"Strongly g, g*, g** Closed Sets In Bitopological Space"

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Abstract

In this paper we introduce strongly g, g*, g** closed sets in bitopological spaces. Properties of these sets are investigated and we introduce six new spaces namely (i, j)- $T_{1/2s}$ space, (i, j)- $T_{1/2s}{}^{*}$ space, (i, j)- $T_{1/2s}{}^{**}$ space, (i, j)- ${}^{*}T_{1/2s}$ space, (i, j)- ${}^{**}T_{1/2s}$ space, (i, j)- ${}^{*}T_{1/2s}{}^{*}$ space.

Key words: (i, j)- strongly g closed sets, (i, j)- strongly g* closed sets and (i, j)- strongly g** closed sets.

1.INTRODUCTION

A triple (X, τ_1, τ_2) where X is a non-empty set and τ_1, τ_2 are topologies in X is called a bitopological space and Kelley[5] initiated the study of such spaces. In 1985, Fukutake[2] introduced the concepts of g-closed sets in bitopological spaces. M.K.R.S. Veerakumar[11] introduced and studied the concepts of g*-closed sets and g*-continuity in topological spaces. Sheik John. M and sundaram. P [10] introduced and studied the concepts of g*-closed sets in bitopological spaces in 2002. The purpose of this paper is to introduce the concept of strongly g, g*, g** closed sets in bitopological spaces. Six new spaces namely, (i, j) - $T_{1/2s}$ space, (i, j) - $T_{1/2s}{}^{*}$ space, (i, j) - $T_{1/2s}{}^{**}$ space, (i, j) - ${}^{*}T_{1/2s}$ space, (i, j) - ${}^{**}T_{1/2s}$ & (i, j) - ${}^{*}T_{1/2s}{}^{*}$ space in bitopological spaces are introduced and some of their properties are investigated.

2.PRELIMINARIES

Throughtout this paper (X ,τ) represents non-empty topological space on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X ,τ), cl(A) and int(A) denote the closure and the interior of A respectively.

Definition2.1: A subset A of a topological space (X, τ) is said to be

1. a semi open set [6] if $A \subseteq cl(\text{int}(A))$ and semi closed set if $\text{int}(clA)) \subseteq A$.
2. a regular open set [6] if $A = \text{int}(cl(A))$.
3. a generalized closed set (briefly g-closed) [7] if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in (X, τ).
4. a generalized star closed set (briefly g*-closed set) [12] if $cl(A) \subseteq U$, whenever $A \subseteq U$ and is g open in (X, τ).
5. a generalized star star closed set (briefly g**-closed) [8] if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is g* open in (X, τ).

6. a strongly generalized closed set (briefly sg-closed) [9] if $cl(\text{int}(A)) \subseteq U$, whenever $A \subseteq U$ and U is open in (X, τ).
7. a strongly generalized star closed set (briefly sg*-closed) [13] if $cl(\text{int}(A) \subseteq U$, whenever $A \subseteq U$ and U is g open in (X, τ).
8. a strongly generalized star star closed set (briefly sg**-closed) [9] if $cl(\text{int}(A) \subseteq U$, whenever $A \subseteq U$ and U is g open in (X, τ).

Definition 2.2: A subset A of a bitopological space (X, τ_1, τ_2) is called

1. an (i, j)-g closed [2] if $\tau_j - cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in τ_i.
2. an (i, j)-g* closed [10] if $\tau_j - cl(A) \subseteq U$, whenever $A \subseteq U$ and U is g open in τ_i.
3. an (i, j)-g**closed [8] if $\tau_j - cl(A) \subseteq U$, whenever $A \subseteq U$ and U is g* open in τ_i.
4. an (i, j)-rg closed [1] if $\tau_j - cl(A) \subseteq U$, whenever $A \subseteq U$ and U is regular open in τ_i.

Definition 2.3: A bitopological space (X, τ_1, τ_2) is called

1. an (i, j)- $T_{1/2}$ space [2] if every (i, j)-g closed set is τ_j-closed.
2. an (i, j)- $T_{1/2}$ *space [10] if every (i, j)-g* closed set is τ_j-closed.
3. an (i, j)- $T_{1/2}$ **space [8] if every (i, j)-g** closed set is τ_j-closed.

3. (i, j)-strongly g, g*, g** closed sets

In this section we introduce the concept of (i, j)-strongly g, g*, g** closed sets in bitopological spaces.

Definition 3.1: A subset A of a bitopological space (X, τ_1, τ_2) is called (i, j)-strongly g closed if $\tau_j - cl(\text{int}(A) \subseteq U$, whenever $A \subseteq U$ and U is open in τ_i.

Definition 3.2: A subset A of a bitopological space (X, τ_1, τ_2) is called (i, j)-strongly g* closed if $\tau_j - cl(\text{int}(A) \subseteq U$, whenever $A \subseteq U$ and U is g open in τ_i.

Definition 3.3: A subset A of a bitopological space (X, τ_1, τ_2) is called (i, j)-strongly g** closed if $\tau_j - cl(\text{int}(A) \subseteq U$, whenever $A \subseteq U$ and U is g* open in τ_i.

Remark 3.4:

(i) By setting $\tau_1 = \tau_2$ in definition (4.1), a (i, j)-strongly g closed set is a strongly g closed set.

(ii) By setting $\tau_1 = \tau_2$ in definition (4,2), a (i, j)-strongly g^* closed set is a strongly g^* closed set.

(iii) By setting $\tau_1 = \tau_2$ in definition (4.3), a (i, j)-strongly g^{**} closed set is a strongly g^{**} closed set.

Theorem 3.5: Every τ_j-closed set is (i, j)-strongly g closed.

Proof: let A be τ_j-closed. Since A is τ_j-closed, $\tau_j - cl(A) = A$ .let $A \subseteq U$ and U be τ_i-open. $\tau_j - cl(\text{int}(A)) \subseteq \tau_j - cl(A) = A \subseteq U$. Therefore A is (i, j)-strongly g closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.6: Let X= {a, b, c}, τ_1= {Φ, {c}, {a, c}, X} and τ_2={Φ, {a}, X}. Then the set A= {b} is (i, j)-strongly g closed but not τ_j-closed in (X, τ_1, τ_2).

Theorem 3.7: Every τ_j-closed set is (i, j)-strongly g*closed.

proof follows from the definition.

The converse of the above theorem is not true as seen in the following example.

Example 3.8: In example (3.6), A={a, b} is (i, j)-strongly g* closed but not τ_j -closed.

Theorem 3.9: Every τ_j-closed set is (i, j)-strongly g** closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.10: in example (3.6), A= {b} is (i, j)-strongly g**closed but not τ_j-closed.

Theorem 3.11: Every (i, j)-g closed set is (i, j)-strongly g closed.

Proof: Let A be (i, j)-g closed. Let $A \subseteq U$ and U be τ_i-open. Since A is (i, j)-g closed, $\tau_j - cl(A) \subseteq U$.$\therefore$ $\tau_j - cl(\text{int}(A)) \subseteq \tau_j - cl(A) \subseteq U$. Hence A is (i, j)-strongly g closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.12: Let X= {a, b, c}, τ_1={ Φ, {a}, {b}, {a, b}, X} and τ_2={Φ, {a}, {a, b}, X}. Then the set A= {b} is (i, j)-strongly g closed but not (i, j)-g closed.

Theorem 3.13: Every (i, j)-g* closed set is (i, j)-strongly g* closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.14: In example (3.6), A= {c} is (i, j)-strongly g* closed but not a (i, j)-g* closed set.

Theorem 3.15: Every (i, j)-g** closed set is (i, j)-strongly g** closed.

proof follows from the definition.

The converse of the above theorem is not true as seen in the following example.

Example 3.16: let X= {a, b, c}, τ_1= {Φ, {b}, X} and τ_2= {Φ, {c}, X}. Then A= {b} is (i, j)-strongly g** closed but not (i, j)-g** closed.

Theorem 3.17: Every (i, j)-strongly g* closed set is (i, j)-strongly g closed.

Proof: Let A be (i, j)-strongly g* closed. Let $A \subseteq U$ and U be τ_i-open. Then $A \subseteq U$ and U is τ_i-g open. Since A is (i, j)-strongly g* closed, $\tau_j - cl(\text{int}(A)) \subseteq U$. Therefore A is (i, j)-strongly g closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.18: let X= {a, b, c}, τ_1= {Φ, {a}, X} and τ_2= {Φ, {a}, {a, b}, X}. Then A= {a, c} is (i, j)-strongly g closed but not (i, j)-strongly g* closed.

Theorem 3.19: Every (i, j)-strongly g** closed set is (i, j)-strongly g closed.

proof follows from the definition.

Theorem 3.20: Every (i, j)-strongly g* closed set is (i, j)-strongly g** closed.

Proof: Let A be (i, j)-strongly g*closed set. Let $A \subseteq U$ and U is τ_i-g*open. Then $A \subseteq U$ and U is τ_i-g open. Since A is (i, j)-strongly g* closed, $\tau_j - cl(\text{int}(A)) \subseteq U$. Therefore A is (i, j)-strongly g**closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.21: Let X= {a, b, c}, τ_1={Φ, {c}, X} and τ_2={Φ, {a}, X}. Then A={a} is (i, j)-strongly g**closed but not (i, j)-strongly g*closed set.

Theorem 3.22: If A is both τ_i -open and (i, j)-strongly g*closed in (X, τ_1, τ_2) , then it is (i, j)-regular closed in (X, τ_1, τ_2) .

Proof: Let A be both τ_i-open and (i, j)-strongly g*closed. Since A is open, $\tau_j - \text{int}(A) = A$. A is τ_i-open $\Rightarrow$ A is τ_i-g open. (i.e.,) $A \subseteq A$,where A is τ_i-g open. Since A is (i, j)-strongly g* closed, $\tau_j - cl(\text{int}(A)) \subseteq A$------ (1).

$A \subseteq \tau_j - cl(A) = \tau_j - cl(\text{int}(A))$.$\therefore$ $A \subseteq \tau_j - cl(\text{int}(A))$ ----------- (2). By (1) & (2)

$A = \tau_j - cl(\text{int}(A))$ and hence A is regular closed in (X, τ_1, τ_2) .

Theorem 3.23: If a subset A of a bitopological space (X, τ_1, τ_2) is both (i, j)-strongly g* closed and τ_j-semi open, then it is (i, j)-g* closed.

Proof : Let A be both (i, j)-strongly g* closed and τ_j-semi open. Let $A \subseteq U$ and U be τ_i-g open. Since A is (i, j)-strongly g* closed, $\tau_j - cl(\text{int}(A)) \subseteq U$. Since A is τ_j-semi open, $A \subseteq \tau_j - cl(\text{int}(A))$.
Then, $\tau_j - cl(A) \subseteq \tau_j - cl(cl(\text{int}(A))) = \tau_j - cl(\text{int}(A)) \subseteq U$. Therefore A is (i, j)-g* closed.

Theorem 3.24: If A is both (i, j)-strongly g closed and τ_j-open, then A is (i, j)-rg closed.

Proof: Let A be (i, j)-strongly g closed. Let $A \subseteq U$ and U be τ_i-regular open $\Rightarrow A \subseteq U$ and U is τ_i-open. Since A is (i, j)-strongly g closed, $\tau_j - cl(\text{int}(A)) \subseteq U$. $\tau_j - cl(A) = \tau_j cl(\text{int}(A)) \subseteq U$. Therefore A is (i, j)-rg closed.

Theorem 3.25: Every (i, j)-g* closed set is (i, j)-strongly g closed.

Proof: Let A be (i, j)-g* closed. Let $A \subseteq U$ and U is τ_i-open. Then $A \subseteq U$ and U is τ_i-g open. Since A is (i, j)-g* closed, $\tau_j - cl(A) \subseteq U$. $\tau_j - cl(\text{int}(A)) \subseteq \tau_j - cl(A) \subseteq U$. Therefore A is (i, j)-strongly g closed.

The converse of the above theorem is not true as seen in the following example.

Example 3.26: Let X= {a, b, c}, τ_1= {Φ, {a}, X} and τ_2={Φ, {c}, X}. Then A= {b} is (i, j)-strongly g closed but not (i, j)-g* closed.

Theorem 3.27: Every (i, j)-g* closed set is (i, j)-strongly g** closed.
proof follows from the definition.

The converse of the above theorem is not true as seen in the following example.

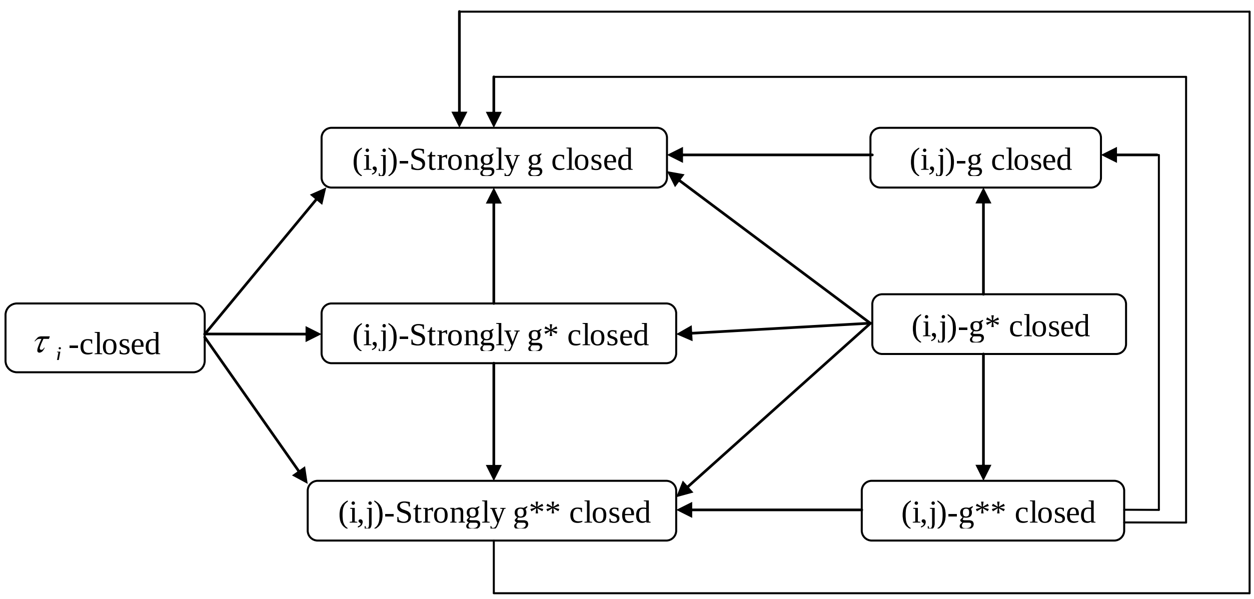
Example 3.28: let X= {a, b, c}, τ_1= {Φ, {b}, X} and τ_2={Φ, {a}, X}. Then A= {b} is (i, j)-strongly g** closed but not (i, j)-g* closed.

Theorem 3.29: Every (i, j)-g** closed set is (i, j)-strongly g closed.
proof follows from the definition.

The converse of the above theorem is not true as seen in the following example.

Example 3.30: Let X= {a, b, c}, τ_1={Φ, {a}, {b}, {a, b}, X} and τ_2={Φ, {a}, X}. Then A= {b} is (i, j)-strongly g closed but not (i, j)-g** closed.

The above results can be represented in the following figure.



where A $\rightarrow$ B represents A implies B but not conversely.

4. Applications of (i, j)-strongly g, g*, g** closed sets.

In this section we introduce six new spaces namely (i, j) - $T_{1/2s}$ space, (i, j) - $T_{1/2s}{}^{*}$ space, (i, j) - $T_{1/2s}{}^{**}$ space, (i, j) - ${}^{*}T_{1/2s}$ space, (i, j) - ${}^{**}T_{1/2s}$ & (i, j) - ${}^{*}T_{1/2s}{}^{*}$ space.

Definition 4.1: A bitopological space (X, τ_1, τ_2) is said to be an (i, j)- $T_{1/2s}$ space if every (i, j)-strongly g closed set is τ_j -closed.

Definition 4.2: A bitopological space (X, τ_1, τ_2) is said to be an (i, j)- $T_{1/2s}{}^{*}$ space if every (i, j)-strongly g*closed set is τ_j -closed.

Definition 4.3: A bitopological space (X, τ_1, τ_2) is said to be an (i, j)- $T_{1/2s}{}^{**}$ space if every (i, j)-strongly g**closed set is τ_j -closed.

Definition 4.4: A bitopological space (X, τ_1, τ_2) is said to be an (i, j)- ${}^{*}T_{1/2s}$ space if every (i, j)-strongly g closed set is (i, j)-strongly g* closed.

Definition 4.5: A bitopological space (X, τ_1, τ_2) is said to be an (i, j)- ${}^{**}T_{1/2s}$ space if every (i, j)-strongly g closed set is (i, j)-strongly g^{**} closed.

Definition 4.6: A bitopological space (X, τ_1, τ_2) is said to be an (i, j)- ${}^{*}T_{1/2s}{}^{*}$ space if every (i, j)-strongly g^{**} closed set is (i, j)-strongly g^{*} closed.

Theorem 4.7: Every (i, j)-$T_{1/2s}$ space is a (i, j)- $T_{1/2}$ space.

Proof: Let (X, τ_1, τ_2) be a (i, j)- $T_{1/2s}$ space. Let A be a (i, j)-g closed set. Then A is (i, j)-strongly g closed. $\therefore$ A is τ_j -closed since (X, τ_1, τ_2) is a (i, j)- $T_{1/2s}$ space. Therefore (X, τ_1, τ_2) is a (i, j)- $T_{1/2}$ space.

Theorem 4.8: Every (i, j)- $T_{1/2s}$ space is a (i, j)- $T_{1/2s}{}^{*}$ space.

Proof: Let (X, τ_1, τ_2) be a (i, j)- $T_{1/2s}$ space. Let A be a (i, j)-strongly g*closed set. Then A is (i, j)-strongly g closed & hence A is τ_j closed since (X, τ_1, τ_2) is a (i, j)- $T_{1/2s}$ space. Therefore (X, τ_1, τ_2) is a (i, j)- $T_{1/2s}{}^{*}$ space.

Theorem 4.9: Every (i, j)- $T_{1/2s}{}^{**}$ space is a (i, j)- $T_{1/2s}{}^{*}$ space.

proof: Let (X, τ_1, τ_2) be a (i, j)- $T_{1/2s}{}^{**}$ space. Let A be a (i, j)-strongly g*closed set. Then A is (i, j)-strongly g** closed. $\therefore$ A is τ_j -closed since (X, τ_1, τ_2) is a (i, j)- $T_{1/2s}{}^{**}$ space. Therefore every (i, j)-strongly g*closed set is τ_j -closed & hence (X, τ_1, τ_2) is a (i, j)- $T_{1/2s}{}^{*}$ space.

Theorem 4.10: Every (i, j)- $T_{1/2s}$ space is a (i, j)- $T_{1/2s}{}^{**}$ space.

Proof: Let (X, τ_1, τ_2) be a (i, j)- $T_{1/2s}$ space. Let A be a (i, j)-strongly g**closed set. Then A is (i, j)-strongly g closed & hence A is τ_j -closed since (X, τ_1, τ_2) is a (i, j)-$T_{1/2s}$ space. $\therefore$ Every (i, j)-strongly g**closed set is τ_j -closed. Therefore (X, τ_1, τ_2) is a (i, j)-$T_{1/2s}{}^{**}$ space.

Theorem 4.11: Every (i, j)- $T_{1/2s}$ space is (i, j)- $T_{1/2}{}^{*}$ space.

Proof: Let (X,τ_1,τ_2) be a (i, j)- $T_{1/2s}$ space. Let A be a (i, j)-g* closed set. Then A is a (i, j)-strongly g closed. Then A is τ_j-closed since (X,τ_1,τ_2) is a (i, j)-$T_{1/2s}$ space. Therefore (X,τ_1,τ_2) is a (i, j)-$T_{1/2}{}^*$ space.

The converse of the above theorem is not true as seen in the following example.

Example 4.12: Let x= {a, b, c}, τ_1= {Φ, {a}, X} and τ_2= {Φ, {a}, {b, c}, X}. Then A= {b} is (i, j)-strongly g closed but not τ_j-closed. $\therefore$ (X,τ_1,τ_2) is not a (i, j)-$T_{1/2s}$ space. Here all the (i, j)-g* closed sets are τ_j-closed. Therefore (X,τ_1,τ_2) is a $T_{1/2}{}^*$ space & hence every (i, j)- $T_{1/2}{}^*$ space need not be a (i, j)- $T_{1/2s}$ space.

Theorem 4.13: Every (i, j)- $T_{1/2s}{}^*$ space is a (i, j)- $T_{1/2}{}^*$ space.

The converse of the above theorem is not true as seen in the following example.

Example 4.14: In example (4.12), A= {b} is (i, j)-strongly g* closed but not τ_j-closed. $\therefore$ (X,τ_1,τ_2) is not a (i, j)- $T_{1/2s}{}^*$ space. All the (i, j)-g* closed sets are τ_j -closed and hence (X,τ_1,τ_2) is (i, j)- $T_{1/2}{}^*$ space. Therefore (i, j)-$T_{1/2}{}^*$ space need not be a (i, j)- $T_{1/2s}{}^*$ space.

Theorem 4.15: Every (i, j)- $T_{1/2s}{}^{**}$ space is (i, j)- $T_{1/2}{}^*$ space.

proof follows from the definition.

The converse of the above is not true as seen in the example.

Example 4.16: In example (4.12), A= {b} is (i, j)-strongly g**closed but not τ_j-closed. Therefore (X,τ_1,τ_2) is not a (i, j)- $T_{1/2s}{}^{**}$ space. (i, j)-g* closed sets are Φ, {b, c}, X and all these sets are τ_j -closed and hence (X,τ_1,τ_2) is (i, j)- $T_{1/2}{}^*$ space. Therefore every (i, j)-$T_{1/2}{}^*$ space need not be a (i, j)-$T_{1/2s}{}^*$ space.

Theorem 4.17: Every (i, j)-${}^*T_{1/2s}$ space is (i, j)- ${}^{**}T_{1/2s}$ space.

Proof: Let (X,τ_1,τ_2) be (i, j)- ${}^*T_{1/2s}$ space. Since (X,τ_1,τ_2) is a (i, j)- ${}^*T_{1/2s}$ space, every (i, j)-strongly g closed set is (i, j)-strongly g* closed. But every (i, j)-strongly g* closed set is (i, j)-strongly g**closed. Therefore every (i, j)-strongly g closed set is (i, j)-strongly g**closed. $\therefore$ (X,τ_1,τ_2) is a (i, j)- ${}^{**}T_{1/2s}$ space.

The converse of the above theorem is not true as seen in the following example.

Example 4.18: Let X={a, b, c}, τ_1={Φ, {a}, X} and τ_2={Φ, {a}, {a, b}, X}. Then A={b} is (i, j)-strongly g closed but not τ_j-closed. (i,e.,) (i, j)-strongly g closed set is not a (i, j)-strongly g* closed. Therefore (X,τ_1,τ_2) is not a (i, j)- ${}^*T_{1/2}$ space. But every (i, j)-strongly g closed set is (i, j)-strongly g**closed. Therefore (X,τ_1,τ_2) is a (i, j)- ${}^{**}T_{1/2s}$ space. Therefore every (i, j)-${}^{**}T_{1/2s}$ space need not be (i, j)- ${}^*T_{1/2s}$ space.

Theorem 4.19: Every (i, j)- $T_{1/2s}$ space is a (i, j)- ${}^*T_{1/2s}$ space.

proof follows from the definition.

The converse of the above theorem is not true as seen in the following example.

Example 4.20: In example (4.14) we have proved that the (i, j)-strongly g*closed sets are all the subsets of X and in example (4.12) we have proved that all these sets are (i, j)-strongly g closed. Therefore every (i, j)-strongly g closed sets are (i, j)-strongly g* closed. $\therefore$ (X,τ_1,τ_2) is a (i, j)-${}^*T_{1/2s}$

space. In the same example we have proved that (X,τ_1,τ_2) is not a $T_{1/2s}$ space. Therefore every (i, j)- ${}^*T_{1/2s}$ space need not be a (i, j)- $T_{1/2s}$ space.

Theorem 4.21: Every (i, j)- $T_{1/2s}{}^{**}$ space is a (i, j)- ${}^*T_{1/2s}{}^*$ space.

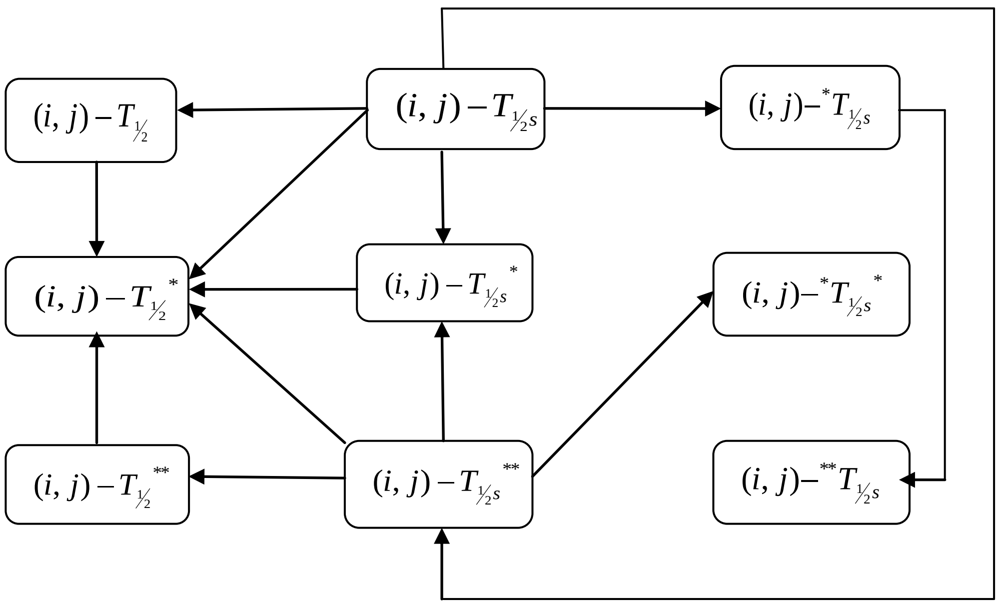
The converse of the above theorem is not true as seen in the following example.

Example 4.22: In example (4.16) we have proved that (X,τ_1,τ_2) is not a (i, j)-$T_{1/2s}{}^{**}$ space. In the same example we have proved that all the (i, j)-strongly g**closed sets are (i, j)-strongly g*closed. Therefore (X,τ_1,τ_2) is a (i, j)-${}^*T_{1/2s}{}^*$ space & hence a (i, j) ${}^*T_{1/2s}{}^*$ space need not be a (i, j)-$T_{1/2s}{}^{**}$ space.

Theorem 4.23: Every space (X,τ_1,τ_2) which is both a (i, j)- ${}^*T_{1/2s}{}^*$ space and a (i, j)-$T_{1/2s}{}^*$ space is a (i, j)- $T_{1/2s}{}^{**}$ space.

Proof: Let (X,τ_1,τ_2) be both (i, j)- ${}^*T_{1/2s}{}^*$ space and (i, j)-$T_{1/2s}{}^*$ space. Let A be (i, j)-strongly g**closed. Then A is (i, j)-strongly g*closed since (X,τ_1,τ_2) is a (i, j)- ${}^*T_{1/2s}{}^*$ space and A is τ_j -closed since (X,τ_1,τ_2) is (i, j)- $T_{1/2s}{}^*$ space. $\therefore$ A is τ_j-closed. Therefore (X,τ_1,τ_2) is (i, j)- $T_{1/2s}{}^{**}$ space.

The above results can be represented in the following figure.



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