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SOME MORE PROPERTIES OF (1,2)S_β-OPEN SETS IN BITOPOLOGICAL SPACES

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Abstract: The aim of this paper is to define some operators using (1,2)S_β-open sets in bitopological spaces and study some of their properties.

Keywords and Phrases: (1,2)semi-open sets, (1,2)S_β-open sets, (1,2)β-closed sets, (1,2)S_β-Interior, (1,2)S_β-Closure, (1,2)S_β-Derived sets.

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1. Introduction and Preliminaries

In the year 1963, Kelly initiated the systematic study of bitopology which is a triple (X, τ, σ), where X is a non-empty set together with two distinct topologies τ, σ on X. Levine initiated semi-open sets and their properties in 1963. In 1983, Abd-El-monsef introduced the notion of β-open sets and β-continuity in topological spaces. In 2013, Alias B.Khalaf and Nehmat K. Ahmed introduced and defined a new class of semi-open sets called S_β-open sets in topological spaces. The aim of this paper is to define some operators of (1,2)S_β-open sets in bitopological spaces and study some of their properties.

Definition 1.1. [5] *Let A be a subset of a bitopological space (X, τ_1, τ_2). Then A is said to be*

(i) $\tau_1\tau_2$*-open if* $A \in \tau_1 \cup \tau_2$,
(ii) $\tau_1\tau_2$*-closed if* $A^c \in \tau_1 \cup \tau_2$,

(iii) $(1,2)\beta$-*open if* $A \subseteq \tau_1\tau_2 - cl(\tau_1 - int(\tau_1\tau_2 - cl(A)))$, *where* τ_1-*Int(A) is the interior of A with respect to the topology* τ_1 *and* $\tau_1\tau_2$-*Cl(A) is the intersection of all* $\tau_1\tau_2$-*closed sets containing A.*

(iv) $(1,2)\beta$-*Int(A) is the union of all (1,2)*β*-open sets contained in A.*

(v) $(1,2)\beta$-*Cl(A) is the intersection of all (1,2)*β*-closed sets containing A.*

Definition 1.2. [5] *A subset A of X is said to be*

(i) (1,2)semi-open if $A \subseteq \tau_1\tau_2\text{-}Cl(\tau_1\text{-}Int(A))$,

(ii) (1,2)regular-open if $A = \tau_1\text{-}Int(\tau_1\tau_2\text{-}Cl(A))$,

(iii) (1,2)β*-open if* $A \subseteq \tau_1\tau_2\text{-}Cl(\tau_1\text{-}Int(\tau_1\tau_2\text{-}Cl(A)))$.

The set of all (1,2)semi-open, (1,2)regular-open, (1,2)β*-open are denoted as (1,2)SO*(X,τ_1,τ_2)*, (1,2)RO*(X,τ_1,τ_2)*, (1,2)*$\beta O(X,\tau_1,\tau_2)$ *or simply, (1,2)SO(X), (1,2)RO(X), (1,2)*$\beta O(X)$ *respectively.*

Definition 1.3. [3] *A subset A of X is said to be*

(i) (1,2)semi-closed if $\tau_1\tau_2\text{-}Int(\tau_1\text{-}Cl(A)) \subseteq A$.

(ii) (1,2)regular-closed if $A = \tau_1\text{-}Cl(\tau_1\tau_2\text{-}Int(A))$

(iii) (1,2)β*- closed if* $\tau_1\tau_2\text{-}Int(\tau_1 - Cl(\tau_1\tau_2\text{-}Int(A))) \subseteq A$.

The set of all (1,2)semi-closed, (1,2)regular-closed, (1,2)β*-closed are denoted as (1,2)SCL*(X,τ_1,τ_2)*, (1,2)RCL*(X,τ_1,τ_2)*, (1,2)*$\beta CL(X,\tau_1,\tau_2)$ *or simply, (1,2)SCL(X), (1,2)RCL(X), (1,2)*$\beta CL(X)$ *respectively.*

Remark 1.4. [5] *For any subset A of X,*

(i) $\tau_1\text{-}Int(A) \subseteq \tau_1\tau_2\text{-}Int(A)$ *and* $\tau_2\text{-}Int(A) \subseteq \tau_1\tau_2\text{-}Int(A)$.

(ii) $\tau_1\tau_2\text{-}Cl(A) \subseteq \tau_1\text{-}Cl(A)$ *and* $\tau_1\tau_2\text{-}Cl(A) \subseteq \tau_2\text{-}Cl(A)$.

(iii) $\tau_1\tau_2\text{-}Cl(A \cap B) \subseteq \tau_1\tau_2\text{-}Cl(A) \cap \tau_1\tau_2\text{-}Cl(B)$.

(iv) $\tau_1\tau_2\text{-}Int(A) \cup \tau_1\tau_2\text{-}Int(B) \subseteq \tau_1\tau_2\text{-}Int(A \cup B)$.

Theorem 1.5. [1] *Let* (X,τ_1,τ_2) *be a bitopological space. If* $A \in \tau_1$ *and* $B \in$ *(1,2)SO(X), then* $A \cap B \in$ *(1,2)SO(X).*

Theorem 1.6. [1] *Let* $A \subset Y \subset (X,\tau_1,\tau_2)$ *and if A is* τ_i*-semi open in X, then A is* τ_i*-semi open in Y.*

Definition 1.7. [8] *A (1,2)semi-open subset A of a bitopological space* (X,τ_1,τ_2) *is said to be (1,2)*S_β*-open if for each* $x \in A$ *there exists a (1,2)*β*-closed set F such that* $x \in F \subseteq A$.

2. (1,2)S_β-Operations

Definition 2.1. *A subset N of a bitopological space* (X,τ_1,τ_2) *is called (1,2)*S_β*-neighborhood, if there exists a (1,2)*S_β*-open set U such that* $A \subseteq U \subseteq N$.

If $A = \{x\}$*, then N is (1,2)*S_β*- neighborhood of x.*

Definition 2.2. *A point $x \in X$ is said to be a (1,2)S_β- interior point of A, if there exists a (1,2)S_β-open set U containing x such that $x \in U \subseteq A$.*

The set of all (1,2)S_β-interior points of A is said to be (1,2)S_β-interior of A and it is denoted by (1,2)S_β-$Int(A)$.

Proposition 2.3. *Let A be any subset of a bitopological space X. If a point x is in the (1,2)S_β-interior of A, then there exists a (1,2)β-closed set F of X containing x such that $F \subseteq A$.*

Proof. Suppose that $x \in$ (1,2)S_β-$Int(A)$. Then there exists a (1,2)S_β-open set U of X containing x such that $U \subseteq A$. Since U is a (1,2)S_β-open set, there exists a (1,2)β-closed set F containing x such that $F \subseteq U \subseteq A$ and hence $x \in F \subseteq A$.

Remark 2.4. *For any subset A of a bitopological space X, the following statements are true.*

(i) (1,2)S_β-Interior of A is the union of all (1,2)S_β-open sets contained in A.

(ii) (1,2)S_β-Int(A) is the largest (1,2)S_β-open set contained in A.

(iii) A is (1,2)S_β-open set if and only if $A =$ (1,2)S_β-$Int(A)$.

Proposition 2.5. *If A and B are any two subsets of a bitopological space X, then*

(i) (1,2)S_β-$Int(\phi) = \phi$, and (1,2)S_β-$Int(X) = X$.

(ii) (1,2)S_β-$Int(A) \subseteq A$.

(iii) If $A \subseteq B$, then (1,2)S_β-$Int(A) \subseteq$ (1,2)S_β-$Int(B)$.

(iv) (1,2)S_β-$Int(A)\cup$ (1,2)S_β-$Int(B) \subseteq$ (1,2)S_β-$Int(A \cup B)$.

(v) (1,2)S_β-$Int(A \cap B) \subseteq$ (1,2)S_β-$Int(A)\cap$(1,2)S_β-$Int(B)$.

(vi) (1,2)S_β-$Int(A–B) \subseteq$ (1,2)S_β-$Int(A)–$ (1,2)S_β-$Int(B)$.

Proof. Follows from definition 2.2.

Note 2.6. *The converse of (iii) (iv), (v), (vi) of the above proposition need not be always true and is shown in the following examples.*

Example 2.7. Let $X = \{a, b, c, d\}$ with the topologies $\tau_1 = \{\phi$, X, {a}, {a, b}} and $\tau_2 = \{\phi$, X, {a}, {c}, {a, c}}. Let $A = \{a, d\}$ and $B = \{a, b, c\}$, then (1,2)S_β-$Int(A) = \{a\}$, (1,2)S_β-$Int(B) = \{a, b\}$. It follows that (1,2)S_β- $Int(A) \subseteq$ (1,2)S_β-$Int(B)$ but A is not a subset of B.

Example 2.8. Let $X = \{a, b, c, d\}$ with the topologies $\tau_1 = \{\phi$, X, {b}, {a, c}, {a, b, c}, {a, c, d}} and $\tau_2 = \{\phi$, X }. Take $A = \{a, c\}$ and $B = \{b, d\}$. Then, $(1, 2)S_\beta$-$Int(A) = \{a, c\}$, (1,2)S_β-$Int(B) = \{b\}$ and (1,2)S_β-$Int(A)\cup$ (1,2)S_β-$Int(B)$ = {a, b, c} and (1,2)S_β-$Int(A \cup B) = X$. It follows that (1,2)S_β- $Int(A \cup B)$ is not a subset of (1,2)S_β- $Int(A) \cup$ (1,2)S_β-$Int(B)$.

Example 2.9. Let $X = \{a, b, c\}$ with the topologies $\tau_1 = \{\phi$, X, {a, c}} and $\tau_2 =$

{ϕ, X, { b}}. Then, (1,2)$S_\beta O(X)$ = {ϕ, X, {a}, {c}, {a, b}, {a, c}, {b, c}}. If we take $A = \{a, b\}, B = \{b, c\}$, then (1,2)$S_\beta$-$Int(A)$ = {a, b}, (1,2)S_β-$Int(B)$ = {b, c} and (1,2)$S_\beta - Int(A) \cap$ (1,2)S_β-$Int(B)$ = {b}, (1,2)S_β-$Int(A \cap B) = \phi$. It follows that (1,2)S_β- $Int(A)$ $\cap$ (1,2)S_β-$Int(B)$ is not a subset of (1,2)S_β- $Int(A \cap B)$.

Also, if we take $A = \{b, c\}$ and $B = \{c\}$, then (1,2)S_β-$Int(A) = \{b, c\}$, (1,2)S_β-$Int(B) = \{c\}$ and (1,2)S_β-$Int(A)$–(1,2)S_β-$Int(B) = \{b\}$ but (1,2)S_β-$Int(A–B) = \phi$. It follows that (1,2)S_β- $Int(A)$–(1,2)S_β-$Int(B)$ is not a subset of (1,2)S_β- $Int(A–B)$.

Definition 2.10. *Let A be a subset of a bitopological space X. A point $x \in X$ is in (1,2)S_β-Closure of A if and only if $A \cap U \neq \phi$, for every (1,2)S_β-open set U containing x.*

The intersection of all (1,2)S_β-closed sets containing F is called (1,2)S_β-Closure of F and is denoted by (1,2)S_β-Cl(F).

Proposition 2.11. *Let A be a subset of a bitopological space X. If $A \cap F \neq \phi$, for every (1,2)β-closed set F of X containing x, then the point x is in (1,2)S_β-Closure of A.*

Proof. Suppose that U is any (1,2)S_β-open set containing x. Then by definition 1.7, there exists (1,2)β-closed set F such that $x \in F \subseteq U$. So by hypothesis, $A \cap F \neq \phi$ which implies that $A \cap U \neq \phi$, for every (1,2)S_β-open set U containing x. Therefore, $x \in$ (1,2)S_β-Cl(A).

Remark 2.12. *For any subset F of a bitopological space X, the following statements are true.*

(i) (1,2)S_β-Cl(F) is the intersection of all (1,2)S_β-closed set in X containing F.

(ii) (1,2)S_β-Cl(F) is the smallest (1,2)S_β-closed set containing F.

(iii) F is (1,2)S_β-closed set if and only if F = (1,2)S_β-Cl(F).

Theorem 2.13. *If F and E are any two subsets of a bitopological space X, then*

(i) (1,2)S_β-Cl(ϕ) = ϕ and (1,2)S_β-$CL(X) = X$.

(ii) For any subset F of X, $F \subseteq$ (1,2)S_β-Cl(F).

(iii) If $F \subseteq E$, then (1,2)S_β-Cl(F) $\subseteq$ (1,2)S_β-Cl(E).

(iv) (1,2)S_β-Cl(F)$\cup$ (1,2)S_β-Cl(E) $\subseteq$ (1,2)S_β-Cl($F \cup E$).

(v) (1,2)S_β-Cl($F \cap E$) $\subseteq$ (1,2)S_β-Cl(F)$\cap$ (1,2)S_β-Cl(E).

Proof. Follows from definition 2.10.

Note 2.14. *From the above theorem, (1,2)S_β-Cl(F)$\cup$ (1,2)S_β-Cl(E) $\neq$ (1,2)S_β-Cl($F \cup E$) and (1,2)S_β-Cl($F \cap E$) $\neq$ (1,2)S_β-Cl(F)$\cap$ (1,2)S_β-Cl(E), it is shown in the following example.*

Example 2.15. Let $X = \{a, b, c, d\}$ with the topologies τ_1 = {ϕ, X, {a}, {b}, {a, b}} and τ_2 = {ϕ, X, {a, b, d}}, then $(1,2)S_\beta$-CL(X) = {ϕ, X, {a}, {b}, {c}, {d},{a, c}, {a, d},{b, c}, {b, d}, {c, d}, {a, c, d}, {b, c, d} }. If we take $F = \{b\}$ and $E = \{a\}$ then $(1,2)S_\beta\text{-}Cl(F) = \{b\}$ and (1,2)S_β-$Cl(E) = \{a\}$ then (1,2)S_β-$Cl(F)\cup$ (1,2)S_β-$Cl(E) = \{a,b\}$ but (1,2)S_β-$Cl(F \cup E) = X$. Hence, (1,2)S_β-$Cl(F)\cup$ (1,2)S_β-$Cl(E) \neq$ (1,2)S_β-$Cl(F \cup E)$.

Again if we take $F = \{a,b\}$ and $E = \{a,c,d\}$, we get (1,2)S_β-$Cl(F) = X$ and (1,2)S_β-$Cl(E) = \{a,c,d\}$, then (1,2)S_β-$Cl(F)\cap$ (1,2)S_β-$Cl(E) = \{a,c,d\}$, but (1,2)S_β-$Cl(F \cap E) = \{a\}$. Hence, (1,2)S_β-$Cl(F \cap E) \neq$ (1,2)S_β-$Cl(F)\cap$ (1,2)S_β-$Cl(E)$.

Definition 2.16. *Let A be a subset of a bitopological space X. A point $x \in X$ is said to be (1,2)S_β-limit point of A if for each (1,2)S_β-open set U containing x, $U \cap (A–\{x\}) \neq \phi$. The set of all (1,2)$S_\beta$-limit points of A is called* $(1,2)S_\beta$- *derived set of A and is denoted by (1,2)S_β-$D(A)$.*

Proposition 2.17. *Let A be any subset of X. If $F \cap (A–\{x\}) \neq \phi$, for every (1,2)$\beta$-closed set F containing x, then $x \in$ (1,2)S_β-$D(A)$.*

Proof. Let U be any (1,2)S_β-open set containing x. Then there exists (1,2)β-closed set F such that $x \in F \subseteq U$. By hypothesis, $F \cap (A–\{x\}) \neq \phi$. Hence $U \cap (A–\{x\}) \neq \phi$. Therefore, $x \in$ (1,2)S_β-$D(A)$.

Proposition 2.18. *If a subset A of a bitopological space X is (1,2)S_β-closed, then A contains the set of all its (1,2)S_β-limit points.*

Proof. Suppose that A is (1,2)S_β-closed set, then $X–A$ is (1,2)S_β- open set. Thus A is (1,2)S_β-closed set if and only if each point of $X–A$ has (1,2)S_β-neighborhood contained in $X–A$, that is, if and only if no point of $X–A$ is (1,2)S_β-limit point of A or equivalently that A contains each of its (1,2)S_β-limit points.

Proposition 2.19. *Let A and B be two subsets of a bitopological space X. If $A \subseteq B$, then (1,2)S_β-$D(A) \subseteq$ (1,2)S_β-$D(B)$.*

Proof. Let $x \in$ (1,2)S_β-$D(A)$. Then by definition 2.16, for all (1,2)S_β-open set U containing x such that $U \cap (A–\{x\}) \neq \phi$. Since $A \subseteq B$, $U \cap (B–\{x\}) \neq \phi$. Therefore $x \in$ (1,2)S_β-$D(B)$ which implies that (1,2)S_β-$D(A) \subseteq$ (1,2)S_β-$D(B)$.

Remark 2.20. *Let A and B be subsets of a bitopological space X. Then we have the following properties:*

(i) (1,2)S_β-$D(\phi) = \phi$.

(ii) (1,2)S_β-$D(A) \cup (1,2)S_\beta$-$D(B)) \subseteq$ (1,2)S_β-$D(A \cup B)$.

(iii) (1,2)S_β-$D(A \cap B) \subseteq$ (1,2)S_β-$D(A)$ $\cap$ (1,2)S_β-$D(B)$.

(iv) If A is (1,2)S_β-closed, then (1,2)S_β-$D(A) \subseteq A$.

Theorem 2.21. *Let X be any bitopological space and A be a subset of X, then*

(i) $A\cup$ *(1,2)*S_β*-*$D(A))$ *is (1,2)*S_β*-closed.*
(ii) (1,2)S_β*-*$D($*(1,2)*S_β*-*$D(A))$*–*$A \subseteq$ *(1,2)*S_β*-*$D(A)$.
(iii) (1,2)S_β*-*$D(A \cup$ *(1,2)*S_β*-*$D(A)) \subseteq A\cup$ *(1,2)*S_β*-*$D(A)$.

Proof. (i) Let $x \notin A\cup$(1, 2)S_β-$D(A)$. Then $x \notin A$ and $x \notin$ (1, 2)S_β-$D(A)$. This implies that there exists a (1, 2)S_β-open set N_x in X which contains no point of A other than x. But $x \notin A$, so N_x contains no point of A, which implies that $N_x \subseteq X$–A. Again N_x is a (1, 2)S_β-open set and it is a neighborhood of each of its points. Also N_x does not contain any point of A implies no point of N_x can be (1, 2)S_β-limit point of A. Therefore, no point of N_x can belong to (1,2)S_β-$D(A)$ and this implies that $N_x \subseteq X$– (1, 2)S_β-$D(A)$. Hence it follows that $x \in N_x \subseteq (X$–$A) \cap (X$– (1, 2)S_β-$D(A)) \subseteq X$–$(A \cup$ (1,2)S_β-$D(A))$. Therefore, $A\cup$(1,2)S_β-$D(A)$ is (1, 2)S_β-closed.

(ii) Let $x \in$ (1, 2)S_β-$D($(1,2)S_β-$D(A))$–A. Then by definition 2.16, U is a (1,2)S_β-open set containing x such that $U \cap$ ((1,2)S_β-$D(A)$–$\{x\}) \neq \phi$. Now let $y \in (U \cap$ (1,2)S_β-$D(A)$–$\{x\})$. Then $y \in U$ and $y \in$ (1,2)S_β-$D(A)$, so $U \cap (A$–$\{y\}) \neq \phi$. Let $z \in (U \cap (A$–$\{y\})$. Then, for $z \in A$ and $x \notin A$, $z \neq x$. Hence $U \cap (A$–$\{x\}) \neq \phi$. Therefore, $x \in$ (1,2)S_β-$D(A)$.

(iii) Let $x \in$ (1,2)S_β-$D(A \cup$ (1,2)S_β-$D(A))$. If $x \in A$, then the result is obvious. So, let $x \in$ (1,2)S_β-$D(A\cup$ (1,2)S_β-$D(A))$–A. Then, by definition 2.16, for each (1,2)S_β-open set U containing x such that $U\cap(A \cup$ (1,2)S_β-$D(A))$–$\{x\})) \neq \phi$. Thus, either $U \cap (A$–$\{x\}) \neq \phi$ or U $\cap$ (1,2)S_p-$D(A)\{x\} \neq \phi$. Now, $U \cap (A$–$\{x\}) \neq \phi$ implies that $x \in$ (1,2)S_β-$D(A)$. Therefore (1,2)S_β-$D(A \cup$(1,2)S_β-$D(A)) \subseteq A \cup$ (1,2)S_β-$D(A)$.

Theorem 2.22. *Let* A *be a subset of a bitopological space* X*,*
then (1,2)S_β*-*$Cl(A) = A\cup$ *(1,2)*S_β*-*$D(A)$*.*

Proof. Since (1,2)S_β-$D(A) \subseteq$ (1,2)S_β-$Cl(A)$ and $A \subseteq$ (1,2)S_β-$Cl(A)$ implies $A\cup$ (1,2)S_β-$D(A) \subseteq$ (1,2)S_β-$Cl(A)$. Again since (1,2)S_β-$Cl(A)$ is the smallest (1,2)S_β-closed set containing A, $A \cup$(1,2)S_β-$D(A)$ is (1,2)S_β-closed. Hence (1,2)S_β-$Cl(A) \subseteq A \cup$(1,2)S_β-$D(A)$. Thus (1,2)S_β-$Cl(A) = A \cup$((1,2)S_β-$D(A))$.

Theorem 2.23. *Let* X *be any bitopological space and* A *be a subset of* X*.*
Then, (1,2)S_β*-*$Int(A) = A$*–(*(1,2)$S_\beta - D(X$–$A))$.

Proof. Obvious.

3. Conclusion

In this work, we have defined some operators of (1,2)S_β-open sets in bitopological spaces and studied their properties. This work will lead to find another operators like $\underset{(1,2)S_\beta}{\wedge}$ - set and $\underset{(1,2)S_\beta}{\vee}$ - set of corresponding sets. Also, these findings will help to carry out more theoretical research for future researchers.

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