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On generalized b star - interior and generalized b star - closure in topological spaces

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Abstract
In this paper, we introduce a new class of generalized b star - interior and generalized b star - closure in topological spaces. Some characterizations and several properties concerning generalized b star - interior and generalized b star - closure are obtained and presented.

Keywords
gbs - closed set, gbs - closed map, gbs - continuous map, contra gbs - continuity.

AMS Subject Classification
54C05, 54C08, 54C10.

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Contents

1. Introduction

Generalized closed sets in topology as a generalization of closed sets introduced by Levine [11]. This concept was found to be useful and many results in general topology were improved. Generalized closed sets have worked by many researchers like Arya et al.[4], Balachandran et al.[5], Bhattarcharya et al.[6], Arockiarani et al.[3], Gnanambal [8], Malgham [13], Nagaveni [16] and Palaniappan et al.[17]. Andrjivic [2] gave a new class of generalized closed set in topological space called b closed sets. A.A. Omari and M.S.M. Noorani [1] made an analytical study and presented the concepts of generalized b closed sets in topological spaces.

In this paper, the notion of gbs -interior is defined and some of its basic properties are investigated. Also we introduce the idea of gbs -closure in topological spaces using the notions of gbs-closed sets and obtain some related results. Through out this paper (X,τ) and (Y,σ) represent the non-empty topological spaces on which no separation axioms are assumed, unless otherwise mentioned.

Let $A \subseteq X$, the closure of A and interior of A will be denoted by $cl(A)$ and $int(A)$ respectively, union of all b - open sets X contained in A is called b - interior of A and it is denoted by $bint(A)$, the intersection of all b - closed sets of X containing A is called b - closure of A and it is denoted by $bcl(A)$.

2. Preliminaries

Definition 2.1. *Let a subset A of a topological space (X,τ), is called*
1) a pre-open set [15] if $A \subseteq int(cl(A))$.
2) a semi-open set [10] if $A \subseteq cl(int(A))$.
3) a α -open set [15] if $A \subseteq int(cl(int(A)))$.
4) a α generalized closed set (briefly αg- closed) [12] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
5) a generalized $*$ closed set (briefly g^*-closed)[21] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is $\hat{g}$ open in X.
6) a generalized b- closed set (briefly gb- closed) [2] if $bcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
7) a generalized semi-pre closed set (briefly gsp - closed) [7] if $spcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
8) a generalized pre-closed set (briefly gp - closed) [8] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
9) a generalized semi-closed set (briefly gs - closed) [7] if

$scl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in X.
10) a semi generalized closed set (briefly sg- closed) [6] if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in X.
11) a generalized pre regular closed set (briefly gpr-closed) [8] if $pcl(A) \subseteq U$ whenever $A \subseteq U$ and U is regular open in X.
12) a semi generalized b- closed set (briefly sgb- closed) [9] if $bcl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in X.
13) a $\ddot{g}$ - closed set [18] if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is sg open in X.
*14) a semi generalized star b - closed set (briefly sg*b - closed)[19] if $bcl(A) \subseteq U$ whenever $A \subseteq U$ and U is sg open in X.*
15) a generalized b star-closed set (briefly gbs-closed) [20] if $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ and U is regular open in X.

3. On Generalized b Star - interior in Topological space

Definition 3.1. *Let A be a subset of X. A point $x \in A$ is said to be gbs - interior point of A is A is a gbs - neighbourhood of x. The set of all gbs - interior points of A is called the gbs - interior of A and is denoted by $gbs-int(A)$.*

Theorem 3.2. *If A be a subset of X. Then $gbs-int(A) = \{\cup G : G$ is a gbs - open, $G \subset A\}$.*

Proof. Let A be a subset of X.

$$\begin{aligned} x \in gbs-int(A) &\Leftrightarrow x \text{ is a } gbs- \text{ interior point of } A \\ &\Leftrightarrow A \text{ is a } gbs \text{ - nbhd of point } x \\ &\Leftrightarrow \text{there exists } gbs \text{ - open set } G \\ &\quad\ \text{such that } x \in G \subset A \\ &\Leftrightarrow x \in \{\cup G : G \text{ is a } gbs\text{-open },\\ &\quad\ G \subset A\} \\ \text{Hence } gbs-int(A) &= \{\cup G : G \text{ is a } gbs\text{-open }, G \subset A\} \end{aligned}$$

□

Theorem 3.3. *Let A and B be subsets of X. Then*

1. *$gbs-int(X) = X$ and $gbs-int(\varphi) = \varphi$.*
2. *$gbs-int(A) \subset A$.*
3. *If B is any gbs - open set contained in A, then $B \subset gbs-int(A)$.*
4. *If $A \subset B$, then $gbs-int(A) \subset gbs-int(B)$.*
5. *$gbs-int\big(gbs-int(A)\big) = gbs-int(A)$.*

Proof. Let A and B be subsets of X.

1. Since X and φ are gbs open sets, by Theorem 3.2

$$\begin{aligned} gbs-int(X) &= \{\cup G : G \text{ is a } gbs \text{ - open}, G \subset X\} \\ &= X \cup \{ \text{ all } gbs \text{ open sets } \} \\ &= X \end{aligned}$$

(i.e.,) $gbs\,int(X) = X$. Since φ is the only gbs - open set contained in $\varphi, gbs-int(\varphi) = \varphi$.

2. Let $x \in gbs-int(A)$

$$\begin{aligned} x \in gbs-int(A) &\Rightarrow x \text{ is an int point of } A. \\ &\Rightarrow A \text{ is a nbhd of } x. \\ &\Rightarrow x \in A \\ \text{Thus, } x \in gbs-int(A) &\Rightarrow x \in A \\ \text{Hence } gbs-int(A) &\subset A. \end{aligned}$$

3. Let B be any gbs - open sets such that $B \subset A$. Let $x \in B$. Since B is a gbs - open set contained in A. x is a gbs - interior point of A.
(i.e.,) $x \in gbs-int(A)$. Hence $B \subset gbs-int(A)$.

4. Let A and B be subsets of X such that $A \subset B$. Let $x \in gbs-int(A)$. Then x is a gbs - interior point of A and so A is a gbs - nbhd of x. Since $B \supset A$, B is also gbs - nbhd of $x \Rightarrow x \in gbs-int(B)$. Thus we have shown that $x \in gbs-int(A) \Rightarrow x \in gbs-int(B)$.

5. Proof is obvious.

□

Theorem 3.4. *If a subset A of space X is gbs - open, then $gbs-int(A) = A$.*

Proof. Let A be gbs - open subset of X. We know that $gbs-int(A) \subset A$. Also, A is gbs - open set contained in A. From Theorem 3.3 (iii) $A \subset gbs-int(A)$. Hence $gbs-int(A) = A$.

The converse of the above theorem need not be true, as seen from the following example. □

Example 3.5. *Let $X = \{a,b,c\}$ with $\tau = \{X, \varphi, \{b\}, \{c\}, \{b,c\}\}$. Then $gbs-O(X) = \{X, \varphi, \{a\}, \{b\}, \{c\}, \{b,c\}\}$. gbs - $int(\{a,c\} = \{a\} \cup \{c\} \cup \{\varphi\} = \{a,c\}$. But $\{a,c\}$ is not gbs - open set in X.*

Theorem 3.6. *If A and B are subsets of X, then $gbs-int(A) \cup gbs-int(B) \subset gbs-int(A \cup B)$.*

Proof. We know that $A \subset A \cup B$ and $B \subset A \cup B$. We have Theorem 3.3 (iv) $gbs-int(A) \subset gbs-int(A \cup B)$, $gbs-int(B) \subset gbs-int(A \cup B)$. This implies that $gbs-int(A) \cup gbs-int(B) \subset gbs-int(A \cup B)$. □

Theorem 3.7. *If A and B are subsets of X, then $gbs-int(A \cap B) = gbs-int(A) \cap gbs-int(B)$.*

Proof. We know that $A \cap B \subset A$ and $A \cap B \subset B$. We have $gbs-int(A \cap B) \subset gbs-int(A)$ and $gbs-int(A \cap B) \subset gbs-int(B)$.
This implies that

$$gbs-int(A \cap B) \subset gbs-int(A) \cap gbs-int(B). \quad (3.1)$$

Again let $x \in gbs-int(A) \cap gbs-int(B)$. Then $x \in gbs-int(A)$ and $x \in gbs-int(B)$. Hence x is a gbs - int point of each of sets A and B. It follows that A and B is gbs - nbhds of x, so that their intersection $A \cap B$ is also a gbs - nbhds of x. Hence $x \in gbs-int(A \cap B)$. Thus $x \in gbs-int(A) \cap gbs-int(A)$ implies that $x \in gbs-int(A \cap B)$. Therefore

$$gbs-int(A) \cap gbs-int(B) \subset gbs-int(A \cap B) \tag{3.2}$$

From (3.1) and (3.2),
We get $gbs-int(A \cap B) = gbs-int(A) \cap gbs-int(B)$. □

Theorem 3.8. *If A is a subset of X, then $int(A) \subset gbs-int(A)$.*

Proof. Let A be a subset of X.

$$\begin{aligned}
\text{Let } x \in int(A) \quad &\Rightarrow \quad x \in \{\cup G : G \text{ is open}, G \subset A\} \\
&\Rightarrow \quad \text{there exists an open set } G \\
&\quad\quad \text{such that } x \in G \subset A \\
&\Rightarrow \quad \text{there exist a } gbs \text{ - open set } G \\
&\quad\quad \text{such that } x \in G \subset A, \\
&\quad\quad \text{as every open set is} \\
&\quad\quad \text{a } gbs \text{ - open set in } X \\
&\Rightarrow \quad x \in \{\cup G : G \text{ is } gbs \text{ - open}, G \subset A\} \\
&\Rightarrow \quad x \in gbs-int(A) \\
\text{Thus } x \in int(A) \quad &\Rightarrow \quad x \in gbs-int(A) \\
\text{Hence } int(A) \quad &\subset \quad gbs-int(A).
\end{aligned}$$

This completes the proof. □

Remark 3.9. *Containment relation in the above theorem may be proper as seen from the following example.*

Example 3.10. *Let $X = \{a,b,c\}$ with $\tau = \{X, \varphi, \{b\}, \{c\}, \{b,c\}\}$. Then $gbs-O(X) = \{X, \varphi, \{a\}, \{b\}, \{c\}, \{b,c\}\}$. Let $A = \{b,c\}$. Now $gbs-int(A) = \{b,c\}$ and $int(A) = \{c\}$. It follows that $int(A) \subset gbs-int(A)$ and $int(A) \neq gbs-int(A)$.*

Theorem 3.11. *If A is a subset of X, then $g-int(A) \subset gbs-int(A)$, where $g-int(A)$ is given by $g-int(A) = \cup\{G : G$ is g - open, $G \subset A\}$.*

Proof. Let A be a subset of X.

$$\begin{aligned}
\text{Let } x \in int(A) \quad &\Rightarrow \quad x \in \{\cup G : G \text{ is } g \text{ - open}, G \subset A\} \\
&\Rightarrow \quad \text{there exists a } g \text{ - open set } G \\
&\quad\quad \text{such that } x \in G \subset A \\
&\Rightarrow \quad \text{there exist a } gbs \text{ - open set } G \\
&\quad\quad \text{such that } x \in G \subset A, \\
&\quad\quad \text{as every } g \text{ open set} \\
&\quad\quad \text{is a } gbs \text{ - open set in } X \\
&\Rightarrow \quad x \in \{\cup G : G \text{ is } gbs \text{ - open}, G \subset A\} \\
&\Rightarrow \quad x \in gbs-int(A) \\
\text{Thus } x \in int(A) \quad &\Rightarrow \quad x \in gbs-int(A) \\
\text{Hence } g-int(A) \quad &\subset \quad gbs-int(A).
\end{aligned}$$

This completes the proof. □

Remark 3.12. *Containment relation in the above theorem may be proper as seen from the following example.*

Example 3.13. *Let $X = \{a,b,c\}$ with $\tau = \{X, \varphi, \{a\}, \{b,c\}\}$. Then $gbs-O(X) = \{X, \varphi, \{a\}, \{b,c\}\}$. and g - open $(X) = \{X, \varphi, \{a\}, \{b\}, \{a,b\}\}$. Let $A = \{b,c\}$, $gbs-int(A) = \{b,c\}$ and $g-int(A) = \{b\}$. It follows that $g-int(A) \subset gbs-int(A)$ and $g-int(A) \neq gbs-int(A)$.*

4. On Generalized b Star - closure in Topological space

Definition 4.1. *Let A be a subset of a space X. We define the gbs - closure of A to be the intersection of all gbs - closed sets containing A. In symbols, $gbs-cl(A) = \{\cap F : A \subset F \in gbsc(X)\}$.*

Theorem 4.2. *If A and B are subsets of a space X. Then*

1. *$gbs-cl(X) = X$ and $gbs-cl(\varphi) = \varphi$*
2. *$A \subset gbs-cl(A)$*
3. *If B is any gbs - closed set containing A, then $gbs-cl(A) \subset B$*
4. *If $A \subset B$ then $gbs-cl(A) \subset gbs-cl(B)$*

Proof. Let A and B are subsets of a space X.

1. By the definition of gbs - closure, X is the only gbs - closed set containing X. Therefore $gbs-cl(X) =$ Intersection of all the gbs - closed sets containing $X = \cap\{X\} = X$. That is $gbs-cl(X) = X$. By the definition of gbs - closure, $gbs-cl(\varphi) =$ Intersection of all the gbs - closed sets containing $\varphi = \{\varphi\} = \varphi$. That is $gbs-cl(\varphi) = \varphi$.
2. By the definition of gbs - closure of A, it is obvious that $A \subset gbs-cl(A)$.
3. Let B be any gbs - closed set containing A. Since $gbs-cl(A)$ is the intersection of all gbs - closed sets containing A, $gbs-cl(A)$ is contained in every gbs - closed set containing A. Hence in particular $gbs-cl(A) \subset B$.
4. Let A and B be subsets of X such that $A \subset B$. By the definition
$gbs-cl(B) = \{\cap F : B \subset F \in gbs-c(X)\}$. If $B \subset F \in gbs-c(X)$, then $gbs-cl(B) \subset F$. Since $A \subset B, A \subset B \subset F \in gbs-c(X)$,
we have $gbs-cl(A) \subset F$. Therefore $gbs-cl(A) \subset \{\cap F : B \subset F gbs-c(X)\} = gbs-cl(B)$.

(i.e.,) $gbs-cl(A) \subset gbs-cl(B)$. □

Theorem 4.3. *If $A \subset X$ is gbs - closed, then $gbs-cl(A) = A$.*

Proof. Let A be gbs - closed subset of X. We know that $A \subset gbs-cl(A)$. Also $A \subset A$ and A is gbs - closed. By Theorem 4.2 (iii) $gbs-cl(A) \subset A$. Hence $gbs-cl(A) = A$. □

Remark 4.4. *The converse of the above theorem need not be true as seen from the following example.*

Example 4.5. *Let $X = \{a,b,c\}$ with topology $\tau = \{X, \varphi, \{b\}, \{b,c\}\}$. Then $gbs-C(X) = \{X, \varphi, \{a\}, \{a,b\}, \{a,c\}\}$. $gbs-cl(\{c\}) = \{a,c\}$. But $\{c\}$ is not gbs - closed set in X.*

Theorem 4.6. *If A and B are subsets of a space X, then $gbs-cl(A\cap B) \subset gbs-cl(A) \cap gbs-cl(B)$.*

Proof. Let A and B be subsets of X. Clearly $A\cap B \subset A$ and $A\cap B \subset B$. By Theorem $gbs-cl(A\cap B) \subset gbs-cl(A)$ and $gbs-cl(A\cap B) \subset gbs-cl(B)$. Hence $gbs-cl(A\cap B) \subset gbs-cl(A) \cap gbs-cl(B)$. □

Theorem 4.7. *If A and B are subsets of a space X then $gbs-cl(A\cup B) = gbs-cl(A) \cup gbs-cl(B)$.*

Proof. Let A and B be subsets of X. Clearly $A \subset A\cup B$ and $B \subset A\cup B$. We have

$$gbs-cl(A) \cup gbs-cl(B) \subset gbs-cl(A\cup B) \tag{4.1}$$

Now to prove $gbs-cl(A\cup B) \subset gbs-cl(A) \cup gbs-cl(B)$. Let $x \in gbs-cl(A\cup B)$ and suppose $x \notin gbs-cl(A) \cup gbs-cl(B)$. Then there exists gbs - closed sets A_1 and B_1 with $A \subset A_1, B \subset B_1$ and $x \notin A_1 \cup B_1$. We have $A\cup B \subset A_1 \cup B_1$ and $A_1 \cup B_1$ is gbs - closed set by Theorem such that $x \notin A_1 \cup B_1$. Thus $x \notin gbs-cl(A\cup B)$ which is a contradiction to $x \in gbs-cl(A\cup B)$. Hence

$$gbs-cl(A\cup B) \subset gbs-cl(A) \cup gbs-cl(B) \tag{4.2}$$

From (4.1) and (4.2), we have $gbs-cl(A\cup B) = gbs-cl(A) \cup gbs-cl(B)$. □

Theorem 4.8. *For an $x \in X$, $x \in gbs-cl(A)$ if and only if $V\cap A \neq \varphi$ for every gbs - open sets V containing x.*

Proof. Let $x \in X$ and $x \in gbs-cl(A)$. To prove $V \cap A \neq \varphi$ for every gbs - open set V containing x.
Prove the result by contradiction. Suppose there exists a gbs - open set V containing x such that $V\cap A = \varphi$. Then $A \subset X-V$ and $X-V$ is gbs-closed. We have $gbs-cl(A) \subset X-V$. This shows that $x \notin gbs-cl(A)$, which is a contradiction. Hence $V \cap A \neq \varphi$ for every gbs - open set V containing x.
Conversely, let $V\cap A = \varphi$ for every gbs - open set V containing x. To prove $x \in gbs-cl(A)$. We prove the result by contradiction. Suppose $x \notin gbs-cl(A)$. Then $x \in X-F$ and $S-F$ is gbs - open. Also $(X-F)\cap A = \varphi$, which is a contradiction. Hence $x \in gbs-cl(A)$. □

Theorem 4.9. *If A is a subset of a space X, then $gbs-cl(A) \subset cl(A)$.*

Proof. Let A be a subset of a space S. By the definition of closure,
$cl(A) = \{\cap F : A \subset F \in C(X)\}$. If $A \subset F \in C(X)$, Then $A \subset F \in gbs-C(X)$, because every closed set is gbs - closed. That is $gbs-cl(A) \subset F$. Therefore $gbs-cl(A) \subset \{\cap F \subset X : F \in C(X)\} = cl(A)$. Hence $gbs-cl(A) \subset cl(A)$. □

Theorem 4.10. *If A is a subset of X, then $gbs-cl(A) \subset g-cl(A)$, where $g-cl(A)$ is given by $g-cl(A) = \{\cap F \subset X : A \subset F$ and f is a g - closed set in $X\}$.*

Proof. Let A be a subset of X. By definition of $g-cl(A) = \{\cap F \subset X : A \subset F$ and f is a g - closed set in $X\}$. If $A \subset F$ and F is g - closed subset of x, then $A \subset F \in gbs-cl(X)$, because every g closed is gbs - closed subset in X. That is $gbs-cl(A) \subset F$. Therefore $gbs-cl(A) \subset \{\cap F \subset X : A \subset F$ and f is a g - closed set in $X\} = g-cl(A)$. Hence $gbs-cl(A) \subset g-cl(A)$. □

Corollary 4.11. *Let A be any subset of X. Then*

1. $\left(gbs-int(A)\right)^c = gbs-cl(A^c)$
2. $gbs-int(A) = \left(gbs-cl(A^c)\right)^c$
3. $gbs-cl(A) = \left(gbs-int(A^c)\right)^c$

Proof. Let A be any subset of X.

1. Let $x \in \left(gbs-int(A)\right)^c$. Then $x \notin gbs-int(A)$. That is every gbs - open set U containing x is such that U not subset of A. That is every gbs - open set U containing x is such that $U\cap A^c \neq \varphi$. By Theorem $x \in \left(gbs-cl(A^c)\right)$ and therefore $\left(gbs-int(A)\right)^c \subset gbs-cl(A^c)$.
   Conversely, let $x \in gbs-cl(A^c)$. Then by theorem, every gbs - open set U containing x is such that $U\cap A^c \neq \varphi$. That is every gbs - open set U containing x is such that U not subset of A. This implies by definition of gbs - interior of A, $x \notin gbs-int(A)$. That is $x \in \left(gbs-int(A)\right)^c$ and $gbs-cl(A^c) \subset \left(gbs-int(A)\right)^c$. Thus $\left(gbs-int(A)\right)^c = gbs-cl(A^c)$.
2. Follows by taking complements in (1).
3. Follows by replacing A by A^c in (1).

□

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