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Properties Of Gsp-Separation Axioms In Topology

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ABSTRACT: *In this paper we define and study gsp-separation axioms , namely , gsp-T_0 , gsp-T_1 , gsp-T_2 gsp-R_0 and gsp-R_1 spaces using gsp-open sets due to J.Dontchev (1995). Also, we study the comparison of these gsp-separation axioms with the existing gp-separation axioms and αg-separation axioms . Further , we also introduce and study the notions of g^*- separations .*

KEY WORDS: *semipreopen sets, gsp-closed sets .g^*-closed sets preopen sets ,gs-closed sets, gsp-irresoluteness, and strongly g^*-continuums functions*

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I. INTRODUCTION

In 1982 A S Mashhour et al[8] have defined and studied the concept of pre-open sets and Spre-continuous functions of topology. In 1983 S.N.Deeb et al [5] have defined and studied the concepts of pre-closed sets , preclosure operater , p-regular spaces and pre-closed functions in topology. In 1998 , T.Noiri et al [14] have defined the concepts of gp-closed sets ans gp-closed functions in topology.In 2012 , Navalagi et al. [12] have defined and studied the concepts of Generalized pre-separation axioms like , gp-T_0 , gp-T_1 , gp-T_2 , gp-R_0 and gp-R_1 spaces using gp-open sets due to T.Noiri et al [14] . In 1986, D. Andrijivic [1] introduced and studied the notion of semipre open sets, semipreclosed sets ,semipreinterior operator and semipre-closed operator in topological spaces.In 1965 , Njstad [13] has defined the concept of α-open sets in topological spaces .In 1983, A.S.Mashhour et al [9] have defined and studied the concepts of α-closed sets , α-closure operator, α-continuity , α-openness and α-closedness in topology. For the first time , N.Levine [6] has introduced the notion g-closed sets and g-open sets in topology. In 1994, H.Maki et al [7] have defined and studied the concepts of αg-closed sets in topological spaces .

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in topological spaces . Recently , in 2014 Thakur C.K.Raman et al [3& 15] have defined and studied the concepts of αg-separation axioms in tology. In 1995 , J.Dontchev [4] has defined and studied the concept of gsp-closed sets, gsp-open sets , gsp-continuous functions and gsp-irresoluteness in topology. In this paper , using gsp-open sets ,we define and study the notions of gsp-T_0 , gsp-T_1 , gsp-T_2 gsp- R_0 and gsp-R_1 spaces .

II. PRELIMINARIES

Throughout this paper (X , τ) and (Y, σ) (or simply X and Y) denote topological spaces on which no separation axioms are assumed unless explicitly stated . If A be a subset of X, the closure of A and the interior of A is denoted by Cl(A) and Int(A) ,respectively.

We give the following define are useful in the sequel :

Definition 2.1: The subset of A of X is said to be.
(i) A pre-open [8]set, if $A \subset Int(Cl(A))$
(ii) A semi-pre open[1] set , if $A \subset Cl(Int(Cl(A)))$
(iii) α-open [13] set, if $A \subset Int(Cl(Int(A)))$

The compliment of a pre-open (resp., semipre-open , α-open) set is called pre-closed [5] (resp., semipre-closed [1], α-closed[9]) set in space X . The family of all pre-open (resp. semipre-open, α-open) sets of a space X is denoted by PO(X) (resp., SPO(X) ,αO(X)) and that of pre-closed (resp.semipre-closed ,α-closed) sets of a space X is denoted by PF(X), (resp.SPF(X) αF(X)).

Definition 2.2[5] : The intersection of all pre-closed sets of X containing subset A is called the pre-closure of A and is denoted by pCl(A).
Definition 2.3[1] : The intersection of all semipre-closed sets of X containing subset A is called the semipre-closure of A and is denoted by spCl(A).
Definition 2.4[9] : The intersection of all α-closed sets of X containing subset A is called the α-closure of A and is denoted by αCl(A).
Definition 2.5[5]: The union of all pre-open sets of X contained in A is called the pre-interior of A and is denoted by pInt (A).
Definition 2.6[1]: The union of all semipre-open sets of X contained in A is called the semipre-interior of A and is denoted by spInt(A).
Definition 2.7[9]: The union of all α-open sets of X contained in A is called the α-interior of A and is denoted by αInt(A).
Definition 2.8 : A sub set A of a space X is said to be :
(i) a generalized closed (briefly, g- closed) **[6]** set if $Cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open set in (X, τ)
(ii) a α- generalized closed (briefly, αg- closed) [**7**] set if $\alpha Cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open set in (X, τ)
(iii) a generalized semi-preclosed (briefly, gsp- closed) [**4**] set if $spCl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ)
(iv) a generalized pre -closed (briefly, gp- closed) [**14**] set if $pCl(A) \subseteq U$ whenever $A \subseteq U$ and U is open in (X, τ)

The complement of a g-closed (resp, αg-closed, gsp-closed, , gp-closed) set in X is called g-open (resp. αg-open, gsp- open, , gp- open) set in X. The family of all gsp-open sets of X is denoted by GSPO(X).
Definition 2.9[12]: The intersection of all gp-closed sets of X containing subset A is called the gp-closure of A and is denoted by gpCl(A).
Definition 2.10[3]: The intersection of all αg-closed sets of X containing subset A is called the αg-closure of A and is denoted by αgCl(A).
Definition 2.11 [12]: A space X is called generalized pre-T_1 (briefly written as gp-T_1) iff to each pair of distinct points x,y of X, there exists a pair of gp-open sets containing x but not y and the other containing y but not x.
Definition 2.12 [12] : A space X is said to be gp-T_2 space if for each pair of distinct points of X there exist disjoint gp-open sets containing them.
Definition 2.13 [3&15]: A space X is called α-generalized-T_0 (briefly written as αg-T_0) iff to each pair of distinct points x,y of X, there exists a αg-open set containing one but not the other.
Definition 2.14 [3&15]: A space X is called α-generalized-T_1 (briefly written as αg-T_1) iff to each pair of distinct points x,y of X, there exists a pair of αg-open sets containing xbut not y and the other containing y but not x.
Definition 2.15 [10]: A space X is called semipre-T_0 (briefly written as semipre-T_0) iff to each pair of distinct points x,y of X, there exists a semipre-open set containing one but not the other.
Definition 2.16 [10]: A space X is called semipre-T_1 (briefly written as semipre-T_1) iff to each pair of distinct points x,y of X, there exists a pair of semipre-open sets containing xbut not y and the other containing y but not x.

III. PROPERTIES OF GSP-SEPARATION AXIOMS

We, define the following
Definition 3.1: A space X is called gsp-T_0 iff to each pair of distinct points x,y of X, there exists a gsp-open set containing one but not the other .
Definition 3.2 : A space X is said to be gp-T_0 space if for each pair of distinct points of X there exists a gp-open set containing one but not the other.
Clearly, every semipre-T_0 is gsp-T_0 . Also, we have the following ,
Note 3.3 : In view of definitions of αg-closed, gp-closed sets and gsp-closed sets, the following is observed in [2] :

$$\alpha\text{g-closed set} \Rightarrow \text{gp-closed set} \Rightarrow \text{gsp-closed set}$$

Hence we have the following implication:

αg-T_0-space $\rightarrow$ gp-T_0-space $\rightarrow$ gsp-T_0-space

We ,define the following

Definition 3.4 : A generalized semipre-closure of set A is denoted by gspCl(A),is the intersection of all gsp-closed sets that contain A

We characterize gsp-T_0-spaces in the following

Theorem 3.5: If in any topological space X, gspclosures of distinct points are distinct , then X is gsp-T_0

Proof: Let x,yϵX, x$\neq$y imply gspCl({x})$\neq$gspCl({y}). Then there exists a point zϵX such that z belongs one of two sets, say, gspCl({y}) but not to gspCl({x}). If we suppose that zϵ gspCl({x}), then zϵ gspCl({y})$\subset$ zϵ gspCl({x}),which is contradiction. So, y ϵX- gspCl({x}),where X- gspCl({x}) is gsp-open set which does not contain x. This shows that X is gsp-T_0.

Next ,we give the following

Theorem 3.6: A space X is gsp-T_0 iff gspCl({x})$\neq$gspCl({y}) for every pair of distinct points x,y of X.

Proof follows from Th.3.5 .

Theorem 3.7 : Every sub space of an gsp-T_0 space is gsp-T_0 space.

Proof: Let x be a space and (Y, τ^*) be a subspace of X where τ^* is the relative topology of τ on Y. Let x,y be two distinct points of Y. As Y$\subset$X, x and y are distinct points X. Since X is an gsp-T_0 space, there exists an gsp-open set G such that $x \in G$ but $y \notin G$.Then G$\cap$Y is an gsp-open set in (Y, τ^*) which contains x but doesnot contain y. Hence (Y, τ^*) is an gsp-T_0 space.

We, define the following

Definition 3.8: A function f: X $\rightarrow$Y is said to be point -gspclosure 1-1 iff x,yϵX such that gspCl({x})$\neq$gspCl({y}) then f(gspCl({x}))$\neq$f(gspCl({y}))

Theorem 3.9: If function f: X $\rightarrow$Y is point -gspclosure 1-1 and X is gsp-T_0 then f is 1-1

Proof: Let x,yϵX with x$\neq$y. Since X is gsp-$T_{0,}$ then gspCl({x})$\neq$gspCl({y}) by Theorem 3.6. But f is point -gspclosure 1-1 implies thatf(gspCl({x}))$\neq$f(gspCl({y})). Hence f(x)$\neq$f(y). Thus ,f is 1-1.

Theorem 3.10: Let f: X $\rightarrow$Y be amapping from gsp-T_0 space X into gsp-T_0 space Y. Then f is point-gspclosure 1-1 iff f is 1-1

Prof follows from Theorem 3.5 above

Theorem 3.11: Let f: X $\rightarrow$Y be an injective gsp-irresolute mapping. If Y is gsp-T_0 then X is gsp-$T_{0.}$

Proof: Let x,yϵX with x$\neq$y. Since f is injective and Y is gsp-T_0, there exists a gspopen set V_x in Y such that f(x) ϵV_x and f(y) $\notin V_x$ or there exists a gspopen set V_y in Y such that f(y) ϵ V_y and f(x) $\notin V_y$ with f(x)$\neq$f(y). By gsp irresoluteness of f, $f^{-1}(V_x)$ is gspopen set in X such that x$\epsilon f^{-1}(V_x)$ and y $\notin f^{-1}$ (V_x) or $f^{-1}(V_y)$ is gspopen set in X such that y$\epsilon f^{-1}(V_y)$ and x $\notin f^{-1}$ (V_y). This shows that X is gsp-T_0.

We define the following mapping analogous to always semi-pre-open mapping.

Definition 3.12 : A mapping f:X$\rightarrow$Y is said to be always gsp-open, if the image of every gsp-open set of X is gsp-open in Y.

Lemma 3.13 : The property of a space being gsp-T_0 is preserved under one-one, onto and always gsp-open mapping.

Proof: Let X be a gsp-T_0 space and Y be any topological space. Let f:X$\rightarrow$Y be a one-one, onto always gsp-open mapping from X to Y. Let u, v$\in$Y with u$\neq$v. Since f is one-one ,onto, there exist distinct points x,y$\in$X. Such that f(x) = u, f(y) = v. Since X is on gsp-T_0 space. There exists gsp-open set G in X such that x$\in$G but $y \notin G$. Since f is always gsp-open, f(G) is an gsp-open set containing f(x) = u but not containing f(y) = v. Thus there exists an gsp-open set f(G) in y such that u$\in$f(G) but $v \notin f(G)$ and hence Y is an gsp-T_0 space.

Next ,we define the following.

Definition 3.14 : A sub set A of a space X is called a gspD-set if there are two gsp-open subsets U and V such that U$\neq$X and A = U$-$X.

Clearly, every gsp-open set is gspD-set.

We, define the following

Definition 3.15: A space X is called a gsp-D_0 if for any disjoint pair of points x and y of X there exists a gspD-set of X containing x but not y or a gspD-set of X containing y but not x.

Cleary, every gsp-T_0 space is gsp-D_0 space.

We prove the following

Theorem 3.16 : If f:X$\rightarrow$Y is gsp-irresolute surjective function and A is a gspD-set in Y, then the inverse image of A is a gspD-set in X.

Proof: Let A be a gspD-set in Y. Then there are gsp-open sets U_1 and U_2 in Y such that A = $U_1 - U_2$ and $U_1 \neq Y$. By the gsp-irresoluteness of f, $f^{-1}(U_1)$ and $f^{-1}(U_2)$ are gsp-open set in X. Since $U_1 \neq Y$, we have $f^{-1}(U_1) \neq X$. Hence $f^{-1}(A) = f^{-1}(U_1) - f^{-1}(U_2)$ is a gspD-set.

We define the following .

Definition 3.17 : A space (X, τ) is gsp-T_1 if and only if for x,y∈X such that x≠y, there exists a gsp-open set containing x but not y and there is a gsp-open set containing y but not x.

It is easy to verify the following :

(i) Every semipre-T_1 space is an gsp-T_1 space
(ii) Every gsp-T_1 space is an gsp-$_{T0}$ space
(iii) Every sg-T_1 space is an gsp-T_1 space . Also,

In view of above Note-3.3 , we have the following implication :

αg-T_1-space → gp-T_1-space → gsp-T_1-space

Theorem 3.18 : A space X is an gsp-T_1 space if and only if{x} is gsp-closed in X for every x∈X.

Proof: Let x,y be two distinct points X such that {x} and {y} are gsp-closed. Then $X-\{x\}$ and $Y-\{y\}$ are gsp-open in X such that $y\in X-\{x\}$ but $x\notin X-\{x\}$ and $x\in X-\{y\}$ but $y\notin X-\{y\}$. Hence, X is an gsp-T_1 space.

Conversely, let X be an gsp-T_1 space and x be any arbitrary point of X. If $y\in X-\{x\}$, then y≠x. Now the space being gsp-T_1 and y is a point different from x, there exists an gsp-open set G_y such that $y\in G_y$ but $x\notin G_y$. Thus for each $y\in X-\{x\}$, there exists an gsp-open set G_y such that $y\in G_y\subset X-\{x\}$. Therefore $\cup\{y|\ y\neq x\}\subset\cup\{G_y|\ y\neq x\}\subset X-\{x\}$ which implies that

$X-\{x\}\subset\cup\{G_y|\ y\neq x\}\subset X-\{x\}$.

Therefore , $X-\{x\}=\cup\{G_y|\ y\neq x\}$. Since G_y gsp-open in X and the union of gsp-open sets in X is gsp-open in X, $X-\{x\}$ is gsp-open in X and so {x} is gsp-closed.

Recall the following.

Definition 3.19 [11]: A topological space (X, τ) is αgs-symmetric if for any x and y in X, x∈ αgsCl({y}) implies y∈αgsCl({x}).

We , define the following .

Definition 3.20 : A topological space (X, τ) is semipre symmetric if for x and y in x, x∈semipreCl({y}) implies y∈semipreCl({x}).

Definition 3.21 : A topological space (X, τ) is gsp-symmetric if for any x and y in X, x∈ gspCl({y}) implies y∈ gspCl({x}).

Clearly , every semipre-symmetric space is gsp-symmetric space.

Theorem 3.22 : If {x} is gsp-closed for each x in X then a space X is semipre-symmetric.

Proof: Suppose x∈ gspCl({y}) and y∉ gspCl({x}). Since {y}⊂X−gspCl({x}) and {y} is gsp-closed, gspCl({y})⊂X−gspCl({x}). Thus x∈ X− gspCl({y}), a contradiction.

Theorem 3.23 : If a space X is extremely disconnected (i.e., closure of every open set is open) and semipre-symmetric, then {x} is gsp-closed, for each x in X.

Proof: Suppose {x}⊂U where U is semipre-open and gspCl({x})⊄U.

Then gspCl({x })∩(X−U) ≠ ∅ Let y∈ gspCl({x })∩(X−U).We have x∈gspCl({x})⊂(X−U) and x∉U, a contradiction. Hence {x} is gsp-closed in X.

Corollary 3.24 : If X is extremely disconnected, then X is gsp-T_1 if and only if X is semipre-symmetric.

Proof: Obvious

Next, we have the following invariant properties.

Theorem 3.25 : Let f:X→Y be an gsp-irresolutes injective map. If Y is gsp-$T_{1,}$ then X is gsp-$T_{1.}$

Proof: Assume that Y is gsp-T_1. Let x,y∈Y be such that x≠y. Then there exists a pair of gsp-open sets u,v in Y such that f(x)∈U, f(y) ∈V and f(x) ∉V, f(y) ∉U. Then $x\in f^{-1}(U)$, $y\in f^{-1}(V)$, $x\notin f^{-1}(U)$ and $y\notin f^{-1}(V)$. Since f is gsp-irresolute, X is gsp-T_1.

Corollary 3.26: A topological space (X, τ) is gsp-T_1 if and only if every finite subset of X is gsp-closed.

We, define the following

Definition 3.27 : A space X is called gsp-D_1 if for any distinct pair of points x and y of X there exists a gsp-D set of X containing x but y and a gsp-D set of X containing y but not x.

Clearly, every gsp-T_1 space is gsp-D_1space.

Theorem 3.28: If Y is a gsp-D_1 and f:X→Y is gsp-irresolute and bijective, then X is gsp-$D_{1.}$

Proof: Suppose that Y is a gsp-D_1 space. Let x and y be any pair of distinct points in X. Since f is injective and Y is gsp-D_1, there exist gsp-D sets G_x and G_y of Y containing f(x) and f(y) respectively, such that f(y)∉G_x and f(x)∉$G_{y.}$ By Theorem 3.16, $f^{-1}(G_x)$ and $f^{-1}(G_y)$ are gsp-D sets in X containing x and y respectively. This implies that X is a gsp-D_1 space.

We, define and study the concept of gsp-R_0 spaces in the following :

Definition 3.29: Let X be a topological space and A ⊂ X.Then the generalized pre-kernel of A denoted by gsp-ker(A), is defined to be the set gsp-ker(A)= {G∈GSPO(X)|A⊂G}

Lemma 3.30 : Let X be a topological space and x X. Then y∈gsp-ker({x}) if and only if x∈gspCl({y})

Proof: Suppose that y gsp-ker({x}). Then there exists a gsp-open set V containing x such that y V.Therefore, we have x gspCl({y}).

Conversely, Suppose that x gsp-ker({y}). Then there exists a gsp-open set V contaning y such that x V.Therefore, we have y gspCl({x}).

Lemma.3.31: Let X be a topological space and A be a subset of X. Then gsp-ker(A)={ x X|gspCl({x}) A≠ ∅}

Proof: Let x gsp-ker(A) and suppose gspCl({x})=∅. Hence x X|gspCl({x}) which is a gsp-open set containing A. This is absurd. Since x gsp-ker(A). consequently, gspCl({x}) A≠ ∅. Next, let gspCl({x}) A≠ ∅ and suppose that x gsp-ker(A). Then there exists gsp-open set U containing A and x U. Let y gspCl({x}) A. hence, U is a gsp-neighbourhood of y where x U. But this is a contradiction, Therefore x gsp-ker(A) and the claim.

Now, we define the following

Definition 3.32: A space X is said to be gsp-R_0 space if every gsp-open set contains the gsp-closure of each of its singletons.

Clearly ,every gsp-R_0 space is gsp-T_1 space.

We recall the following :

Definition 3.33 [12]: A topological space (X,τ) is said to be gp-R_0 space if every gp-open set contains the gp-closure of each of its singletons.

Definition 3.34 [3]: A topological space X is said to be αg-R_0 space if αgCl({x})⊂U Whenever U is αg-open and x U.

Hence , we have the following w.r.t. Note-3.3:

αg-R_0-space → gp-R_0-space → gsp-R_0-space

Now , we characterize the gsp-R_0 spaces in the following.

Theorem 3.35: For any topological space X the following properties are equivalent:

(i) X is gsp-R_0 space;

(ii) Foe any F∈GSPC(X, τ) x∉F⇒F⊂U and x∉U for some U∈GSPC(X, τ);

(iii) For any F∈GSPC(X, τ) x∉F ⇒F∩gspCl({x})=φ;

(iv) For any distinct points x and y either gspCl({x})= gspCl({y}) or gspCl({x}) gspCl({y})=φ.

Proof: (i) ⇒ (ii): Suppose F∈GSPC(X, τ) and x∉F. Then by(i) gspCl({x})⊂X|F. Set U=Xgsp({x}) then U∪∈GSPO(X, τ), F⊂U and x∉U

(ii) ⇒ (iii): Let F∈GSPC(X, τ), x∉F. Therefore, there exists U∈GSPO(X, τ) such that F⊂U and x∉U. Since U∈GSPO(X, τ), Ug∩spCl({x})=φ. and F∩gspCl({x})=φ.

(iii) ⇒ (iv): Suppose that gspCl({x})≠ gspCl({y}) for distinct points x,y ∈X. There exist z ∈gspCl({x}) such that z∉gspCl({y}). One can also assume that z∈ gspCl({y}) such that z∉ gspCl({x}). There exists

V∈GSPO(X, τ) such that y∉V and z∈V. Hence x∈V. Therefore we obtain x∉ gspCl({y}).By(iii) we obtain gspCl({x})∩gspCl({y})=φ. The proof of otherwise is similar.

(iv) ⇒ (i): Let V∈GSPO(X, τ) and x∈V. For each y∉V, x≠ y and x∉gspCl({y}). This show that gspCl({x})≠gspCl({y}). By (iv) gspCl({x})∩gspCl({y})=φ for each y∈X|V. Hence gspCl(p{x})∩(U{gspCl({y})| y X|V}=φ. On the other hand, since V∈GSPO(X, τ) and y∉X|V. We have gspCl({y})⊂X|V. Therefore X|V= U{gspCl({y})| y X|V}. Therefore we obtain (X|V) ∩ gspCl({x})=φ and gspCl({x})⊆V. Hence (X, τ) is gsp-R_0 space.

Finally, we define and study the following.

Definition 3.36: A space X is said to be a gsp-R_1 if for x,y in X with gspCl({x}) ≠ gspCl({y}), there exists disjoint gsp-open sets U and V such that gspCl({x}) ⊂ U and gspCl({y}) ⊂ V.

We recall the following

Definition 3.37[12] : A topological space X is said to be gp-R_1 space if for x,y in X with gpCl({x}) gpCl({y}), there exist disjoint gp-open sets U and V such that gpCl({x}) is a subset of U and gpCl({y}) is a subset of V.

Definition 3.38[3] : A topological space X is said to be αg-R_1 space if for x,y in X with αgCl({x}) gpCl({y}), there exist disjoint αg-open sets U and V such that αgCl({x}) is a subset of U and αgCl({y}) is a subset of V

In view of Note-3.3 , we have the following :

αg-R_1-space → gp-R_1-space → gsp-R_1-space

We, prove the following

Theorem 3.39: If X is gsp-R_1, then X is gsp-R_0-space.

Proof: Let U be a gsp-open and x U. If y U then since x gspCl({y}), gspCl({x}) gspCl({y}). Hence there exists a gsp-open V such that gspCl({x}) V and x V, which implies y gspCl({x}). Thus gspCl({y}) U. Therefore (X, τ) is gsp-R_0 space.

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