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(1,2)*-δgp Closed Sets in Bitopological Spaces

KEY WORDS: (1,2)*-δgp closed sets,(1,2)*-δgp open sets and (1,2)*-δgp open.

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ABSTRACT

The aim of this paper is to introduce the concepts of (1,2)δ*gp* *– closed sets. This set placed between (1,2)δgp *- pre-closed and (1,2)δgp *-closed sets. Also we discussed the relationship between this type of closed set and other existing closed sets in bitopological spaces. Also we introduce new class of open sets namely (1,2)δgp *-open sets. We obtain some of their basic properties.

1 Introduction

In 1963 , Kelley [4] initiated the study of bitopological spaces. A nonempty set X equipped with two topological spaces τ_1 and τ_2 is called a bitopological spaces and is denoted by (X,τ_1,τ_2). Fukutake [3] introduced generalized closed sets in bitopological space. M. Lellis Thivagar and O.Ravi [7] introduced a new type of generalized sets called (1,2)*-semi generalized closed sets and a new class of generalized functions called (1,2)*-semi generalized continuous maps in 2006. S.S. Benchalli and J.B.Toranagatti [1] introduced delta generalized pre-closed sets in topological space. In this paper, we introduced the new concepts of $(1,2)^*-\delta gp$ closed sets and $(1,2)^*-\delta gp$ open sets and study their basic properties in bitopological spaces.

2 Preliminaries

Throughout this paper (X,τ_1,τ_2) (or briefly X) represent bitopological spaces on which no separation axioms are assumed unless otherwise mentioned.

Definition 2.1. [8] A subset B of a bitopological space (X,τ_1,τ_2) is called $\tau_1\tau_2-$open if $B=U_1\bigcup U_2$ where $U_1\in\tau_1$ and $U_2\in\tau_2$. The complement of $\tau_1\tau_2-$open is called $\tau_1\tau_2-$closed.

Remark 2.2. [8] $\tau_1\tau_2-$open X subset of need not necessarily from a topology.

Definition 2.3. [8] A subset A of a bitopological space (X,τ_1,τ_2) is called

(i) The $\tau_1\tau_2-$closure of A, denoted by $\tau_1\tau_2$-cl(A) is defined by $\tau_1\tau_2-$closure $(A)=\bigcap\{F/ A\subseteq F$ and F is $\tau_1\tau_2-$closed$\}$.

(ii) The $\tau_1\tau_2-$interior of A, denoted by $\tau_1\tau_2$ -int(A) is defined by $\tau_1\tau_2-$interior $(A)=\bigcup\{F/ A\subseteq F$ and F is $\tau_1\tau_2-$open$\}$.

Definition 2.4. A subset A of a bitopological space (X,τ_1,τ_2) is called

(i) (1,2)*-pre-open [8] if $A\subseteq\tau_1\tau_2\text{-int}(\tau_1\tau_2\text{-cl}(A))$and (1,2)*-pre-closed if $\tau_1\tau_2\text{-cl}(\tau_1\tau_2\text{-int}(A))\subseteq A$.

(ii) $(1,2)^*-b$ open [5] if $A \subseteq (\tau_1\tau_2\text{-cl}(\tau_1\tau_2\text{-int}(A))) \bigcup (\tau_1\tau_2\text{-int}(\tau_1\tau_2\text{-cl}(A)))$ and $(1,2)^*$-b closed if $(\tau_1\tau_2\text{-cl}(\tau_1\tau_2\text{-int}(A))) \bigcap (\tau_1\tau_2\text{-int}(\tau_1\tau_2\text{-cl}(A))) \subseteq A$.
(iii) $(1,2)^*$-regular-open [11] if $A = \tau_1\tau_2\text{-int}(\tau_1\tau_2\text{-cl}(A))$ and $(1,2)^*$- regular-closed if $A = \tau_1\tau_2\text{-cl}(\tau_1\tau_2\text{-int}(A))$.
The $(1,2)^*$-pre-closure of a subset A of X, denoted by $(1,2)^*$-pcl(A) is the intersection of all $(1,2)^*$-pre-closed sets containing A. The $(1,2)^*$-pre-interior of a subset A of X, denoted by $(1,2)^*$-pint(A) is the union of $(1,2)^*$-pre-open sets contained in A.

Definition 2.5. A subset A of a bitopological space (X,τ_1,τ_2) is called
(i) $(1,2)^*$- generalized closed set (briefly $(1,2)^*$-g closed) [10] if $\tau_1\tau_2\text{-cl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_1\tau_2$-open in X.
(ii) (1, 2)*- generalized b -closed set (briefly $(1,2)^*$-gb closed) [12] if $\tau_1\tau_2\text{-bcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_1\tau_2$-open in X.
(iii) (1, 2)*- generalized pre-closed set (briefly $(1,2)^*$-gp closed) [13] if $\tau_1\tau_2\text{-pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_1\tau_2$-open in X.
(iv) (1, 2)*- generalized pre regular closed set (briefly $(1,2)^*$-gpr closed) [9] if $\tau_1\tau_2\text{-pcl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $(1,2)^*$-regular open in X.
The complement of the above mentioned closed sets are their respective open sets.

3 $(1,2)^*$-δgp Closed Sets

We introduce the following definitions.

Definition 3.1. The $(1,2)^*$-δ interior of a subset A of X is the union of all $(1,2)^*$-regular open set of X contained in A and is denoted by $(1,2)^*$-δ int(A). The subset A is called $(1,2)^*$-δ open if $A = (1,2)^*$-δ int(A), ie. a set is $(1,2)^*$-δ open if it is the union of $(1,2)^*$-regular open sets. The complement of a $(1,2)^*$-δ open is called $(1,2)^*$-δ closed. Alternatively, a set $A \subseteq (X,\tau_1,\tau_2)$ is called $(1,2)^*$-δ closed if $A = (1,2)^*$-δcl(A), where $(1,2)^*\text{-}\delta\text{cl}(A) = \{x \in X : \tau_1\tau_2\text{-int}(\tau_1\tau_2\text{-cl}(A)) \bigcap A \neq \phi,\ U \in \tau_1\tau_2, x \in U\}$.

Definition 3.2. $(1,2)^*$-δ generalized closed set (briefly $(1,2)^*$-δg closed) if $\tau_1\tau_2\text{-}\delta\text{cl}(A) \subseteq U$ whenever $A \subseteq U$ and U is $\tau_1\tau_2$-open in X.

Definition 3.3. A subset A of a bitopological space (X,τ_1,τ_2) is called $(1,2)^*$- delta generalized pre-closed (briefly, $(1,2)^*$-δgp closed) if $(1,2)^*$-pcl(A) $\subseteq U$ whenever $A \subseteq U$ and U is $(1,2)^*$-δ open in X. The family of all $(1,2)^*$-δgp closed sets in a bitopological space X is denoted by δGPC(X).

Example 3.4. Let $X = \{a,b,c\}$, $\tau_1 = \{\phi,\{a\},X\}$ and $\tau_2 = \{\phi,\{b\},\{a,b\},X\}$, then $(1,2)^*$-δGPC(X) $= \{\phi,\{c\},\{b,c\},\{a,c\},X\}$.

Theorem 3.5. Every $(1,2)^*$-closed set is $(1,2)^*$-δgp closed set.

Example 3.7. Let $X = \{a, b, c\}$, $\tau_1 = \{\phi, \{b\}, X\}$ and $\tau_2 = \{\phi, \{a\}, \{a, c\}, X\}$. Then $\{a, b\}$ is $(1,2)^*$-δgp closed but not $(1,2)^*$-closed.

Theorem 3.8. Every $(1,2)^*$-pre-closed set is $(1,2)^*$-δgp closed set.
Proof. Suppose that A is $(1,2)^*$-pre-closed. Let $A \subseteq U$ and U is $(1,2)^*$-δ open in X. Since A is $(1,2)^*$-pre-closed, $(1,2)^*$-pcl(A) = A. Hence $(1,2)^*$-pcl(A) $\subseteq U$. Therefore A is $(1,2)^*$-δgp closed.

Remark 3.9. The converse of the above theorem is not true in general as shown in the following example.

Example 3.10. Let $X = \{a, b, c, d\}$, $\tau_1 = \{\phi, \{b\}, \{a, b\}, \{a, b, c\}, X\}$ and $\tau_2 = \{\phi, \{a\}, \{b\}, \{a, b\}, X\}$. Then $\{a, b, d\}$ is $(1,2)^*$-δgp closed but not $(1,2)^*$-preclosed.

Theorem 3.11. Every $(1,2)^*$-gp closed set is $(1,2)^*$-δgp closed set.
Proof. Suppose that A is $(1,2)^*$-gp closed. Let $A \subseteq U$ and U is $(1,2)^*$-δ open in X. Suppose A is not $(1,2)^*$-δgp closed, then $(1,2)^*$-pcl(A) $\not\subset U$. Since every $(1,2)^*$-δ open set is $\tau_1\tau_2$-open, $(1,2)^*$-pcl(A) $\not\subset U$. and U is $\tau_1\tau_2$-open. This contradicts that A is $(1,2)^*$-δgp closed.

Remark 3.12. The converse of the above theorem is not true in general as shown in the following example.

Example 3.13. Let $X = \{a, b, c, d\}$, $\tau_2 = \{\phi, \{b\}, \{a, b, c\}, X\}$ and $\tau_2 = \{\phi, \{a\}, \{a, b\}, X\}$. Then $\{a, c\}$ is $(1,2)^*$-δgp closed but not $(1,2)^*$-gp closed.

Theorem 3.14. Every $(1,2)^*$-δgp closed set is $(1,2)^*$-gpr closed set.
Proof. Suppose that A is $(1,2)^*$-δgp closed. Let $A \subseteq U$ and U is $(1,2)^*$- regular open in X. Suppose A is not $(1,2)^*$-gpr closed, then $(1,2)^*$-pcl(A) $\not\subset U$ and U is $(1,2)^*$-regular open. Since every $(1,2)^*$-regular open set is $(1,2)^*$-δ open in X, $(1,2)^*$-pcl(A) $\not\subset U$ and U is $(1,2)^*$-δ open. This contradicts that A is $(1,2)^*$-gpr closed.

Remark 3.15. The converse of the above theorem is not true in general as shown in the following example.

Example 3.16. Let $X = \{a, b, c\}$, $\tau_1 = \{\phi, \{b\}, \{a, b\}, \{b, c\}, X\}$ and $\tau_2 = \{\phi, \{a\}, \{a, c\}, X\}$. Then $\{a, b\}$ is $(1,2)^*$-gpr closed but not $(1,2)^*$-δgp closed.

Remark 3.17. The following example shows that $(1,2)^*$-δgp closed set is independent of $(1,2)^*$-b closed and $(1,2)^*$-gb closed sets.

Example 3.18. Let $X = \{a, b, c\}$, $\tau_1 = \{\phi, \{a\}, X\}$ and $\tau_2 = \{\phi, \{c\}, \{a, c\}, X\}$. Then $\{a\}$ is $(1,2)^*$-gb closed and $(1,2)^*$-b closed but not $(1,2)^*$-δgp closed.

Example 3.19. Let $X=\{a,b,c,d\}$, $\tau_1=\{\phi,\{a\},\{a,b,c\},X\}$ and $\tau_2=\{\phi,\{b\},\{a,b\},X\}$. Then $\{a,b,c\}$ is $(1,2)^*$-δgp closed but not $(1,2)^*$-b closed and $(1,2)^*$-gb closed.

4 properties of $(1,2)^*$-δgp closed sets

Theorem 4.1. If A is $(1,2)^*$-δgp closed set in a bitopological space (X,τ_1,τ_2) and $A\subseteq B\subseteq(1,2)^*$-pcl(A), then B is $(1,2)^*$-δgp closed.

Proof. Suppose that A is $(1,2)^*$-δgp closed set in a bitopological space (X,τ_1,τ_2) and $A\subseteq B\subseteq(1,2)^*$-pcl(A). Let $B\subseteq U$ and U is $(1,2)^*$-δ open in X. Since $A\subseteq B$ and $B\subseteq U$, we have $A\subseteq U$. Since A is $(1,2)^*$-δgp closed set, $(1,2)^*$-pcl(A) $\subseteq U$. Also since $B\subseteq(1,2)^*$-pcl(A), $(1,2)^*$-pcl(B) $\subseteq(1,2)^*$-pcl$[(1,2)^*$-pcl(A)$]\subseteq(1,2)^*$-pcl(A) $\subseteq$ U. Therefore B is $(1,2)^*$-δgp closed.

Remark 4.2. Union of any two $(1,2)^*$-δgp closed sets in a bitopological space (X,τ_1,τ_2) need not be $(1,2)^*$-δgp closed set as shown in the following example.

Example 4.3. Let $X=\{a,b,c,d,e\}$, $\tau_1=\{\phi,\{a,b\},\{a,b,c,d\},X\}$ and $\tau_2=\{\phi,\{c,d\},X\}$. Then $\{a\}$ and $\{b\}$ are two $(1,2)^*$-δgp closed sets in X. But the union of $\{a\}$ and $\{b\}$ are $\{a,b\}$ is not $(1,2)^*$-δgp closed in X.

Remark 4.4. Intersection of any two $(1,2)^*$-δgp closed sets in a bitopological space (X,τ_1,τ_2) need not be $(1,2)^*$-δgp closed set as shown in the following example.

Example 4.5. Let $X=\{a,b,c,d,e\}$, $\tau_1=\{\phi,\{b\},\{d\},\{b,d\},\{a,b,c,d\},X\}$ and $\tau_2=\{\phi,\{b\},\{d\},\{e\},\{b,e\},\{b,d\},\{d,e\},\{b,d,e\},X\}$. Then $\{a,b,d\}$ and $\{b,c,d\}$ are two $(1,2)^*$-δgp closed sets in X. But the intersection of $\{a,b,d\}$ and $\{b,c,d\}$ are $\{b,d\}$ is not $(1,2)^*$-δgp closed in X.

Theorem 4.6. Let A be a $(1,2)^*$-δgp closed set in X if and only if $(1,2)^*$-pcl(A) - A contains no non empty $(1,2)^*$-δ closed set.

Proof. Suppose that $(1,2)^*$-δgp closed set in X. Let F be $(1,2)^*$-δ closed and $F\subseteq(1,2)^*$-pcl(A) - A, then $F\subseteq(1,2)^*$-pcl(A) and $F\subseteq X$ - A implies $A\subseteq X$ - F. Since F is $(1,2)^*$-δ closed, then X - F is $(1,2)^*$-δ open containing A, it follows that $(1,2)^*$-pcl(A) $\subseteq$ X - F and thus $F\subseteq X$ - $[(1,2)^*$-pcl(A)$]$. This implies that $F\bigcap F\subseteq\{X-(1,2)^*\text{-pcl(A)}\}\bigcap\{(1,2)^*\text{-pcl(A)}\}=(1,2)^*\text{-pcl}(\phi)$ and $F\subseteq\phi$. Hence $(1,2)^*$-pcl(A) - A contains no non empty $(1,2)^*$-δ closed set. Conversely, suppose that $(1,2)^*$-pcl(A) - A contains no non empty $(1,2)^*$-δ closed set. Let $A\subseteq U$ and U is $(1,2)^*$-δ open in X. Suppose that $(1,2)^*$-pcl(A) $\not\subset U$, then $(1,2)^*\text{-pcl(A)}\bigcap U^c\neq\phi$. Since $A\subseteq U, U^c\subseteq A^c$. Then $(1,2)^*\text{-pcl(A)}\bigcap U^c\subseteq(1,2)^*\text{-pcl(A)}\bigcap A^c=$ $(1,2)^*$-pcl(A) - A. Then $(1,2)^*\text{-pcl(A)}\bigcap U^c$ is $(1,2)^*$-δ closed in X. Which is contradiction, therefore $(1,2)^*$-pcl(A) $\subseteq U$. Hence A is $(1,2)^*$-δgp closed in X.

Theorem 4.7. If $A \subseteq X$ is both $(1,2)^*$-δ open and $(1,2)^*$-δgp closed, then A is $(1,2)^*$-pre closed in X.

Proof. Let A be $(1,2)^*$-δ open and $(1,2)^*$-δgp closed set in X, then $(1, 2)^*$- pcl(A) $\subseteq$ A. Always $A \subseteq (1,2)^*$-pcl(A). Then $(1,2)^*$-pcl(A) = A and hence A is $(1,2)^*$-pre closed.

Theorem 4.8. A set A be $(1,2)^*$-δgp closed in X. Then A is $(1,2)^*$-preclosed if and only if $(1,2)^*$-pcl(A) - A is $(1,2)^*$-δ closed set.

Proof. Suppose that A is $(1,2)^*$-δgp closed in X and A is $(1,2)^*$-pre-closed. Since A is $(1,2)^*$-pre-closed, $(1,2)^*$-pcl(A) = A. Then $(1,2)^*$-pcl(A) - A = ϕ is $(1,2)^*$-δ closed. Conversely, suppose that A is $(1,2)^*$-δgp closed and $(1,2)^*$-pcl(A) - A is $(1,2)^*$-δ closed. Since A is $(1,2)^*$-δgp closed, by theorem 4.6, $(1,2)^*$-pcl(A) - A contains no non empty $(1,2)^*$-δ closed set. Since $(1,2)^*$-pcl(A) - A is itself $(1,2)^*$-δ closed, $(1,2)^*$-pcl(A) - A = ϕ. Then $(1,2)^*$-pcl(A) = A. Hence A is $(1,2)^*$-pre-closed.

Theorem 4.9. If A is $(1,2)^*$-δgp closed in X and $A \subseteq B \subseteq (1,2)^*$-pcl(A), then $(1,2)^*$-pcl(B) - B contains no non empty $(1,2)^*$-δ closed set.

Proof. Let A be $(1,2)^*$-δgp closed in X and $A \subseteq B \subseteq (1,2)^*$-pcl(A). Then by theorem 4.1, B is $(1,2)^*$-δgp closed. Again by theorem 4.6, $(1,2)^*$-pcl(B) - B contains no non empty (1, $(1,2)^*$-δ closed set.

5 $(1,2)^*$-δgp Open Sets

Definition 5.1. A subset A of a bitopological space (X,τ_1,τ_2) is called $(1,2)^*$-delta generalized pre-open set (briefly $(1,2)^*$-δgp open) if A^c is $(1,2)^*$-δgp closed. The family of all $(1,2)^*$-δgp open sets in a bitopological space X is denoted by δGPO(X).

Example 5.2. Let $X = \{a, b, c\}, \tau_1 = \{\phi, \{a\}, X\}$ and $\tau_2 = \{\phi, \{b\}, \{a, b\}, X\}$, then $(1,2)^*$-δGPO(X) = $\{\phi, \{a\}, \{b\}, \{a, b\}, X\}$.

Theorem 5.3. A subset A is $(1,2)^*$-δgp open if and only if $F \subseteq (1,2)^*$-pint(A), whenever $F \subseteq A$ and F is $(1,2)^*$-δ closed.

Proof. Let A be $(1,2)^*$-δgp open. Then A^c is $(1,2)^*$-δgp closed. Suppose $F \subseteq A$ and F is $(1,2)^*$-δ closed. Then F^c is $(1,2)^*$-δ open and $A^c \subseteq F^c$. Since A^c is $(1,2)^*$-δgp closed, $(1,2)^*$-pcl$(A^c) \subseteq F^c$. Also since $(1,2)^*$-pcl$(A^c) = \{(1,2)^*\text{-pint}(A)\}^c, \{(1,2)^*\text{-pint}(A)\}^c, \{(1,2)^*\text{-pint}(A)\}^c \subseteq F^c$. Hence $F \subseteq (1,2)^*$-pint(A). Conversely, Suppose $F \subseteq (1,2)^*$-pint(A), whenever $F \subseteq A$ and F is $(1,2)^*$-δ closed. Then $A^c \subseteq F^c$ and F^c is $(1,2)^*$-δ open. Take $U = F^c$, since $F \subseteq (1,2)^*$-pint(A), $\{(1,2)^*\text{-pint}(A)\}^c \subseteq F^c = U$. Also since $(1,2)^*$-pcl$(A^c) = \{(1,2)^*\text{-pint}(A)\}^c$, $(1,2)^*$-pcl$(A^c) \subseteq U$. Then A^c is $(1,2)^*$-δgp closed. Therefore A is $(1,2)^*$-δgp open.

Theorem 5.4. A set A is $(1,2)^*$-δgp closed in X if and only if $(1,2)^*$-pcl(A)- A is $(1,2)^*$-δgp open.

Proof. Suppose that A is $(1,2)^*$-δgp closed in X. Let S be a $(1,2)^*$-δ closed and $S \subseteq (1,2)^*\text{-pcl}(A) - A$. Since A is $(1,2)^*$-δgp closed in X, $(1,2)^*\text{-pcl}(A) - A$ contains no non empty $(1,2)^*$-δ closed set. Since $S \subseteq (1,2)^*\text{-pcl}(A) - A$, $S = \phi \subseteq (1,2)^*\text{-pint}[(1,2)^*\text{-pcl}(A) - A]$. Then $(1,2)^*\text{-pcl}(A) - A$ is $(1,2)^*$-δgp open. Conversely, Suppose that $(1,2)^*\text{-pcl}(A) - A$ is $(1,2)^*$-δgp open. Let $A \subseteq U$ and U is $(1,2)^*$-δ open. Since $A \subseteq U$, $U^c \subseteq A^c$. Therefore $(1,2)^*\text{-pcl}(A) \cap U^c = (1,2)^*\text{-pcl}(A) - A$. Since U is $(1,2)^*$-δ open in X, U^c is $(1,2)^*$-δ closed in X. Also since $(1,2)^*\text{-pcl}(A)$ is $(1,2)^*$-δ closed in X and U^c is $(1,2)^*$-δ closed in X, $[(1,2)^*\text{-pcl}(A)] \cap U^c$ is $(1,2)^*$-δ closed in X. Since $(1,2)^*\text{-pcl}(A) - A$ is $(1,2)^*$-δgp open, $[(1,2)^*\text{-pcl}(A)] \cap U^c \subseteq (1,2)^*\text{-pint}[(1,2)^*\text{-pcl}(A) - A] = (1,2)^*\text{-pint}[(1,2)^*\text{-pcl}(A) \cap (A^c)] = \phi$. Then $(1,2)^*\text{-pcl}(A) \subseteq U$. Hence A is $(1,2)^*$-δgp closed.

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