, X, {c}}, σ_1 = {ϕ, Y, {b}}, σ_2 = {ϕ, Y, {a, c}}, η_1 = {ϕ, Z, {a}} and η_2 = {ϕ, Z, {a, b}}. The map f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) defined as f(a) = b, f(b) = a, f(c) = c and the map g : (Y, σ_1, σ_2) → (Z, η_1, η_2) be an identity map are (1,2)*-rω-continuous but g ∘ f is not (1,2)*-rω-continuous, since $(g \circ f)^{-1}$ ({c}) = {c} is not (1,2)*-rω-closed set in X.

Result: 3.27 [31]
Every (1, 2)*-rω-continuous map is (1,2)*-rgα-continuous

4. (1,2)*- rω-IRRESOLUTE MAPPINGS:

Definition: 4.1
A map f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called

(i) (1, 2)*-rω-irresolute if the inverse image of every (1, 2)*-rω-closed set in Y is (1, 2)*-rω-closed in X.

(ii) (1, 2)*-rgα-irresolute if f^{-1}(V) is (1, 2)*-rgα-closed in X, for every (1, 2)*-rgα-closed V in Y.

Theorem: 4.2
Every (1, 2)*-rω-irresolute function is (1, 2)*-rω-continuous but not conversely.

Proof:
Assume that f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is (1,2)*-rω-irresolute and V is $\sigma_{1,2}$-closed set in Y. So it is (1, 2)*-rω-closed set in Y by Remark 2.12. By our assumption inverse image of V is a (1, 2)*-rω-closed set in X. Therefore, f is (1, 2)*-rω-continuous.

Example: 4.3
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. Let Y = {a, b, c}, σ_1 = {ϕ, Y, {a}, {a, b}} and σ_2 = {ϕ, Y}. Then the sets in {ϕ, X, {a}, {a, b}}are called $\sigma_{1,2}$-open and the sets in {ϕ, X, {c}, {b, c}}are called $\sigma_{1,2}$-closed. Then the map f : X → Y defined as f(a) = b, f(b) = a and f(c) = c is (1,2)*-rω-continuous but not (1,2)*-rω-irresolute because f^{-1}({b}) = {a} is not an (1,2)*-rω-closed set in X.

Theorem: 4.4
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 any two maps. Then g ∘ f is (1, 2)*-rω-continuous if g is (1, 2)*-continuous and f is (1,2)*-rω-continuous.

Proof:
Let V be any $\eta_{1,2}$-closed set in Z. Then g^{-1}(V) is $\sigma_{1,2}$-closed in Y, since g is (1,2)*-continuous. Then $f^{-1}(g^{-1}(V))$ is (1, 2)*-rω-closed in X, as f is (1, 2)*-rω-continuous. That is, $(g \circ f)^{-1}$(V) is (1, 2)*-rω-closed in X. Hence g ∘ f is (1, 2)*-rω-continuous.

Theorem: 4.5
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 any two maps. Then g ∘ f is (1, 2)*-rω-irresolute if g is (1, 2)*-rω-irresolute and f is (1,2)*-rω-irresolute.

Proof:
Let V be any (1, 2)*-rω-closed set in Z. Since g is (1, 2)*-rω-irresolute, g^{-1}(V) is (1,2)*-rω-closed in Y. Then $f^{-1}(g^{-1}(V))$ = $(g \circ f)^{-1}$(V) is (1, 2)*-rω-closed in X, as f is (1, 2)*-rω-irresolute. Therefore, g ∘ f is (1, 2)*-rω-irresolute.

Theorem: 4.6
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 any two maps. Then g ∘ f is (1, 2)*-rω-continuous if g is (1, 2)*-rω-continuous and f is (1, 2)*-rω-irresolute.

Proof:
Let V be any $\eta_{1,2}$-closed set in Z. Since g is (1, 2)*-rω-continuous, g^{-1}(V) is (1, 2)*-rω-closed in Y.
Then $f^{-1}(g^{-1}(V))$ = $(g \circ f)^{-1}$(V) is (1, 2)*-rω-closed in X, as f is (1,2)*-rω-irresolute. Therefore, g ∘ f is (1, 2)*-rω-continuous.

5. (1,2)*-rω-HOMEOMORPHISMS:

We introduce the following definitions.

Definition: 5.1
A bijection f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called (1,2)*-rω-homeomorphism if both f and f^{-1} are (1,2)*-rω-continuous.

Definition: 5.2
A bijection f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called
(i) (1,2)*-regular generalized α-homeomorphism (briefly, (1, 2)*-rgα-homeomorphism) if f and f^{-1} are (1,2)*-rgα-continuous.

(ii) (1, 2)*-rwg-homeomorphism if both f and f^{-1} are (1,2)*- rwg-continuous.

Definition: 5.3
A bijection f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called (1,2)*-ω*-homeomorphism if both f and f^{-1} are (1,2)*-ω-irresolute.

Definition: 5.4
(i) A bijection f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called (1, 2)*-rgαc-homeomorphism if both f and f^{-1} are (1,2)*-rgα-irresolute.

(ii) A bijection f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) is called (1, 2)*-rωc-homeomorphism if both f and f^{-1} are (1,2)*-rω-irresolute.

Example 5.5
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d}, {c, d}, {a, c, d}, {b, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, 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, d}, {a, c, d}, {b, c, d}} are called $\sigma_{1,2}$-closed. If the map f : X → Y is an identity map, then f is bijective, (1,2)*-rω-continuous and f^{-1} is (1,2)*-rω-continuous. Therefore f is (1,2)*-rω-homeomorphism.

Theorem: 5.6
Every (1, 2)*-homeomorphism is an (1, 2)*-rω-homeomorphism.

Proof:
Let f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) be a (1,2)*-homeomorphism. Then f and f^{-1} are (1, 2)*-continuous and f is bijection. As every (1, 2)*-continuous map is (1, 2)*-rω-continuous, we have f and f^{-1} are (1, 2)*-rω-continuous. Therefore f is (1, 2)*-rω-homeomorphism.

Remark: 5.7
The converse of Theorem 5.6 need not be true as shown in the following example.

Example: 5.8
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d}, {c, d}, {a, c, d}, {b, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, 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, d}, {a, c, d}, {b, c, d}} are called $\sigma_{1,2}$-closed.If the map f : X → Y is an identity map, then f is (1,2)*-rω-homeomorphism but it is not (1,2)*-homeomorphism.

Theorem: 5.9
Every (1, 2)*-ω-homeomorphism is an (1, 2)*-rω- homeomorphism.

Proof:
Let f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) be a (1,2)*-ω-homeomorphism. Then f and f^{-1} are (1, 2)*-ω-continuous and f is bijection. As every (1, 2)*-ω-continuous map is (1, 2)*-rω-continuous, we have f and f^{-1} are (1, 2)*-rω-continuous. Therefore f is (1, 2)*-rω-homeomorphism.

Remark: 5.10
The converse of Theorem 5.9 need not be true as shown in the following example.

Example: 5.11
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d}, {c, d}, {a, c, d}, {b, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, 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, d}, {a, c, d}, {b, c, d}} are called $\sigma_{1,2}$-closed. If the map f : X → Y is the identity map, then this map is (1,2)*-rω-homeomorphism but it is not (1,2)*-ω-homeomorphism.

Theorem 5.12
Every (1, 2)*-rω-homeomorphism is an (1, 2)*-rgα-homeomorphism.

Proof:
Let f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) be a (1,2)*-rω-homeomorphism. Then f and f^{-1} are (1, 2)*-rω-continuous and f is bijection. As every (1, 2)*-rω-continuous map is (1,2)*-rgα-continuous, we have f and f^{-1} are (1,2)*- rgα-continuous. Therefore f is (1, 2)*- rgα-homeomorphism.

Remark: 5.13
The converse of Theorem 5.12 need not be true as shown in the following example.

Example: 5.14
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d}, {c, d}, {a, c, d}, {b, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, 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, d}, {a, c, d}, {b, c, d}} are called $\sigma_{1,2}$-closed. If the map f : X → Y is the identity map, then the map is (1,2)*-rgα-homeomorphism but it is not (1,2)*-rω-homeomorphism.

Corollary: 5.15
Every (1, 2)*-ω*-homeomorphism is an (1, 2)*-rω-homeomorphism.

Proof:
It is evident that every (1,2)*-ω*-homeomorphism is a (1,2)*-ω-homeomorphism. By Theorems 5.9 and 5.12., every (1,2)*-ω-homeomorphism is a (1,2)*-rgα-homeomorphism and hence (1,2)*-ω*-homeomorphism is a (1,2)*-rgα-homeomorphism.

Theorem: 5.16
Every (1, 2)*-rω-homeomorphism is an (1, 2)*-rwg-homeomorphism.

Proof:
Let f : (X, τ_1, τ_2) → (Y, σ_1, σ_2) be (1,2)*-rω-homeomorphism. Then f and f^{-1} are (1, 2)*-rω-continuous and f is bijection. Since every (1,2)*-rω-continuous map is (1,2)*-rwg-continuous, we have f and f^{-1} and (1,2)*-rwg-continuous. Therefore f is (1, 2)*-rwg-homeomorphism.

Remark: 5.17
The converse of Theorem 5.16 need not be true as shown in the following example.

Example: 5.18
Let X = {a, b, c, d}, τ_1 = {ϕ, X, {a}} and τ_2 = {ϕ, X, {b}, {a, b, c}}. Then the sets in {ϕ, X, {a}, {b}, {a, b}, {a, b, c}} are called $\tau_{1,2}$-open and the sets in {ϕ, X, {d}, {c, d}, {a, c, d}, {b, c, d}} are called $\tau_{1,2}$-closed. Let Y = {a, b, c, d}, 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. If the map f : X → Y is defined as f(a) =c, f(b) = b, f(c) = a and f(d) = d, then f is rwg-homeomorphism but it is not rω-homeomorphism.

Remark: 5.19
The concepts of

(i) (1, 2)*-rωc-homeomorphisms and ω*-homeomorphisms are independent.

(ii) (1, 2)*-rω-homeomorphisms and (1, 2)*-g-homeomorphisms are independent.

Example: 5.20
In Example 5.18, if the map f : X → Y is an identity map, then f is (1,2)*-ω*-homeomorphism but it is not (1,2)*-rωc-homeomorphism, since f is not (1,2)*-rω-irresolute.

Example: 5.21
In Example 5.18, if the map f : X → Y is an identity map, then f is (1,2)*-rωc-homeomorphism but it is not (1,2)*-ω*-homeomorphism, since f is not (1,2)*-ω-irresolute.

Example: 5.22
In Example 5.18, if the map f : X → Y is defined as f(a) =c, f(b) = b, f(c) = a and f(d) = d, then f is (1,2)*-rω-homeomorphism but it is not (1,2)*-g-homeomorphism.

Example: 5.23
In Example 5.18, if the map f : X → Y is defined as f(a) =c, f(b) = b, f(c) = a and f(d) = d, then f is (1,2)*-g-homeomorphism but it is not (1,2)*-rω-homeomorphism.

Theorem: 5.24
Every (1, 2)*-rωc-homeomorphism is an (1, 2)*-rω-homeomorphism.

Proof:
Let f : $(X, \tau_1, \tau_2) \to (Y, \sigma_1, \sigma_2)$ be an (1,2)*-rωc-homeomorphism. Then f and f^{-1} are (1, 2)*-rω-irresolute and f is bijection. By Theorem 4.2 f and f^{-1} are (1, 2)*-rω-continuous. Therefore f is (1, 2)*-rω-homeomorphism.

Remark: 5.25
The converse of Theorem 5.24 need not be true as shown in the following example.

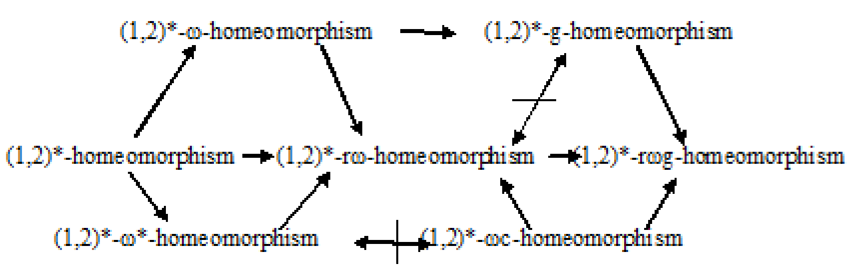
Example: 5.26
In Example 5.18, if the map f : X → Y is the identity map, then f is (1,2)*-rω-homeomorphism but it is not (1,2)*-rωc-homeomorphism, since f is not (1,2)*-rω-irresolute.

Theorem: 5.27
Every (1,2)*-rωc-homeomorphism is (1,2)*-rwg-homeomorphism.

Proof:
Proof follows from Theorems 5.16. and 5.24.

Example: 5.28
In Example 5.18, if the map f : X → Y is an identity map, then f is (1,2)*-rwg-homeomorphism but it is not (1,2)*-rωc-homeomorphism, since f is not (1,2)*-rω-irresolute.

Remark: 5.29
The following diagram summarizes the above discussions.



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