A Study on (i,j)g*^{s}sI Closed and Open Sets in Bitopological Spaces

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ABSTRACT
An Ideal on a set X is a non empty collection of subsets of X with heredity property which is also closed under finite unions. In this paper, (i,j)g*^{s}s closed and open sets are introduced with respect to an ideal in a bitopological space and their properties are investigated. Additionally, we compare them with other sets to show their relationships and characterize many other results.

Keywords
(i,j)g*^{s}s closed sets, (i,j)g*^{s}sI closed sets and (i,j)g*^{s}sI open sets .

1. INTRODUCTION
J.C.Kelly[8] introduced the notion of bitopological spaces. Such spaces are equipped with two arbitrary topologies. Furthermore, Kelly extended some of the standard results of separation axioms in a topological space to a bitopological space. Fukutake [31] introduced the concepts of g-closed set in bitopological spaces and after that Sheik John and P.Sundaram[17] introduced g*closed sets in bitopological spaces.

Recently G.B.Navalgi[4] introduced a new class of g*s closed sets and after that several authors turned towards generalization of various concepts of topology by considering bitopological spaces.

In this paper, the concept of (i,j)g*^{s}s closed and open sets with respect to ideal bitopological spaces are introduced and their properties are discussed.

2. PRELIMINARIES
Throughout this paper (X,τ_1,τ_2) and (Y,σ_1,σ_2) represents bitopological spaces on which separation axioms are assumed unless otherwise mentioned. If A is a subset of X with a topology τ , then closure of A is denoted by τ-cl(A) or cl(A) and the interior of A is denoted by τ-int(A) or int(A).

We recall the following definitions which are useful in the sequel.

Definition 2.1. An ideal I on a topological space[12] (X,τ) is a non-empty collection of subsets of X which satisfies the following properties. (1) $A \in I$ and $B \subseteq A$ implies $B \in I$, (2) $A \in I$ and $B \in I$ implies $A \cup B \in I$.

An ideal topological space is a topological space (X,τ) with an ideal I on X and is denoted by (X, τ, I). For a subset $A \subseteq X$, $A^*(I,\tau)=\{x \in X : A \cap U \notin I$ for every $U \in \tau(X,x)\}$ is called the local function of A with respect to I and τ [12]. We simply write A* in case there is no chance for confusion. A kuratowski closure operator cl*(.) for a topology $\tau^*(I, \tau)$ called the τ *- topology , finer than τ is defined by $cl^*(A) = A \cup A^*$ [32].

Definition 2.2: A subset A of a topological space (X,τ) is called

1)Generalized closed[20] (briefly g-closed) ,if cl (A) $\subseteq$ U whenever $A \subseteq U$ and U is open in (X, τ)

2)α-open [21] if $A \subseteq int(cl(int(A)))$,α-closed [21] if $cl(int(cl(A))) \subseteq A$.

3)Semi-open [14] if $A \subseteq cl(int(A))$,semi-closed[14] if $int(cl(A)) \subseteq A$

4)Semi-pre-open [3] if $A \subseteq cl(int(cl(A)))$,semi-pre-closed[3] if $int(cl(int(A))) \subseteq A$.

5)Pre-closed [19] if $int(cl(A)) \subseteq A$,pre-open set[19] $A \subseteq int(cl(A))$.

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

1) (i,j)-g*closed[17] if τ_j-cl(A) $\subseteq$U whenever A $\subseteq$U and U is g-open in τ_i

2) (i,j)-gs-closed[22] if τ_j-scl(A) $\subseteq$U whenever A $\subseteq$U and U is open in τ_i

3) (i,j)-αg-closed[22] if τ_j-αcl(A) $\subseteq$U whenever A $\subseteq$U and U is open in τ_i

4) (i,j)-sg-closed[13] if τ_j-scl(A) $\subseteq$U whenever A $\subseteq$U and U is semi-open in τ_i

5) (i,j)-rg-closed[9] if τ_j-cl(A) $\subseteq$U whenever A $\subseteq$U and U is regular-open in τ_i

6) (i,j)g*^{s}s closed[11] if τ_j-scl(A) $\subseteq$U whenever A $\subseteq$U and U is rg-open in τ_i

7) (i,j)-gsp-closed[5] if τ_j-spcl(A) $\subseteq$U whenever A $\subseteq$U and U is open in τ_i

8) (i,j)-gp-closed[29] if τ_j-αcl(A) $\subseteq$U whenever A $\subseteq$U and U is open in τ_i

9) (i,j)-gpr-closed[21] if τ_j-pcl(A) $\subseteq$U whenever A $\subseteq$U and U is regular-open in τ_i

10) (i,j)-αgr-closed[20] if τ_j-pcl(A) $\subseteq$U whenever A $\subseteq$U and U is regular-open in τ_i

11) (i,j)-pre-semi-closed[25] if τ_j-spcl(A) $\subseteq$U whenever A $\subseteq$U and U is g-open in τ_i

12) (i,j)-gα closed[20] if τ_j-cl(A) $\subseteq$U whenever A $\subseteq$U and U is α-open in τ_i

13) (i,j)g*$^\alpha$s closed[11] if τ_j-αcl(A) $\subseteq$U whenever A $\subseteq$U and U is rg-open in τ_i

Definition 2.4. A subset A of an ideal topological space (X, τ, I) is said to be

1) αI-open [6] **,** if $A \subseteq int(Cl^*(int(A)))$.

2) gα - I – closed [16], if α I cl(A) $\subseteq$ U whenever $A \subseteq U$ and U is α - open in X

3) αg - I – closed [16], if α I cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in X.
4) wgα-I-closed [10], if αIcl (int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is α-open in (X, τ).
5) wαg-I-closed [10], if αIcl (int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ).
6) Ig-closed [15] , if A*$\subseteq$ U whenever A $\subseteq$ U and U is open in X.
The complements of the above mentioned closed sets are called their respective open sets.

3. SOME RESULTS ON (i, j)$^{1.}$ ℓs CLOSED SETS

Definition 3.1:A subset A of a bitopological space (X, τ_1 ,τ_2) is called (i, j)-g^{*s}s-closed set[11] if τ_j-scl(A)$\subseteq$ U whenever A$\subseteq$U and U is rg-open in τ_i

Proposition 3.2:

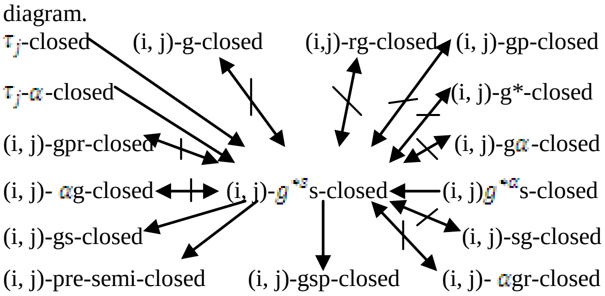
1. Every τ_j- closed set is (i, j)-g^{*s}s-closed.
2. Every τ_j- α-closed set is (i, j)-g^{*s}s-closed.
3. Every (i, j)-g^{*s}s-closed set is (i, j)-gs-closed.
4. Every (i, j)-g^{*s}s-closed set is (i, j)-gsp-closed.
5. Every (i, j)-g^{*s}s-closed set is (i, j)-pre-semi-closed.
6. Every (i, j) - $g^{*\alpha}$s-closed set is (i, j)-g^{*s}s-closed.

The converse of the above theorems need not be true .

Remark 3.3: The concept of (i, j)-g^{*s}s-closed sets is independent of the following classes of sets namely, (i,j)-g*-closed, (i,j)-gp-closed, (i,j)-rg-closed, (i,j)-g-closed , (i,j)-αg-closed, (i,j)-gpr-closed , (i,j)-sg-closed, (i,j)-αgr-closed and (i,j)-gα-closed.

For detailed proof and counter example refer [11].

All the above results can be represented by the following diagram.



Proposition 3.4: If A and B are (i, j)-g^{*s}s-closed set then A$\cup$ B is also (i, j)-g^{*s}s-closed.

Proof: Let A and B be (i, j)-g^{*s}s-closed. Let U be rg- open in τ_i such that A$\cup$ B$\subseteq$ U. Then A$\subseteq$ U and B$\subseteq$ U.Hence τ_j-scl(A) $\subseteq$U and τ_j-scl (B) $\subseteq$ U. Therefore τ_j-scl (A$\cup$B) $\subseteq$ τ_j-scl(A)$\cup$ τ_j-scl (B) $\subseteq$U.Hence A$\cup$ B is (i,j)-g^{*s}s-closed.

Proposition 3.5: If A is (i,j)-g^{*s}s-closed in (X, τ_1 ,τ_2) then τ_j-scl (A)-A contains no-non empty τ_j-rg closed set.

Proof: Let A is (i, j)-g^{*s}-s closed set and F be a non-empty τ_j-rg closed set, such that F$\subseteq$ τ_j-scl (A)-A.Then F$\subseteq$ τ_j-scl(A)$\cap A^c$.Then F$\subseteq$ τ_j-scl (A) and F$\subseteq A^c$… (1)

Since F$\subseteq$ A^c $\Rightarrow$A$\subseteq F^c$. Also A is (i,j)-g^{*s}-s closed, A$\subseteq F^c$ $\Rightarrow$ F^c is τ_j-rg-open.Then τ_j-scl (A) $\subseteq F^c$.Then F$\subseteq(\tau_j - \text{scl (A)})^c$…(2). From (1) and (2) we have F$\subseteq$ τ_j-scl (A)$\cap$ $(\tau_j - \text{scl (A)})^c$.Therefore F$\subseteq\phi$, which is a contradiction. Hence τ_j-scl (A)-A contains no non-empty τ_j-rg-closed set.

4. (i, j)-$^{1.}$ ℓsI CLOSED SETS

Definition4.1: Let (X,τ_1,τ_2) be a bitopological space and I be an Ideal on X. A subset A of X is said to be (i,j)g*^{s}sI Closed set with respect to an ideal I if τ_j-scl(A)\U $\in$ I , whenever A$\subseteq$U and U is τ_i-rg open in X, for i,j=1,2 and i$\neq$j.

Theorem 4.2: The intersection of two (i,j)g*^{s}sI Closed sets is also an (i,j)g*^{s}sI Closed set.

Proof: Let A and B be two (i,j)g*^{s}sI Closed sets in (X,τ_1,τ_2,I). If U is τ_i-rg open in X ,then A$\subseteq$U and B$\subseteq$U. Therefore A$\cap$B $\subseteq$U. Also τ_j-scl(A)\U $\in$ I and τ_j-scl(B)\U $\in$ I and hence τ_j-scl(A$\cap$B)\U=τ_j-scl(A)\U $\cap$ τ_j-scl(B)\U$\in$ I. Thus A$\cap$B is also an (i,j)g*^{s}sI Closed set.

Remark 4.3: The Union of two (i,j)g*^{s}sI Closed sets need not be an (i,j)g*^{s}sI Closed set ,as shown by the following example.

Example 4.4: Let X={a,b,c} with topologies τ_1={ϕ,{a},{a,c},X} and τ_2 ={ϕ,{a},{c},{a,c},X} and an ideal I={ϕ,{a}}.Then {a} and {c} are (1,2)g*^{s}sI Closed but their union {a,c} is not (1,2)g*^{s}sI Closed.

Theorem 4.5: Let A$\subset$Y$\subset$X and suppose that A is (i,j)g*^{s}sI Closed in (X,τ_1,τ_2,I) , then A is (i,j)g*^{s}sI Closed relative to the subspace Y of X and with respect to the Ideal I$_y$={F$\subset$Y ; F$\in$ I }.

Proof: Suppose A$\subset$U$\cap$Y and U is τ_i-rg open in X , then A$\subseteq$U. Since A is (i,j)g*^{s}–sI Closed in (X,τ_1,τ_2,I) we have τ_j-scl(A)\U $\in$ I.Then (τ_j-scl(A) $\cap$Y) \(U$\cap$Y) = (τ_j-scl(A)\U)$\cap$Y$\in$ I$_y$, whenever A$\subset$U$\cap$Y and U is τ_i-rg open. Hence A is (i,j)g*^{s}sI Closed relative to the subspace (Y,τ_1\Y,τ_2\Y).

Theorem 4.6: If A is (i,j)g*^{s}sI Closed and A$\subset$B$\subset$ τ_j-scl(A) in (X,τ_1,τ_2,I) ,then B is (i,j)g*^{s}–sI Closed in (X,τ_1,τ_2,I).

Proof: Let A be (i,j)g*^{s}sI Closed and A$\subset$B$\subset$ τ_j-scl(A) in (X,τ_1,τ_2,I).Suppose B$\subset$ U and U is τ_i-rg open ,then A$\subset$U ,since A is (i,j)g*^{s}sI Closed. We have τ_j-scl(A)\U $\in$ I. Now B$\subset$$\tau_j$-scl(A) . Therefore τ_j-scl(B)\U$\subset$ τ_j-scl(A)\U$\in$ I. Therefore, B is also (i,j)g*^{s}sI Closed in (X,τ_1,τ_2,I).

Theorem 4.7: Let Y be a subspace of X. Then a set A is (i,j)g*^{s}sI Closed in Y if and only if it is equal to the intersection of a (i,j)g*^{s}sI Closed set of X with Y.

Proof: Necessary: Let A= C$\cap$Y, where C is (i,j)g*^{s}sI Closed in X. Then X\C is (i,j)g*^{s}sI open in X , so that (X\C) $\cap$Y is (i,j)g*^{s}sI open in Y(By definition of subspace Topology).But

(X\C) ∩Y=Y\A. Therefore, Y\A is (i,j)g*^{s}sI open in Y. Therefore A is (i,j)g*^{s}sI Closed in Y.

Sufficient: Conversely assume that A is (i,j)g*^{s}sI Closed in Y. Then Y\A is (i,j)g*^{s}sI open in Y, so that by definition, it equals the intersection of a (i,j)g*^{s}–sI Open set U of X with Y. Therefore, (X\U) is (i,j)g*^{s}sI Closed in X and A= Y∩ (X\U) = intersection of a (i,j)g*^{s}sI Closed set of X with Y.

Theorem 4.8 : A set A is (i,j)g*^{s}sI Closed in (X,τ_1,τ_2,I) if and only if F ⊂ τ_j –scl(A)\A and F is τ_i –rg closed in X implies F∈I.

Proof: Necessary: Assume that A is (i,j)g*^{s}sI Closed. Let F ⊂ τ_j –scl(A)\A and suppose F is τ_i –rg closed , then A⊂ X\F.By our assumption , τ_j –scl(A)\ (X\F) ∈I.But F⊂τ_j –scl(A)\ (X\F) and hence F∈I.

Sufficient: Conversely , assume that F ⊂ τ_j –scl(A)\A and F is τ_i –rg closed in X , implies F∈I.

Suppose A⊂ U and U is τ_i –rg open, then τ_j –scl(A)\U=τ_j –scl(A) ∩ (X\U) is a τ_i –rg closed set in X that is contained in τ_j –scl(A)\A. By assumption , τ_j –scl(A)\U ∈I.⇒ A is (i,j)g*^{s}sI Closed.

Theorem4.9: Every τ_j-closed set is (i,j)g*^{s}sI Closed in X.

Proof: Let A be a τ_j-closed set. Let U be τ_i-rg open and A⊆U. Since A is τ_j-closed , τ_j –cl(A)=A Then. τ_j –cl(A) ⊆U , τ_j –scl(A) ⊆ τ_j –cl(A) ⊆U . Therefore τ_j –scl(A)\U = ϕ ∈I. ∴ A is (i,j)g*^{s}–sI Closed in X.

The converse is not true as seen by the following example:

Example 4.10: Let X={a,b,c} with topologies τ_1={ϕ,{a},{a,c},X} and τ_2 ={ϕ,{a},{c},{a,c},X} and an ideal I={ϕ,{a}}.Then {a} and {c} are (1,2)g*^{s}sI Closed but not τ_2 –closed.

Theorem 4.11: Every τ_j-α-closed set is (i,j)g*^{s}sI Closed in X.

Proof: Let A be a τ_j-α-closed set. Let U be τ_i-rg open and A⊆U.Since A is τ_j-α-closed , τ_j α-cl(A)=A. Then τ_j –α-cl(A) ⊆U , τ_j –scl(A) ⊆ τ_j –α-cl(A) ⊆U. Therefore τ_j –scl(A)\U ∈I. ∴ A is (i,j)g*^{s}sI Closed in X.

The converse is not true as seen by the following example:

Example4.12: Let X={a,b,c} ,τ_1={ϕ,{a},{c},{a,c},X} , τ_2 ={ϕ,{a},{a,c},X} and I={ϕ,{a}}.Then {a,b} and {c} are (1,2)g*^{s}sI Closed but not τ_2 –α-closed.

Remark4.13: Every (i,j)g*^{s}s Closed set is (i,j)g*^{s}sI Closed but the converse is not true as seen from the following example:

Example 4.14: Let X={a,b,c} ,τ_1={ϕ,{a},{a,c},X} , τ_2 ={ϕ,{a,b},X} and I={ϕ,{a}}.Then {b,c} is (1,2)g*^{s}sI Closed but not(1,2)g*^{s}s Closed.

Theorem4.15: Let A be a (i,j)g*^{s}sI Closed in(X,τ_1,τ_2,I) and F be a τ_j-closed set in(X,τ_1,τ_2) , then A∩F is a (i,j)g*^{s}sI Closed in(X,τ_1,τ_2,I).

Proof: Let A be a (i,j)g*^{s}sI Closed in(X,τ_1,τ_2,I) and F be a τ_j-closed set in(X,τ_1,τ_2).By Theorem 4.11, every τ_j-closed set , F is (i,j)g*^{s}sI Closed in X. Also by Theorem 4.2 the intersection of two (i,j)g*^{s}sI Closed sets is also an (i,j)g*^{s}sI Closed set.Then A∩F is a (i,j)g*^{s}sI Closed in (X,τ_1,τ_2,I).

5. (i,j)g*ssI OPEN SETS

Definition 5.1: Let (X,τ_1,τ_2) be a bitopological space and I be an ideal on X. A subset A⊂X is said to be (i,j)g*^{s}sI Open in X ,with respect to the ideal I ,if X\A is (i,j)g*^{s}sI Closed.

Theorem 5.2: A set A is (i,j)g*^{s}sI Open in (X,τ_1,τ_2,I) if and only if F\U ⊂τ_j –sint(A) , for some U∈I, whenever F⊂A and F is τ_i –rg closed.

Proof: Necessary: Let A be (i,j)g*^{s}sI Open. Suppose F⊂A and F is τ_i –closed. Then F is τ_i –rg closed. We have, X\A ⊂ X\F. By assumption, let τ_j –scl(X\A) ⊂ (X\F) ∪ U, for some U∈ I. Then(X\ [(X\F) ∪ U]) ⊂ X\ τ_j –scl(X\A) Therefore F\U ⊂ τ_j –sint(A).

Sufficient: Conversely, assume that F⊂A and F is τ_i –rg closed and F\U ⊂ τ_j –sint(A) ,for some U∈ I. Consider a τ_i –rg open set G , such that X\A⊂ G. Then x\G ⊂ A. By assumption,(X\G)\U ⊂ τ_j –sint(A) = X\$\tau_j$ –scl(X\A) , for some U∈I. Therefore X\(G∪U) ⊂ X\$\tau_j$ –scl(X\A). Then τ_j –scl(X\A) ⊂ G∪U , for some U∈I. Therefore τ_j –scl(X\A)\G ∈I.Hence X\A is (i,j)g*^{s}sI Closed . Therefore A is (i,j)g*^{s}sI Open .

Remark 5.3: If A and B are (i,j)g*^{s}sI open sets in (X,τ_1,τ_2,I) , then A∩B need not be an (i,j)g*^{s}sI open set ,as shown by the following example.

Example 5.4: Let X={a,b,c} ,τ_1={ϕ,{a},{a,c},X} ,τ_2 ={ϕ,{a},{c},{a,c},X} and I={ϕ,{a}}.Then {a,b} and {b,c} are (1,2)g*^{s}sI open but {b} is not (1,2)g*^{s}sI open.

Theorem 5.5: If A⊂B⊂X , A is (i,j)g*^{s}sI open relative to B and B is (i,j)g*^{s}sI open relative to X, then A is (i,j)g*^{s}sI open relative to X.

Proof: Suppose A⊂B⊂X and let A be (i,j)g*^{s}sI open relative to B and B be (i,j)g*^{s}sI open relative to X. Suppose let F⊂ A and F is τ_i –rg closed .Since A is (i,j)g*^{s}–sI open relative to B , by theorem 5.2 , F\$U_1$ ⊂τ_j –$sint_B$(A) , for some U_1∈I. ⇒there exists an τ_i –rg open set G_1 such that F\$U_1$ ⊂ G_1∩ B⊂A_1 , for some U_1∈I. Since B is (i,j)g*^{s}sI open relative to X and let F⊂ B , then we have F\$U_2$ ⊂τ_j –sint(B) , for some U_2∈I. ⇒ there exists an τ_i –rg open set G_2 such that F\$U_2$ ⊂ G_2 ⊂B , for some U_2∈I. Now F\ (U_1∪ U_2) ⊂ (F\$U_1$)∩(F\$U_2$) ⊂ A∩B⊂A.⇒ F \(U_1∪ U_2) ⊂ τ_j –sint(A) , for some U_1∪ U_2∈I. Hence A is (i,j)g*^{s}sI open relative to X.

Theorem 5.6: If τ_j –sint(A) ⊂ B ⊂ A and if A is (i,j)g*^{s}–sI open in (X,τ_1,τ_2,I) ,then B is (i,j)g*^{s}sI open in (X,τ_1,τ_2,I).

Proof: Suppose τ_j –sint(A) ⊂ B ⊂ A and if A is (i,j)g*^{s}sI open , then (X\A) ⊂ (X\B) ⊂ τ_j –scl(X\A) and (X\A) is (i,j)g*^{s}sI closed. Then by theorem4.6, (X\B) is (i,j)g*^{s}sI closed and hence B is (i,j)g*^{s}sI open.

Theorem 5.7: A set A is (i,j)g*^{s}sI closed in (X,τ_1,τ_2,I) if and only if τ_j –scl(A)\A is (i,j)g*^{s}–sI open.

Proof: Necessary: Suppose F⊂τ_j –scl(A)\A and F is τ_i –rg closed then by theorem 4.8 , F∈ I.

Therefore F\U =ϕ for some U∈I. Clearly, F\U⊂τ_j –sint(τ_j –scl(A)\A).Then by theorem 5.2, τ_j –scl(A)\A is (i,j)g*^{s}sI open.

Sufficient: Conversely, suppose A⊂ G and G is τ_j –closed in (X,τ_1,τ_2,I) then ,τ_j –scl(A)∩(X\G)⊂ τ_j –scl(A)∩(X\A) =τ_j –scl(A)\A. By hypothesis, τ_j –scl(A)∩(X\G)\U⊂ τ_j –sint(τ_j –scl(A)\A) =ϕ, for some U∈I.Thenτ_j –scl(A)∩(X\G) ⊂ U∈I and hence =τ_j –scl(A)\G∈I. Then A is (i,j)g*^{s}sI closed.

6. CONCLUSION

In this paper (i,j)g*^{s}s closed and open sets with respect to an ideal in a bitopological space are defined and some of their properties are investigated. Additionally, the inclusion relations of these sets are compared with many other existing sets in the literature and they are depicted in the diagram for quick reference. Also we have characterized many other results on it.

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