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On G*Bω - Closed Sets In Bitopological Spaces

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ABSTRACT : The aim of this paper is to introduce the concepts of closed sets in bitopological space called (i, j) - generalized star bω - closed sets, (i, j) - generalized star bω - open sets and study their basic properties.

KEYWORDS : (i, j) - generalized star bω - closed sets, (i, j) - generalized star bω - open sets.

I. INTRODUCTION

Generalized closed sets form a stronger tool in the characterization of bitopological spaces. The study of bitopological spaces was initiated by Kelly [8] and thereafter a large number of papers have been done to generalize the topological concepts to bitopological setting. Fukutake [5] introduced g - closed sets in bitopological spaces. Abo Khadra and Nasef [1] discussed b - open sets in bitopological spaces. Alswidi et al. [2] introduced a new notions on an ij - ω - closed sets in bitopological spaces.

In this paper, a new class of sets in bitopological spaces called (i, j) - g*bω - closed sets is introduced. A comparative study has been done with already existing closed sets and (i, j) - g*bω - closed sets.

II. PRELIMINARIES

A triple (X, τ_1, τ_2) where X is a non empty set and τ_1 and τ_2 are topologies on X is called a bitopological space. For a subset A of (X, τ_1, τ_2), the closure of A and the interior of A with respect to τ_i is denoted by i - cl(A) and i - int(A) respectively for i = 1, 2. The intersection of all τ_i - closed sets containing A is called i - cl(A). The union of all τ_i - open sets contained in A is i - int(A).

Definition 2.1 For i, j = 1, 2 and i ≠ j, a subset A of a bitopological space (X, τ_1, τ_2) is called

(i) **(i, j) - semi closed** (Maheswari et al., 1977 - 78) if j - int(i - cl(A)) ⊆ A.

(ii) **(i, j) - α - closed** [7] if i - cl(j - int(i - cl(A))) ⊆ A.

(iii) **(i, j) - pre closed** [7] if i - cl(j - int(A)) ⊆ A.

(iv) **(i, j) - regular closed** [4] if i - cl(j - int(A)) ⊆ A.

(v) **(i, j) - b - closed** [3] if (j - int(i - cl(A))) ∪ (i - cl(j - int(A))) ⊆ A.

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The complements of the above mentioned sets are called (i, j) - semi open, (i, j) - α - open, (i, j) - pre open, (i, j) - regular open and (i, j) - b - open sets respectively.

The intersection of all τ_j - semi closed (resp. τ_j - α - closed, τ_j - pre closed, τ_j - regular closed and τ_j - b - closed) subsets of (X, τ) containing A is called the τ_j - semi closure (resp. τ_j - α - closure, τ_j - pre closure, τ_j - regular closure and τ_j - b - closure) of A and is denoted by τ_j - scl(A) (resp. τ_j - αcl(A), τ_j - pcl(A), τ_j - rcl(A) and τ_j - bcl(A)).

Definition 2.2 For i, j = 1, 2 and i ≠ j, a subset A of a bitopological space (X, τ_1, τ_2) is called

(i) **(i, j) - generalized closed** (briefly, **(i, j) - g - closed**) [5] if τ_j - cl(A) ⊆ U whenever A ⊆ U and U is τ_i - open in X.

(ii) **(i, j) - regular generalized closed** (briefly, **(i, j) - rg - closed**) [3] if τ_j - cl(A) ⊆ U whenever A ⊆ U and U is τ_i - regular open in X.

(iii) **(i, j) - weakly generalized closed** (briefly, **(i, j) - wg - closed**) [6] if τ_j - cl(A)[τ_i - int(A)] ⊆ U whene1ver A ⊆ U and U is τ_i - open in X.

(iv) **(i, j) - generalized star closed** (briefly, **(i, j) - g* - closed**) [13] if τ_j - cl(A) ⊆ U whenever A ⊆ U and U is τ_i - g - open in X.

(v) **(i, j) - generalized** α **- closed** (briefly, **(i, j) - gα - closed**) [9] if τ_j - αcl(A) ⊆ U whenever A ⊆ U and U is τ_i - α - open in X.

(vi) **(i, j) - α - generalized closed** (briefly, **(i, j) - αg - closed**) [12] if τ_j - αcl(A) ⊆ U whenever A ⊆ U and U is τ_i - open in X.

(vii) **(i, j) - generalized star pre closed** (briefly, **(i, j) - g*p - closed**) [14] if τ_j - pcl(A) ⊆ U whenever A ⊆ U and U is τ_i - g - open in X.

(viii) **(i, j) - generalized star semi closed** (briefly, **(i, j) - g*s - closed**) [12] if τ_j - scl(A) ⊆ U whenever A ⊆ U and U is τ_i - gs - open in X.

(ix) **(i, j) - generalized # semi closed** (briefly, **(i, j) - g#s - closed**) [15] if τ_j - scl(A) ⊆ U whenever A ⊆ U and U is τ_i - αg - open in X.

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

III. (i, j) - g*bω - CLOSED SETS

In this section, the concept of (i, j) - g*bω - closed sets in bitopological spaces is defined and some of their characterizations and properties are studied.

Definition 3.1 A subset A of a bitopological space (X, τ_1, τ_2) is called ***(i, j) - generalized star b omega closed*** (briefly, **(i, j) - g*bω - closed**) if τ_j - bcl(A) ⊆ U whenever A ⊆ U and U is τ_i - gs - open in (X, τ_1, τ_2), where i, j = 1, 2 and i ≠ j.

The set of all (i, j) - g*bω - closed sets in (X, τ_1, τ_2) is denoted by G*bωC(i, j).

Remark 3.2 By setting $\tau_i = \tau_j$ in definition 3.1, an (i, j) - g*bω - closed set is a g*bω - closed set [11].

Example 3.3 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. Then φ, X, {b}, {c}, {b, c} are (1, 2) - g*bω - closed.

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Theorem 3.4 Every τ_j - closed (resp. τ_j - semi closed, τ_j - α - closed, τ_j - pre closed, τ_j - regular closed) set in (X, τ_1, τ_2) is (i, j) - g*bω - closed.

Proof: Let A be τ_j - closed (resp. τ_j - semi closed, τ_j - α - closed, τ_j - pre closed, τ_j - regular closed) in (X, τ_1, τ_2) such that A $\subseteq$ U, where U is τ_i - gs - open. Since A is τ_j - closed (resp. τ_j - semi closed, τ_j - α - closed, τ_j - pre closed, τ_j - regular closed), τ_j - cl(A) (resp. τ_j - scl(A), τ_j - αcl(A), τ_j - pcl(A), τ_j - rcl(A)) = A $\subseteq$ U. But τ_j - bcl(A) $\subseteq$ τ_j - cl(A) (resp. τ_j - scl(A), τ_j - αcl(A), τ_j - pcl(A), τ_j - rcl(A)). Therefore τ_j - bcl(A) $\subseteq$ U. Hence A is an (i, j) - g*bω - closed set in (X, τ_1, τ_2).

The converse of the above theorem is not true in general as can be seen from the following examples:

Example 3.5 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. The subsets {b} is (1, 2) - g*bω - closed but not τ_2 - closed.

Example 3.6 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a, b}} and τ_2 = {φ, X, {a}}. The subsets {a, c} is (1, 2) - g*bω - closed but not τ_2 - semi closed.

Example 3.7 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {a, b}} and τ_2 = {φ, X, {a}, {b}, {a, b}}. The subsets {a}, {b} are (1, 2) - g*bω - closed but not τ_2 - α - closed, not τ_2 - pre closed and not τ_2 - regular closed.

Theorem 3.8 Every (i, j) - g*s - closed set in (X, τ_1, τ_2) is (i, j) - g*bω - closed.

Proof: Let A $\subseteq$ U and U be τ_i - gs - open in (X, τ_1, τ_2). Since A is (i, j) - g*s - closed in (X, τ_1, τ_2), τ_j - scl(A) $\subseteq$ U. But τ_j - bcl(A) $\subseteq$ τ_j - scl(A) $\subseteq$ U. Therefore A is (i, j) - g*bω - closed.

The converse of the above theorem is not true in general as can be seen from the following example:

Example 3.9 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}} and τ_2 = {φ, X, {a}, {b, c}}. The subsets {b}, {c}, {a, b} and {a, c} are (1, 2) - g*bω - closed but not (1, 2) - g*s - closed.

Remark 3.10 The following examples show that (i, j) - g*bω - closed set is independent from (i, j) - semi closed set, (i, j) - α - closed set and (i, j) - pre closed set.

Example 3.11 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}}. The subset {a, c} is (1, 2) - semi closed, (1, 2) - α - closed and (1, 2) - pre closed but not (1, 2) - g*bω - closed.

Example 3.12 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a, b}} and τ_2 = {φ, X, {a}}. The subset {a, c} is (1, 2) - g*bω - closed but not (1, 2) - semi closed, not (1, 2) - α - closed and not (1, 2) - pre closed.

Remark 3.13 The following examples show that (i, j) - g*bω - closed set is independent from (i, j) - regular closed set and (i, j) - g - closed set, (i, j) - wg - closed.

Example 3.14 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. The subset {a, c} is (1, 2) - regular closed and (1, 2) - g - closed (1, 2) - wg - closed but not (1, 2) - g*bω - closed.

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Example 3.15 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. The subset {b} is (1, 2) - g*bω - closed but not (1, 2) - regular closed and not (1, 2) - g – closed, not (1, 2) - wg - closed.

Remark 3.16 The following examples show that (i, j) - g*bω - closed set is independent from (i, j) - rg - closed set and (i, j) - g* - closed set.

Example 3.17 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}}. The subset {a, c} is (1, 2) - rg - closed (1, 2) - g* - closed but not (1, 2) - g*bω - closed.

Example 3.18 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}}. The subset {b} is (1, 2) - g*bω - closed but not (1, 2) - rg - closed, not (1, 2) - g* - closed.

Remark 3.19 The following examples show that (i, j) - g*bω - closed set is independent from (i, j) - gα - closed set and (i, j) - g*p - closed set.

Example 3.20 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}}. The subset {a, c} is (1, 2) - gα - closed and (1, 2) - g*p - closed but not (1, 2) - g*bω - closed.

Example 3.21 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {a, b}} and τ_2 = {φ, X, {a}, {b}, {a, b}}. The subsets {a}, {b} are (1, 2) - g*bω - closed but not (1, 2) - gα - closed and not (1, 2) - g*p - closed.

Remark 3.22 The following examples show that the concepts (i, j) - αg - closed set and (i, j) - g*bω - closed set are independent.

Example 3.23 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. The subset {a, c} is (1, 2) - αg - closed but not (1, 2) - g*bω - closed.

Example 3.24 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {a, b}} and τ_2 = {φ, X, {a}, {b}, {a, b}}. The subsets {a}, {b} are (1, 2) - g*bω - closed but not (1, 2) - αg - closed.

Remark 3.25 The following examples show that the concepts (i, j) - $g^{\#}s$ - closed set and (i, j) - g*bω - closed set are independent.

Example 3.26 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. The subset {a, c} is (1, 2) - $g^{\#}s$ - closed but not (1, 2) - g*bω - closed.

Example 3.27 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}} and τ_2 = {φ, X, {a}, {b, c}}. The subsets {b}, {c}, {a, b} and {a, c} are (1, 2) - g*bω - closed but not (1, 2) - $g^{\#}s$ - closed.

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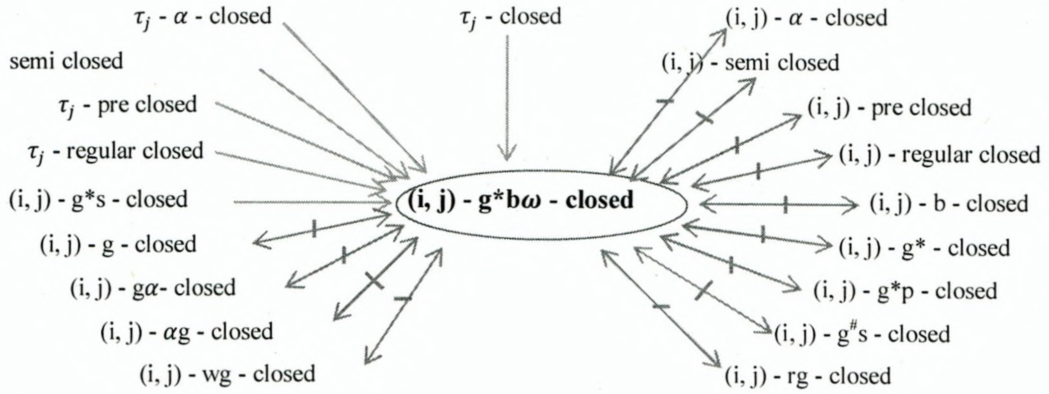
The following diagram shows the relationships of (i, j) - g*bω - closed sets with other sets:



where A $\longrightarrow$ B represents A implies B and A $\leftrightarrow$ B represents A and B are independent.

Remark 3.28 Union of two (i, j) - g*bω - closed sets need not be (i, j) - g*bω - closed as can be seen from the following example:

Example 3.29 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {a, b}} and τ_2 = {φ, X, {a}, {b}, {a, b}}. Let A = {a} and B = {b}. Then A ∪ B = {a, b} is not (1, 2) - g*bω - closed but A = {a} and B = {b} are (1, 2) - g*bω - closed.

Remark 3.30 Difference of two (i, j) - g*bω - closed sets need not be (i, j) - g*bω - closed set as can be seen from the following example:

Example 3.31 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a, b}} and τ_2 = {φ, X, {a}}. Let A = {a, c} and B = {c}. Then A and B are (1, 2) - g*bω - closed but A \ B = {a} is not (1, 2) - g*bω - closed.

Theorem 3.32 If a subset A of a bitopological space (X, τ_1, τ_2) is (i, j) - g*bω - closed then τ_j - bcl(A) \ A contains no nonempty τ_i - gs - closed set.

Proof: Let A be an (i, j) - g*bω - closed set and F be a τ_i - gs - closed set such that F ⊆ τ_j - bcl(A) \ A. Therefore A ⊆ F^c and F ⊆ τ_j - bcl(A). Since F^c is τ_i - gs - open and A is (i, j) - g*bω - closed, τ_j - bcl(A) ⊆ F^c. Thus F ⊆ [τ_j - bcl(A)]^c = X \ [τ_j - bcl(A)]. Hence F ⊆ [τ_j - bcl(A)] ∩ [X \ [τ_j - bcl(A)]] = φ. Therefore F = φ. Hence τ_j - bcl(A) \ A contains no nonempty τ_i - gs - closed set.

Theorem 3.33 Let A be an (i, j) - g*bω - closed set in (X, τ_1, τ_2). Then A is τ_j - b - closed if and only if τ_j - bcl(A) \ A is τ_i - gs - closed in (X, τ_1, τ_2).

Proof: Suppose that A is (i, j) - g*bω - closed. Let A be τ_j - b - closed. Then τ_j - bcl(A) = A. Therefore τ_j - bcl(A) \ A = φ is τ_i - gs - closed in (X, τ_1, τ_2).

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Conversely, suppose that A is (i, j) - g*bω - closed and τ_j - bcl(A) \ A is τ_i - gs - closed. Since A is (i, j) - g*bω - closed, τ_j - bcl(A) \ A contains no nonempty τ_i - gs - closed set (by Theorem 3.32). Since τ_j - bcl(A) \ A is τ_i - gs - closed, τ_j - bcl(A) \ A = φ. Then τ_j - bcl(A) = A. Hence A is τ_j - b - closed.

Theorem 3.34 Let A and B be subsets of (X, τ_1, τ_2) such that $A \subseteq B \subseteq \tau_j$ - bcl(A). If A is (i, j) - g*bω - closed then B is (i, j) - g*bω - closed.

Proof: Let A and B be subsets such that $A \subseteq B \subseteq \tau_j$ - bcl(A). Suppose that A is (i, j) - g*bω - closed. Let B ⊆ U and U be τ_i - gs - open in (X, τ_1, τ_2). Then A ⊆ U. Since A is (i, j) - g*bω - closed, τ_j - bcl(A) ⊆ U. Since $B \subseteq \tau_j$ - bcl(A), τ_j - bcl(B) $\subseteq \tau_j$ - bcl[τ_j - bcl(A)] = τ_j - bcl(A) ⊆ U. Therefore B is (i, j) - g*bω - closed.

Remark 3.35 In general an (i, j) - g*bω - closed set need not be equal to an (j, i) - g*bω - closed set.

Example 3.36 consider X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {a, b}} and τ_2 = {φ, X, {a}, {b}, {a, b}}. Then the subsets {a} and {a, c} are (1, 2) - g*bω - closed but not (2, 1) - g*bω - closed.

Theorem 3.37 If $\tau_1 \subseteq \tau_2$ in (X, τ_1, τ_2) then G*bωC(2, 1) ⊆ G*bωC(1, 2).

Proof: Let A ∈ G*bωC(2, 1). Let U ∈ GSO(X, τ_1) such that A ⊆ U. Since GSO(X, τ_1) ⊆ GSO(X, τ_2), U ∈ GSO(X, τ_2). Since A is (2, 1) - g*bω - closed, τ_1 - bcl(A) ⊆ U. Since $\tau_1 \subseteq \tau_2$, τ_2 - bcl(A) $\subseteq \tau_1$ - bcl(A). Thus τ_2 - bcl(A) ⊆ U. Hence A is (1, 2) - g*bω - closed. That is, A ∈ G*bωC(1, 2).

The converse of the above theorem need not be true as seen from the following example:

Example 3.38 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {b}, {a, b}} and τ_2 = {φ, X, {a}, {a, b}}. Then G*bωC(2, 1) ⊆ G*bωC(1, 2) but $\tau_1 \nsubseteq \tau_2$.

IV. (i, j) - g*bω - OPEN SETS

In this section, (i, j) - g*bω - open sets in bitopological spaces is introduced and their properties are studied.

Definition 4.1 A set A of a bitopological space (X, τ_1, τ_2) is called ***(i, j) - generalized star b omega open*** (briefly, **(i, j) - g*bω - open**) if its complement is (i, j) - g*bω - closed.

The set of all (i, j) - g*bω - open sets in (X, τ_1, τ_2) is denoted by G*bωO(i, j).

Theorem 4.2 A subset A of a bitopological space (X, τ_1, τ_2) is (i, j) - g*bω - open if and only if $F \subseteq \tau_j$ - bint(A) whenever F ⊆ A and F is τ_i - gs - closed in (X, τ_1, τ_2).

Proof: Suppose that A is (i, j) - g*bω - open. Let F ⊆ A and F be τ_i - gs - closed. Then $A^c \subseteq F^c$ and F^c is τ_i - gs - open. Since A^c is (i, j) - g*bω - closed, τ_j - bcl(A^c) ⊆ F^c. Since τ_j - bcl(A^c) = [τ_j - bint(A)]^c, [τ_j - bint(A)]$^c \subseteq F^c$. Hence $F \subseteq \tau_j$ - bint(A).

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Conversely, suppose that F $\subseteq \tau_j$ - bint(A) whenever F $\subseteq$ A and F is τ_i - gs - closed in (X, τ_1, τ_2). Let U be τ_i - gs - open in (X, τ_1, τ_2) and $A^c \subseteq$ U. Then U^c is τ_i - gs - closed and $U^c \subseteq$ A. Hence by assumption $U^c \subseteq \tau_j$ - bint(A). That is τ_j - bcl(A^c) $\subseteq$ U. Therefore A^c is (i, j) - g*bω - closed. Hence A is (i, j) - g*bω - open.

Theorem 4.3 If a subset A is (i, j) - g*bω - closed in (X, τ_1, τ_2) then τ_j - bcl(A) \ A is (i, j) - g*bω - open.

Proof: Suppose that A is (i, j) - g*bω - closed in (X, τ_1, τ_2). Let F $\subseteq \tau_j$ - bcl(A) \ A and F be τ_i - gs - closed. Since A is (i, j) - g*bω - closed, τ_j - bcl(A) \ A does not contain nonempty τ_i - gs - closed sets (by Theorem 3.32). Hence F = φ. Thus F $\subseteq \tau_j$ - bint[τ_j - bcl(A) \ A]. Hence τ_j - bcl(A) \ A is (i, j) - g*bω - open.

Theorem 4.4 If a set A is (i, j) - g*bω - open in (X, τ_1, τ_2) then G = X whenever G is τ_i - gs - open and τ_j - bint(A) ∪ A^c $\subseteq$ G.

Proof: Suppose that A is (i, j) - g*bω - open in (X, τ_1, τ_2), G is τ_i - gs - open and τ_j - bint(A) ∪ $A^c \subseteq$ G. Then $G^c \subseteq$ {τ_j - bint(A) ∪ A^c}^{c} = τ_j - bcl(A^c) \ A^c. Since A^c is (i, j) - g*bω - closed, τ_j - bcl(A^c) \ A^c contains no nonempty τ_i - gs - closed set in (X, τ_1, τ_2) (by Theorem 3.32). Therefore G^c = φ. Hence G = X.

Remark 4.5 The converse of the above theorem is not true in general as can be seen from the following example:

Example 4.6 Let X = {a, b, c} with the topologies τ_1 = {φ, X, {a}, {a, b}} and τ_2 = {φ, X, {a}, {b}, {a, b}}. Let A = {c} and G = X. Then G is τ_1 - gs - open, τ_2 - bint(A) ∪ A^c = φ ∪ {a, b} = {a, b} $\subseteq$ G, but A = {c} is not (1, 2) - g*bω - open.

Theorem 4.7 Let (X, τ_1, τ_2) be a bitopological space. If x ∈ X then singleton {x} is either τ_i - gs - closed or (i, j) - g*bω - open.

Proof: Let x ∈ X and suppose that {x} is not τ_i - gs - closed. Then X \ {x} is not τ_i - gs -open. Consequently, X is the only τ_i - gs - open set containing the set X \ {x}. Therefore X \ {x} is (i, j) - g*bω - closed. Hence {x} is (i, j) - g*bω - open.

V. CONCLUSION

In this research, we introduce the concept of g*bω - continuous, closed maps in these spaces and present some results.

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