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α*-closed sets in bitopological spaces

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ABSTRACT

In this paper we introduce α*-closed sets in bitopological spaces.Properties of this sets are investigated and we introduce seven new bitopological spaces namely, (i,j)- T_α^*, (i,j)- ${}_{\alpha g}T_\alpha^*$,(i,j)- ${}_{gs}T_\alpha^*$, (i,j) - ${}_{g}T_\alpha^*$, (i,j)- ${}_{gsp}T_\alpha^*$,(i,j)- ${}_{gp}T_\alpha^*$,(i,j)- ${}_{gpr}T_\alpha^*$.

Key words: (i,j)- α*-closed sets, (i,j)- T_α^* spaces, (i,j)- ${}_{\alpha g}T_\alpha^*$ spaces,(i,j)- ${}_{gs}T_\alpha^*$ spaces, (i,j) - ${}_{g}T_\alpha^*$ spaces, (i,j)- ${}_{gsp}T_\alpha^*$ spaces,(i,j)- ${}_{gp}T_\alpha^*$ spaces,(i,j)- ${}_{gpr}T_\alpha^*$ spaces.

1.INTRODUCTION

A triple (X, τ_1, τ_2) where X is a non-empty set and τ_1 and τ_2 are topologies in X is called a bitopological space andKelly**[7]** initiated the study of such spaces. In 1985,Fukutake**[3]** introduced the concepts of g-closed sets in bitopological spaces.Levine **[9]** introduced the class of generalized closed sets,a super class of closed sets in 1970.M.K.R.S.Veerakumar**[17]** introduced and studied the concepts of g*-closed sets and g*-continuity in topological spaces.Sheik John.M and Sundaram.P**[14]** introduced and studied the concepts of g*-closed sets in bitopological spaces in 2002.Pauline Mary Helen,Ponnuthai Selvarani and Veronica Vijayan **[13]** introduced g**-closed sets in topological spaces in 2012.The purpose of this paper is to introduce the concepts of (i,j)-α*-closed sets, (i,j)- T_α^* spaces, (i,j)- ${}_{\alpha g}T_\alpha^*$ spaces,(i,j)- ${}_{gs}T_\alpha^*$ spaces, (i,j) - ${}_{g}T_\alpha^*$ spaces, (i,j)- ${}_{gsp}T_\alpha^*$ spaces,(i,j)- ${}_{gp}T_\alpha^*$ spaces,(i,j)- ${}_{gpr}T_\alpha^*$ spaces in bitopological spaces and investigate some of their properties.

2.PRELIMINARIES

Definition 2.1

A subset A of a topological space (X,τ) is said to be

1. a pre-open set**[10]** if A⊆ int(cl(A)) and a pre-closed set if cl(int(A)) ⊆A
2. a semi-open **[8]** if A⊆ cl(int(A)) and a semi-closed set if int(cl(A)) ⊆A
3. a regular open set**[10]** if A=int(cl(A))

4. a generalized closed set**[9]** (briefly g-closed set) if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X,τ).
5. a α-open set **[11]** if A $\subseteq$ int(cl(int(A))) and an α-closed if cl(int(cl(A))) $\subseteq$ A
6. a semi-preopen set**[1]** if A $\subseteq$ cl(int(cl(A))) and a semi – preclosed set if int(cl(int(A))) $\subseteq$ A.
7. a α*-closed set **[18]** if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is α-open in (X,τ).

If A is a subset of X with topology τ,then the closure of A is denoted by τ-cl(A) or cl(A),the interior of A is denoted by τ-int(A) or int(A) and the complement of A in X is denoted by A^c.

For a subset A of (X, τ_i,τ_j), τ_j-cl(A)(resp. τ_i-int(A)) denotes the closure (resp.interior)of A with respect to the topology τ_j.

Definition 2.2

A subset A of a topological space (X, τ_i,τ_j) is called

1. (i,j) –g-closed**[3]** if τ_j-cl(A) $\subseteq$ U whenever A$\subseteq$ U and U is open in τ_i.
2. (i,j) –rg-closed **[12]** if τ_j-cl(A) $\subseteq$ U whenever A$\subseteq$ U and U is regular open in τ_i.
3. (i,j) –gpr-closed **[5]** if τ_j-pcl(A) $\subseteq$ U whenever A$\subseteq$ U and U is regular open in τ_i.
4. (i,j) –ωg-closed **[4]** if τ_j-cl(τ_i –int(A)) $\subseteq$ U whenever A$\subseteq$ U and U is open in τ_i.
5. (i,j) –ω-closed **[6]** if τ_j-cl(A) $\subseteq$ U whenever A $\subseteq$U and U is semi open in τ_i.
6. (i,j)-gs-closed**[16]** if τ_j-scl(A) $\subseteq$ U whenever A$\subseteq$ U and U is open in τ_i.
7. (i,j)-gsp-closed**[2]** if τ_j-spcl(A) $\subseteq$ U whenever A$\subseteq$ U and U is open in τ_i.
8. (i,j)-αg-closed**[16]** if τ_j-αcl(A) $\subseteq$ U whenever A$\subseteq$ U and U is open in τ_i.

Definition 2.3

A bitopological space (X, τ_i,τ_j) is called

1. an (i,j)-$T_{1/2}$space**[3]** if every (i,j)-g-closed set is τ_j-closed.
2. an (i,j)-$T_b$space **[16]** if every (i,j)-gs-closed set is τ_j-closed.
3. an (i,j)-$T_d$space **[16]** if every (i,j)-gs-closed set is (i,j)-g-closed.
4. an (i,j)-${}_{\alpha}T_d$space **[3]** if every (i,j)-αg-closed set is (i,j)-g-closed.
5. an (i,j)-${}_{\alpha}T_b$space **[16]** if every (i,j)-αg-closed set is τ_j –closed.

3.(i,j)-α*-closed sets

We introduce the following definition.

Definition 3.1 A subset A of a topological space (X,τ_1,τ_2) is said to be an (i,j)- α^*-closed set if

τ_j-cl(A) $\subseteq$ U whenever A$\subseteq$ U and U is α- open in τ_i..We denote the family of all (i,j)- α^*-closed sets in (X,τ_1,τ_2) by $\alpha^*C(i,j)$.

Remark 3.2 By setting $\tau_1=\tau_2$ in definition (3.1), a (i,j)- α^*-closed set is a α^*-closed set.

Proposition 3.3 Every τ_j-closed subset of (X,τ_1,τ_2) is (i,j)- α^*-closed.

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

Example 3.4 Let X={a,b,c}, $\tau_1=\{\emptyset,\{c\},\{a,c\},X\}$ and $\tau_2=\{\emptyset,\{a\},X\}$.Then the set A={b} is (1,2)-α^*-closed but not τ_2-closed in (X,τ_1,τ_2).

Proposition 3.5 If A is (i,j)-α^*-closed and τ_i-α – open, then A is τ_j-α –closed.

Proposition 3.6 If A is both (i,j)-α^*-closed and τ_i-α - open ,then it is τ_j–closed.

Proposition 3.7 In a bitopological space (X,τ_1,τ_2) every (i,j)-α^*-closed set is

(i) (i,j)-g-closed
(ii) (i,j)-rg-closed (iii) (i,j)-gpr-closed (iv) (i,j)-ωg-closed.

The following examples show that the converse of the above proposition is not true.

Example 3.8 Let X={a,b,c}, $\tau_1=\{\emptyset,\{a\},X\}$ and $\tau_2=\{\emptyset,\{a\},\{a,b\},X\}$.Then the set A={b} is (1,2)-g-closed but not (1,2)-α^*-closed.

Example 3.9 Let X={a,b,c}, $\tau_1=\{\emptyset,\{a,b\},X\}$ and $\tau_2=\{\emptyset,\{a\},X\}$.Then the set A={b} is (1,2)-rg-closed but not (1,2)-α^*-closed.

Example 3.10 Let X={a,b,c}, $\tau_1=\{\emptyset,\{c\},\{a,b\},X\}$ and $\tau_2=\{\emptyset,\{a\},X\}$.Then the set A={c} is (1,2)-gpr-closed but not (1,2)-α^*-closed.

Example 3.11 Let X={a,b,c}, $\tau_1=\{\emptyset,\{a,b\},X\}$ and $\tau_2=\{\emptyset,\{a\},X\}$.Then the set A={a} is (1,2)-ωg-closed but not (1,2)-α^*-closed.

Theorem 3.12 Every (i,j)-α^*-closed set is a (i,j)-gs-closed set.

The converse of the above theorem need not be true.

Example 3.13 Let X={a,b,c}, τ_1={∅,{a},X} and τ_2={∅,{a},{a,b},X}.Then the set A={b} is (1,2)-gs-closed but not (1,2)-α*-closed .

Theorem 3.14 Every (i,j)-α*-closed set is a (i,j)-gp-closed set.

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

Example 3.15 Let X={a,b,c}, τ_1={∅,{c},{a,b},X} and τ_2={∅,{a},X}.Then the set A={b} is (1,2)-gp-closed but not (1,2)-α*-closed.

Theorem 3.16 Every (i,j)-α*-closed set is a (i,j)-gα-closed set.

The converse of the above theorem need not be true.

Example 3.17 Let X={a,b,c}, τ_1={∅,{a,b},X} and τ_2={∅,{a},X}.Then the set A={b} is (1,2)-gα-closed but not (1,2)-α*-closed.

Theorem 3.18 Every (i,j)-α*-closed set is a (i,j)-αg-closed set.

The following example support that the converse of the above theorem is not true.

Example 3.19 Let X={a,b,c}, τ_1={∅,{a,b},X} and τ_2={∅,{a},X}.Then the set A={b} is (1,2)-αg-closed but not (1,2)-α*-closed.

Theorem 3.20 Every (i,j)-α*-closed set is a (i,j)-gsp-closed set.

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

Example 3.21 Let X={a,b,c}, τ_1={∅,{a,b},X} and τ_2={∅,{a},X}.Then the set A={b} is (1,2)-gsp-closed but not (1,2)-α*-closed.

Theorem 3.22 Every (i,j)-ω-closed set is a (i,j)- α*-closed set.

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

Example 3.23 Let X={a,b,c}, τ_1={∅,{c},{a,c},X} and τ_2={∅,{a},X}.Then the A={b} is (1,2)- α*-closed but not (1,2)-ω-closed.

Proposition 3.24 If A,B ∈ α*C(i,j) then A∪B ∈α*C(i,j)

Remark 3.25 The intersection of two (i,j)- α^*-closed set need not be (i,j)- α^*-closed as seen from the following example.

Example 3.26 Let $X=\{a,b,c\}$, $\tau_1=\{\emptyset,\{a\},\{b,c\},X\}$ and $\tau_2=\{\emptyset,\{b\},\{b,c\},\{c\},\{a,c\},X\}$. Let $A=\{a,b\}$ and $B=\{b,c\}$. Then A and B are (2,1)-α^*-closed sets but $A\cap B=\{b\}$ is not a (2,1)-α^*-closed set.

Remark 3.27 $\alpha^*C(1,2)$ is generally not equal to $\alpha^*C(2,1)$

Example 3.28 In example (3.26), $A=\{b\} \notin \alpha^*C(2,1)$ but $A=\{b\}\in \alpha^*C(1,2)$.

Hence $\alpha^*C(2,1)\neq \alpha^*C(1,2)$

Proposition 3.29 If $\tau_1\subseteq \tau_2$ in (X, τ_1,τ_2), then $\alpha^*C(1,2) \subseteq \alpha^*C(2,1)$

Proposition 3.30 If A is a (i,j)-α^*-closed, then τ_j-Cl(A)\A contains no non-empty τ_i -α-closed set.

Proof Let A be a (i,j)-α^*-closed set and let F be a τ_i -α-closed set such that $F \subseteq \tau_j\text{-Cl}(A)\backslash A$. Since $A\in \alpha^*C(i,j)$, we have $\tau_j\text{–Cl}(A) \subseteq F^c$ $\therefore$ $F\subseteq(\tau_j\text{–Cl}(A))^c$ and hence $F \subseteq (\tau_j\text{-Cl}(A) \cap((\tau_j\text{-Cl}(A))^c=\emptyset$. $\therefore$ $F= \emptyset$

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

Example 3.31 Let $X=\{a,b,c\}$, $\tau_1=\{\emptyset,\{b\},\{c\},\{b,c\},\{a,c\},X\}$ and $\tau_2=\{\emptyset,\{a\},\{b,c\},X\}$

Let $A=\{b\}$. Then τ_2-cl(A)\A $=\{c\}$ is not τ_1-α-closed.i.e. τ_2-cl(A)\A contains no nonempty τ_1-α-closed set but $A=\{b\}$ is not (1,2)-α^*-closed.

Theorem 3.32 If A is (i,j)-α^*-closed in (X, τ_i, τ_j), then A is τ_j-closed if and only if τ_j-Cl(A)\A is τ_i-α-closed.

Proof: Necessity: If A is τ_j-closed then τ_j-Cl(A)=A (i.e) τ_j-Cl(A)\A $= \emptyset$ which is τ_i-α-closed.

Sufficiency: If τ_j-Cl(A)\A is τ_i-α-closed, since A is (i,j)-α^*-closed by proposition 3.29, τ_j-Cl(A)\A contains no non empty τ_i-α-closed set.$\therefore$ τ_j-Cl(A)\A $= \emptyset$ and hence A= τ_j-Cl(A) and A is τ_j-closed.

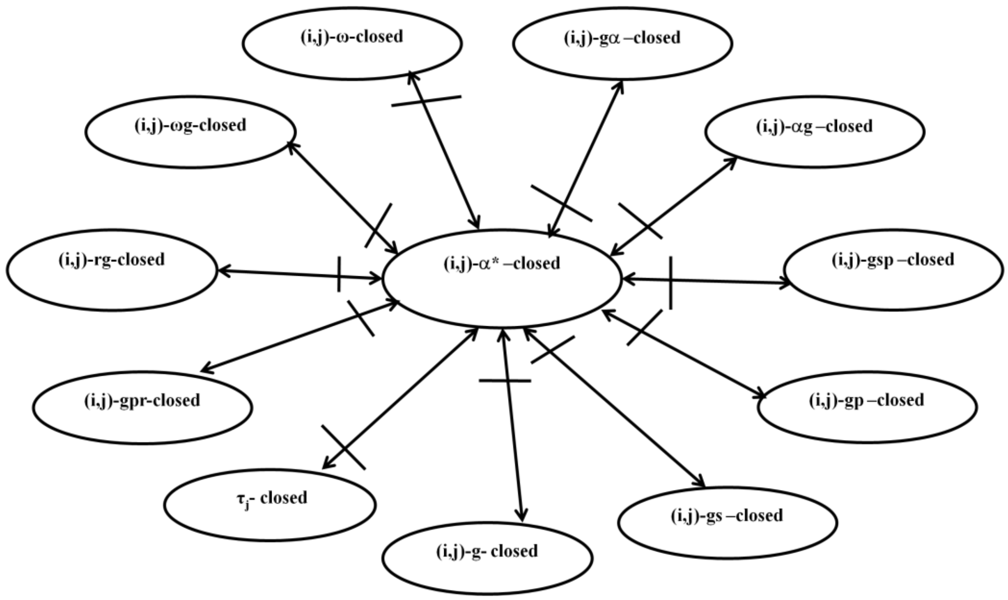
Theorem 3.33 If A is an (i,j)-α^*-closed set of (X, τ_i, τ_j) such that $A\subseteq B\subseteq \tau_j\text{-Cl}(A)$, then B is also an (i,j)-α^*-closed set of (X, τ_i, τ_j).

Proof : Let A be a (i,j)-α^*-closed set. Let U be a τ_i-α-open set such that $B\subseteq U$ then $A\subseteq B\subseteq U$. Then $\tau_j\text{-Cl}(A) \subseteq U$, since A is (i,j)-$\alpha^*$-closed. $B\subseteq \tau_j\text{-Cl}(A) \Rightarrow \tau_j\text{-Cl}(B) \subseteq\tau_j\text{-Cl}(A) \subseteq U$, $\therefore$ $\tau_j\text{-Cl}(B) \subseteq U$

∴ B is a (i,j)-α*-closed set.

Proposition 3.34 For each element x of (X, τ_1, τ_2), {x} is either τ_i-α-closed or X-{x} is (i,j)-α*-closed.

The following figure gives all the above results we have proved.



where A $\longrightarrow$ B represents A implies B and A $\nrightarrow$ B represents A does not imply B.

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

As applications of (i,j)-α*-closed sets, we introduce seven new bitopological spaces, (i,j)- T_α^* space, (i,j)- ${}_{\alpha g}T_\alpha^*$ space,(i,j)- ${}_{gs}T_\alpha^*$ space, (i,j) - ${}_{g}T_\alpha^*$ space, (i,j)- ${}_{gsp}T_\alpha^*$ space,(i,j)- ${}_{gp}T_\alpha^*$ space and(i,j)- ${}_{gpr}T_\alpha^*$ space.

We introduce the following definitions.

Definition 4.1A bitopological space (X, τ_1, τ_2) is said to be an (i,j)- T_α^*space, if every (i,j)-α*-closed set is τ_j-closed.

Definition 4.2 A bitopological space (X, τ_1, τ_2) is said to be an (i,j)- ${}_{\alpha g}T_\alpha^*$space, if every (i,j)-αg-closed set is (i,j)-α*-closed.

Definition 4.3 A bitopological space (X, τ_1, τ_2) is said to be an (i,j)- ${}_{gs}T_\alpha^*$space, if every (i,j)-gs-closed set is (i,j)-α*-closed.

Definition 4.4 A bitopological space (X, τ_1, τ_2) is said to be an (i,j) - ${}_{g}T_{\alpha}^{*}$space, if every (i,j)-g-closed set is (i,j)-α*-closed.

Definition 4.5 A bitopological space (X, τ_1, τ_2) is said to be an (i,j) - ${}_{gsp}T_{\alpha}^{*}$space, if every (i,j)-gsp-closed set is (i,j)-α*-closed.

Definition 4.6A bitopological space (X, τ_1, τ_2) is said to be an (i,j) - ${}_{gp}T_{\alpha}^{*}$space, if every (i,j)-gp-closed set is (i,j)-α*-closed.

Definition 4.7A bitopological space (X, τ_1, τ_2) is said to be an (i,j) - ${}_{gpr}T_{\alpha}^{*}$space, if every (i,j)-gpr-closed set is (i,j)-α*-closed.

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

The converse of the above theorem is not true.

Example 4.9 In example (3.8), (X, τ_1, τ_2) is a (1,2)-T_{α}^{*} space, since all the (i,j)-α*-closed sets are τ_j-closed. Since A={a,b}is (1,2)-g-closed but not τ_2 –closed,it is not a (1,2)-$T_{1/2}$ space.

Theorem 4.10 Every (i,j)-T_b space is a (i,j)-T_{α}^{*} space.

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

Example 4.11 In example (3.8), we have proved that the (i,j)-α*-closed sets are X, ∅,{b,c} which are τ_j-closed.Hence (X, τ_1, τ_2) is a (1,2)-T_{α}^{*} space. Since A={a,b}is (1,2)-gs-closed but not τ_2 –closed. Hence (X, τ_1, τ_2) is not a (1,2)-T_b space.

Theorem 4.12 A space which is both (i,j)- ${}_{\alpha}T_d$ and (i,j)-$T_{1/2}$ is a (i,j)- T_{α}^{*} space.

Theorem 4.13 Every (i,j)-${}_{\alpha}T_b$ space is a (i,j)-T_{α}^{*} space.

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

Example 4.14 In example (3.8), (X, τ_1, τ_2) is a (1,2)-T_{α}^{*} space.Since A={b} is a (1,2)-αg-closed but not τ_2-closed.Hence (X, τ_1, τ_2) is not a (1,2)- ${}_{\alpha}T_b$ space.

Theorem 4.15 Every (i,j)-T_b space is a (i,j)- ${}_{gs}T_{\alpha}^{*}$ space.

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

Theorem 4.16 In example (3.31), (X, τ_1, τ_2) is a (i,j)- ${}_{gs}T_\alpha^*$ space.It is not a (i,j)-T_b space,since A={a,b} is (1,2)-gs-closed but not τ_2 -closed .

Theorem 4.17 Every (i,j)- ${}_{\alpha}T_b$ space is a (i,j)- ${}_{\alpha g}T_\alpha^*$ space.

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

Example 4.18 In example (3.31), (X, τ_1, τ_2) is a (1,2)-${}_{\alpha g}T_\alpha^*$ space ,since every(i,j)-αg-closed set in it is (i,j)-α*-closed.Since A={a,b} is a (1,2)-αg-closed but not τ_2-closed, (X, τ_1, τ_2) is not a (1,2)- ${}_{\alpha}T_b$ space.

Theorem 4.19 Every (i,j)- $T_{1/2}$ space is a (i,j)- ${}_{g}T_\alpha^*$ space.

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

Example 4.20 In example (3.4), we have proved that the (i,j)-g-closed sets are X, ∅,{b},{a,b},{b,c} which are (i,j)-α*-closed in (X, τ_1, τ_2),where X={a,b,c}, τ_1={∅,{c},{a,c},X} and τ_2={∅,{a},X}. A={b} is (1,2)-g-closed but not τ_2 -closed .Hence (X, τ_1, τ_2) is not a (1,2)- $T_{1/2}$ space.

Theorem 4.21 A space is both (i,j)- ${}_{g}T_\alpha^*$ space and (i,j)-T_α^* space if and only if it is a (i,j)-$T_{1/2}$ space.

Theorem 4.22 A space (X, τ_i, τ_j) which is both (i,j)- ${}_{\alpha}T_d$ and (i,j)- $T_{1/2}$ is a (i,j)- T_α^* space.

Theorem 4.23 A space (X, τ_i, τ_j) which is both (i,j)- ${}_{gs}T_\alpha^*$ space and (i,j)-T_α^* space is a (i,j)-T_b space.

Theorem 4.24 A space (X, τ_i, τ_j) which is both (i,j)-${}_{\alpha g}T_\alpha^*$ space and (i,j)-T_α^* space is a (i,j)-${}_{\alpha}T_b$ space.

Theorem 4.25 Every (i,j)-${}_{\alpha g}T_\alpha^*$ space is a (i,j)- ${}_{g}T_\alpha^*$ space.

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

Example 4.26 Let X={a,b,c}, τ_1={∅,{a},{b,c},X} and τ_2={∅,{c},{a,c},X}.(X, τ_1, τ_2) is a (1,2)-${}_{g}T_\alpha^*$ space,since all its (i,j)-g-closed sets, X, ∅,{b},{a,b},{a,c} are (i,j)-α*-closed. A={a} is (1,2)-αg-closed but not (1,2)-α*-closed.Hence (X, τ_1, τ_2) is not a (1,2)- ${}_{\alpha g}T_b$ space.

Theorem 4.27 Every (i,j)-${}_{gs}T_\alpha^*$ space is a (i,j)- ${}_{g}T_\alpha^*$ space.

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

Example 4.28 Consider example 4.26, (X, τ_1, τ_2) is a (1,2)- ${}_{g}T_\alpha^*$ space.But it is not a (1,2)- ${}_{gs}T_\alpha^*$ space,since A={a} is (1,2)-gs-closed but not (1,2)-α* -closed .

Theorem 4.29 Every (i,j)- ${}_{gp}T_\alpha^*$ space is a (i,j)- ${}_{g}T_\alpha^*$ space.

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

Example 4.30 In example 3.15, (X, τ_1, τ_2) is a (1,2)- ${}_{g}T_\alpha^*$ space. But it is not a (1,2)- ${}_{gp}T_\alpha^*$ space,since A={b} is (1,2)-gp-closed but not (1,2)-α*-closed.

Theorem 4.31 Every (i,j)- ${}_{gsp}T_\alpha^*$ space is a (i,j)- ${}_{g}T_\alpha^*$ space.

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

Example 4.32 Consider example 3.10, where X={a,b,c}, τ_1={∅,{c},{a,b},X} and τ_2={∅,{a},X}.

(X, τ_1, τ_2) is a (1,2)- ${}_{g}T_\alpha^*$ space. But it is not a (1,2)- ${}_{gsp}T_\alpha^*$ space,since A={b} is (1,2)-gsp-closed but not (1,2)-α*-closed .

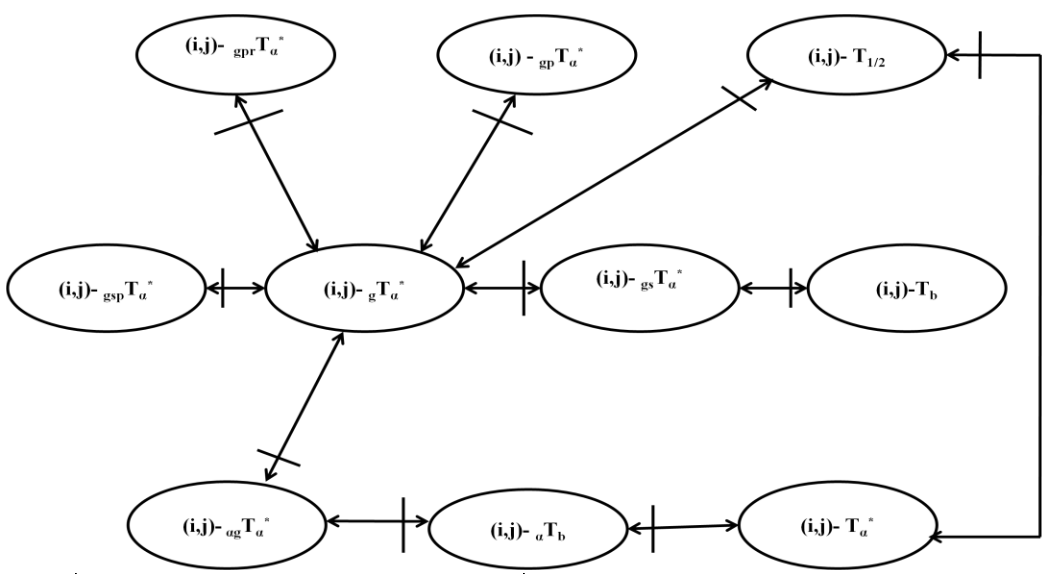
Theorem 4.33 Every (i,j)- ${}_{gpr}T_\alpha^*$ space is a (i,j)- ${}_{g}T_\alpha^*$ space.

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

Example 4.34 Consider example 3.10, where X={a,b,c}, τ_1={∅,{c},{a,b},X} and τ_2={∅,{a},X}.

(X, τ_1, τ_2) is a (1,2)- ${}_{g}T_\alpha^*$ space. But it is not a (1,2)- ${}_{gpr}T_\alpha^*$ space,since A={c} is (1,2)-gpr-closed set but not (1,2)-α*-closed .

All the results we have proved in this section can be represented by the following figure:



where A → B represents A implies B and A ↛ B represents A does not imply B.

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