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On soft-πgp-separation axioms

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Abstract
The aim of the paper is to study soft-πgp-separation axioms and obtain some of their characterization.

Keywords: Soft-πgp-T_i-spaces. (i= 0, 1, 2)

1. Introduction

General Topology plays a significant role in space time geometry as well as in different branches of Mathematics. Molodtsov [12] introduced soft set sets as a new mathematical tool for dealing with uncertainties which is free from the difficulties. A soft set is a collection of approximation descriptions of an object. The concept of π-closed sets in topological space was initiated by Zaitsav [15] and the concept of πg-closed set was introduced by Noiri and Dontchev [13]. Soft separation axioms for soft topological spaces were studied and introduced by Shabir *et al.* [14]. Arokia Lancy and Arockiarani. I [2] introduced soft-β-separation axioms and derived some of its characterization. Soft semi-open sets and its properties along with soft semi-separation axioms were introduced and studied by Bin Chen [3]. Introduction of soft point along with the study on interior point, neighborhood system, continuity and compactness is found in due to Zorlutuna [16]. Many Researchers extended the result of generalization of various soft closed sets in many directions. P.K. Das [6], Kharal *et al.* [10] developed soft function over classes of soft sets. Cigdem Gunduz Aras *et al.*, [1] in 2013 studied and discussed the properties of soft continuous mappings. V. Christy and K.Mohana [4] studied the characterization of soft-πgp-closed sets in soft topological spaces.

In this paper, we investigate the soft-πgp-separation axioms such as soft-πgp-T_i (i=0, 1,2)-spaces.

2. Preliminaries

Let U be an initial universe set and E be a collection of all possible parameters with respect to U, where parameters are the characteristics or properties of objects in U. Let P (U) denote the power set of U, and let $A \subseteq E$.

Definition: 2.1 [12] A pair (F, A) is called a soft set over U, where F is a mapping given by $F: A \rightarrow P(U)$. In other words, a soft set over U is a parameterized family of subsets of the universe U. For a particular $e \in A$. F (e) may be considered the set of e-approximate elements of the soft set (F, A).

Definition: 2.2 [12] Two soft set (F,A) and (G,B) over a common universe U is said to be soft equal if (F,A) is a soft subset (G,B) and (G,B) is a soft subset of (F,A).

Definition: 2.3: [1] A soft set (F,A) over X is said to be absolute soft set denoted by $\overline{A}$ or X_A, if for al $e \in A$,F(e)=X. Clearly, we have $X'_A = \varphi_A$ and $\varphi'_A = X_A$

Let (F, E) be a soft set X. The soft set (F,E) is called a soft point, denoted by (X_e, E),if for the element $e \in E$, F(e)={x} and F(e')= ϕ for all $e' \in E-\{e\}$.

Definition: 2.4 [11] For two soft sets (F, A) and (G, B) over a common universe U,
Union of two soft sets of (F,A) and (G,B) is the soft set (H,C),where $C = A \cup B$, and $\forall e \in C$,

$$H(e) = \begin{cases} F(e) & ,if\ e \in A - B \\ G(e) & ,if\ e \in B - A \\ F(e) \cup G(e) & ,if\ e \in A \cap B \end{cases}$$

We write (F,A) ∪(G,B)=(H,C).

Definition: 2.5 [14] Let τ be the collection of soft sets over X, and then τ is called a soft topology on X if τ satisfies the following axioms:

(i) ϕ, $\widetilde{X}$ belong to τ
(ii) The union of any number of soft sets in τ belongs to τ.
(iii) The intersection of any two soft sets in τ belongs to τ.

The triplet (X, τ, E) is called a soft topological space over X.Let (X,τ,E) be a soft space over X, then the members of τ are said to be soft open sets in X.

Definition: 2.6 [6] Let (X, τ, E) be a soft topological space over X and the soft interior of (F,E) denoted by Int(F,E) is the union of all soft open subsets of (F,E). Clearly, (F,E) is the largest soft open set over X which is contained in (F,E).The soft closure of (F,E) denoted by Cl(F,E) is the intersection of all closed sets containing (F,E). Clearly, (F, E) is smallest soft closed set containing (F,E).

Int (F,E) = ∪ { (O,E): (O,E) is soft open and (O,E) $\widetilde{\subseteq}$ (F,E)}.

Cl(F,E) = ∩{ (O,E): (O,E) is soft closed and (F,E) $\widetilde{\subseteq}$ (O,E)}.

Definition:2.7 [7] The Intersection (H,C) of two soft sets (F,A) and (G,B) over a common universe U denoted (F,A) ∩ (G,B) is defined as C= A∩ B and H(e) = F(e) ∩ G(e) for all e∈C.

Definition: 2.8 [4]

1. a soft-semi open [9],if (A,E) $\widetilde{\subseteq}$ Cl(Int(A,E))
2. a soft-regular open [7], if (A,E)= Int(Cl(A,E)).
3. a soft-pre-open [7], if (A,E) $\widetilde{\subseteq}$ Int (Cl(A,E)).
4. a soft-clopen [9], if (A,E) is both soft open and soft closed.

The complement of the soft semi open, soft regular open, soft pre-open sets are their respective soft semi closed, soft regular closed and soft pre -closed sets.
The finite union of soft regular open sets is called soft π-open set and its complement is soft-π-closed set. The soft regular open set of X is denoted by SRO(X) or SRO(X, τ, E).

Definition: 2.9: [8] Let (X, τ, E) and (Y, τ*, E) be two soft topological spaces. A function f:(X,τ,E)→(Y,τ*,E) is said to be Soft-continuous[14],if f^{-1}(F,E) is soft-open in (X,τ,E),for every soft-open set (F,E) of (Y,τ*,E).

Definition: 2.10: [4]

1. A soft subset (A,E) of a soft topological space X is called soft-πgp-closed set in X if spcl(A,E) $\widetilde{\subseteq}$ (U,E) whenever (A,E) $\widetilde{\subseteq}$ (U,E) and (U,E) is soft-π-open in X.
2. Let X and Y be two topological spaces and the function f: X→Y. Then the function f is soft-πgp-irresolute if f^{-1}(F,E) is soft-πgp-open in X, for every soft-πgp-open set (F,E) of Y.

Definition 2.11: [5] Let (X,τ,E) and (Y,τ*,E) be two soft topological spaces and f:(X,τ,E)→(Y,τ*,E) be a function.Then the function f is said to be soft-πgp-continuous function if f^{-1}(G,E) is soft-πgp-closed(open) set in (X,τ,E) for every soft-closed(open) set (G,E) of (Y,τ*,E).

Definition:2.12 [5]**:** Let (X,τ,E) and (Y,τ*,E) be two soft topological spaces and f: (X,τ,E)→(Y,τ*,E) be a function. Then the function f is soft-contra-πgp-continuous if f^{-1} (F, E) is soft-πgp-closed in (X, τ, E) for every soft-open (F, E) in (Y,τ*,E)

Definition: 2.13: [5]

1. The Soft πgp-Closure of a soft set (G,E) is defined to be the intersection of all soft πgp-closed sets containing the soft set (G,E) and is denoted by s-πgp-cl(G,E).
2. The Soft πgp-Interior of a soft set (G,E) is defined to be the union of all soft πgp-open sets contained the soft set (G,E) and is denoted by s-πgp-int(G,E).

Definition:2.14: [9] A function f:(X,τ,E)→(Y,τ*,E) is called soft regular open if f((F,A)) is soft-regular open(soft-regular-closed) if f(F,A) is soft-regular-open(soft-regular-closed) in Y, for every soft-open(soft-closed) set of X.

Definition: 2.15: [9]

1. A soft topological space X is said to be soft-T_0-space if for two disjoint pints x and y, there exist a soft open sets (F,E) and (G,E) containing one but not the other.
2. A soft topological space X is said to be soft-T_1-space if for two disjoint pints x and y of X, there exist a soft open sets (F,E) and (G,E) such that x $\widetilde{\in}$ (F,E), y $\widetilde{\notin}$ (F,E) and y$\widetilde{\in}$ (G,E), x $\widetilde{\notin}$ (G,E).
3. A soft topological space X is said to be soft-T_2-space if for two disjoint pints x and y of X, there exist a disjoint open sets (F,E) and (G,E) such that x $\widetilde{\in}$ (F,E) and y$\widetilde{\in}$ (G,E).

Definition: 2.16: [1] A space X is called soft-connected if X is not the union of two disjoint non-empty soft-open sets.
Throughout this paper we denote (X, τ, E), (Y, τ*, E) and (Z, τ**, E) as X, Y and Z.

3. Soft-πgp-separation axioms

Definition: 3.1

1. A soft topological space X is said to be soft-πgp-T_0-space if for two disjoint points x and y of X, there exists a soft-πgp- open sets (F,E) and (G,E) such that x$\widetilde{\in}$ (F,E) or y$\widetilde{\in}$ (F,E) and y$\widetilde{\in}$ (G,E) or x$\widetilde{\in}$ (G,E).
2. A soft topological space X is said to be soft-πgp-T_1-space if for two disjoint points x and y of X, there exists a soft-πgp- open sets (F,E) and (G,E) such that x$\widetilde{\in}$ (F,E) and y$\widetilde{\notin}$ (F,E) and y$\widetilde{\in}$ (G,E) and x$\widetilde{\notin}$ (G,E).
3. A soft topological space X is said to be soft-πgp -T_2-space if for two disjoint points x and y of X, there exists a disjoint soft-πgp- open sets (F,E) and (G,E) such that x$\widetilde{\in}$ (F,E) and y$\widetilde{\in}$ (G,E).

Theorem: 3.2
A soft space X is soft -πgp-T_0 -space iff soft πgp-closures of distinct points are distinct.

Proof: Let x and y be distinct points of X. Since X is a soft-πgp-T_0-space, there exists a soft πgp-open set (F,E) such

that $x \tilde{\in}$ (F,E) and $y \tilde{\notin}$ (F,E). Consequently, X-(F,E) is a soft-πgp-closed set containing y but not x. But soft-πgp-cl(y) is the intersection of all soft-πgp-closed sets containing y. Hence $y \tilde{\in}$ soft-πgp-cl(y), but $x \tilde{\notin}$ soft-πgp-cl(y) as $x \tilde{\notin}$ X−(F,E). Therefore,
soft-πgp-cl(x) $\neq$ soft-πgp-cl(y).
Conversely, let soft-πgp-cl(x) $\neq$ soft-πgp-cl(y) for $x \neq y$. Then there exists at least one point $z \tilde{\in} X$ such that $z \tilde{\notin}$ soft-πgp-cl(y). We have to prove $x \tilde{\notin}$ soft-πgp-cl(y), because if $x \tilde{\in}$ soft-πgp-cl(y), then $\{x\} \tilde{\subset}$ soft-πgp-cl(y) $\Rightarrow$ soft-πgp-cl(x) $\tilde{\subset}$ soft-πgp-cl(y). So, $z \tilde{\in}$ soft-πgp-cl(y), which is a contradiction. Hence $x \tilde{\notin}$ soft-πgp-cl(y) $\Rightarrow x \tilde{\in}$ X – soft-πgp-cl(y), which is a soft-πgp-open set containing x but not y. Hence X is a soft-πgp-T_0-space.

Theorem: 3.3
A soft space X is soft-πgp-T_1-space iff each singleton is soft-πgp-closed set.

Proof: Let X be a soft-πgp-T_1-space and $x \tilde{\in} X$. Let $y \tilde{\in}$ X-{x}. Then for $x \neq y$, there exists soft-πgp-open set U_y such that $y \tilde{\in} U_y$ and $x \tilde{\notin} U_y$.
Conversely, $y \tilde{\in} U_y \subset$ X-{x}. That is X-{x} = $\cup\{U_y$: $y \tilde{\in}$ X-{x}},which is soft-πgp-open set.
Hence {x} is soft-πgp-closed set.
Conversely, suppose {x} is soft-πgp-closed set for every $x \tilde{\in} X$. Let x, $y \tilde{\in} X$ with $x \neq y$. Now, $x \neq y \Rightarrow y \tilde{\in}$ X-{x}. Hence X-{x} is soft-πgp-open set containing y but not x. Similarly, X-{y} is soft-πgp-open set containing x but not y. Therefore, X is a soft-πgr-T_1-space.

Theorem: 3.4
If every point (x,E) of X is a soft-πgp-closed, then X is a soft-πgp-T_1-space.

Proof: Let (x,E) and (y,E) be two distinct points of X and by hypothesis (x,E) and (y,E) are soft πgp-closed.Then (x,E)' and (y,E)' are soft-πgp-open such that (y,E) $\tilde{\in}$ (x,E)', (y,E) $\tilde{\notin}$ (x,E) and (x,E) $\tilde{\in}$ (y,E)', (x,E) $\tilde{\notin}$ (y,E).Hence the soft topological space X is a soft-πgp-T_1-space.

Theorem: 3.5
If f: X→Y is soft-πgp -continuous injection and Y is soft-T_1-space, then X is soft-πgp- T_1- space.

Proof: Let f:X→Y be a soft-πgp- continuous injection and Y be soft-T_1 -space. For any two distinct points x_1,x_2 of the soft space X, there exists distinct points y_1,y_2 of the soft space Y such that $y_1 = f(x_1)$ and $y_2 = f(x_2)$. Since Y is soft-T_1- space, there exists soft open sets (F, E) and (G, E) in Y such that $y_1 \tilde{\in}$ (F,E) and $y_2 \tilde{\notin}$ (F,E) and $y_1 \tilde{\notin}$ (G,E), $y_2 \tilde{\in}$ (G,E). i.e. $x_1 \tilde{\in} f^{-1}$((F,E)), $x_1 \tilde{\notin}$
f^{-1}((G,E)) and $x_2 \tilde{\in} f^{-1}$((G,E)), $x_2 \tilde{\notin} f^{-1}$((F,E)). Since f is soft-πgp - continuous, f^{-1}((F,E)),
f^{-1}((G,E)) are soft-πgp -open sets in X. Thus for two distinct points x_1,x_2 of the soft space X, there exists soft-πgp - open sets f^{-1}((F,E)) and f^{-1}((G,E)) such that $x_1 \tilde{\in} f^{-1}$((F,E)), $x_2 \tilde{\notin}$
f^{-1}((G,E)) and $x_2 \tilde{\in} f^{-1}$((G,E)), $x_2 \tilde{\notin} f^{-1}$((F,E)). Therefore, X is a soft-πgp -T_1 - space.

Theorem: 3.6
If f : X→Y be soft-πgp –irresolute function, and Y is soft-πgp - T_1 - space, then X is soft-πgp -T_1 -space.

Proof: Let x_1, x_2 be two distinct points in a soft space X. Since f is injective, there exists distinct points y_1, y_2 of a soft space Y such that $y_1 = f(x_1)$ and $y_2 = f(x_2)$. Since Y is soft-πgp -T_1 -space, there exists soft-πgp- open sets (F,E) and (G,E) in Y such that $y_1 \tilde{\in}$ (F,E) and $y_2 \tilde{\notin}$ (F,E) and $y_1 \tilde{\notin}$ (G,E), $y_2 \tilde{\in}$ (G,E). i.e. $x_1 \tilde{\in} f^{-1}$((F,E)), $x_1 \tilde{\notin} f^{-1}$((G,E)) and $x_2 \tilde{\in} f^{-1}$((G,E)), $x_2 \tilde{\notin} f^{-1}$((F,E)). Since f is soft-πgp- irresolute, f^{-1}((F,E)), f^{-1}((G,E)) are soft-πgp - open sets in X. Thus, for two distinct points x_1,x_2 of X, there exists soft-πgp- open sets f^{-1}((F,E)) and f^{-1}((G,E)) such that $x_1 \tilde{\in} f^{-1}$((F,E)), $x_1 \tilde{\notin}$ f^{-1}((G,E)) and $x_2 \tilde{\in} f^{-1}$((G,E)), $x_2 \tilde{\notin} f^{-1}$((F,E)). Hence X is a soft-πgp-T_1- space.

Theorem: 3.7
If f :X→ Y be soft-πgp -continuous injection, and Y is soft-T_2-space, then X is soft-πgp -T_2 -space.
Proof: Let f : X→Y be soft-πgp- continuous injection and Y be soft-T_2-space.Then for any two distinct points x_1 and x_2 of a soft space X, there exists distinct points y_1, y_2 of a soft space Y such that $y_1 = f(x_1)$, $y_2 = f(x_2)$. Since Y is soft-T_2 -space, there exists disjoint soft open sets (F,E) and (G,E) in Y such that $y_1 \tilde{\in}$ (F,E) and $y_2 \tilde{\in}$ (G,E). i.e. $x_1 \tilde{\in} f^{-1}$((F,E)), $x_2 \tilde{\in} f^{-1}$((G,E)). Since f is soft-πgp - continuous, f^{-1}((F,E)) & f^{-1}((G,E)) are soft-πgp-open sets in X. since f is soft injective, f^{-1}((F,E))$\cap$ f^{-1}((G,E)) = f^{-1}((F,E)$\cap$(G,E)) = $f^{-1}(\varphi)= \varphi$.Thus, for two disjoint points x_1, x_2 of X, there exists disjoint soft-πgp-open sets f^{-1}((F,E)) and f^{-1}((G,E)) such that $x_1 \tilde{\in} f^{-1}$((F,E)) and $x^2 \tilde{\in} f^{-1}$((G,E)).Hence X is soft-πgp-T_2-space.

Theorem: 3.8
If f: X→Y be the soft-πgp-irresolute injective function and Y is soft-πgp- T_2 -space, then X is soft-πgp-T_2-space.

Proof: Let x_1, x_2 be any two distinct points in a soft space X. Since f is soft injective, there exists distinct points y_1, y_2 of a soft space Y such that $y_1 = f(x_1)$ and $y_2 = f(x_2)$. Since Y is soft-πgp-T_2-space, there exist disjoint soft-πgp-open sets (F,E) and (G,E) in Y such that $y_1 \tilde{\in}$ (F,E) and
$y_2 \tilde{\in}$ (G,E). i.e, $x_1 \tilde{\in} f^{-1}$((F,E)), $x_2 \tilde{\in} f^{-1}$((G,E)). Since f is soft-πgp-irresolute, f^{-1}((F,E)), f^{-1}((G,E)) are disjoint soft-πgp-open sets in X. Thus, for two distinct points x_1,x_2 of X, there exists disjoint soft-πgp-open sets f^{-1}((F,E)) and f^{-1}((G,E)) such that $x_1 \tilde{\in} f^{-1}$((F,E)) and $x_2 \tilde{\in} f^{-1}$((G,E)). Hence X is a soft-πgp-T_2-space.

Theorem: 3.9
A soft topological space X is soft-πgp-T_2 –space iff for distinct points x,y of X, there exists a soft-πgp-open set (F,E) containing x but not y such that $y \tilde{\notin}$ soft-πgp-cl(F,E).

Proof
Let x and y be two distinct points in a soft-πgp-T_2-space X. Then there exists distinct soft-πgp-open sets (G,E) and (H,E) such that $x \tilde{\in}$ (G,E) and $y \tilde{\in}$ (H,E). This implies $x \tilde{\in}$ (H,E)'. So, (H,E)' = (F,E) is soft-πgp-closed set containing x but not y and soft-πgp-cl(F,E)=(F,E). Hence $y \tilde{\notin}$ soft-πgp-cl(F,E). Let x and y be two distinct points of X. Then there exists a soft-πgp-open set (F,E) containing x but not y such that $y \tilde{\notin}$ soft-πgp-cl(F,E) $\Rightarrow$ y (soft-πgp-cl(F,E))'. Hence (F,E) and (soft-πgp-cl(F,E))' are disjoint soft-πgp- open sets containing x and y respectively. Therefore the space X is a soft-πgp-T_2-space.

Definition: 3.10
A space X is said to be soft Urysohn space, if each pair of distinct soft points and x and y of X, there exist two soft open sets (U,E) and (V,E) such that x $\tilde{\in}$ (U,E) and y $\tilde{\in}$ (V,E) and s-cl(U,E) ∩ s-cl(V,E) =φ.

Theorem: 3.11
Let X and Y are soft spaces. If for each pair of distinct soft points x and y in X, there exist a function f of X into Y such that f(x) ≠ f(y), Y is an soft-Urysohn space and f is soft contra-πgp-continuous at x and y, then X is s-πgp -T_2-space.

Proof
Let x and y be any distinct soft points in X. Then, there exists a soft-Urysohn space Y and a function f: X → Y such that f(x) ≠ f(y) and f is soft contra-πgp-continuous at x and y. Let z=f(x) and v= f(*y*). Then z ≠ v. Since Y is soft-Urysohn, there exist soft open sets (A,E) and (B,E) containing z and v, respectively such that s-cl(A,E) ∩ s-cl(B,E) = φ. Since f is soft-contra-πgp-continuous at x and y, then there exists-πgp-open sets (F,E) and (G,E) containing x and y respectively such that f(F,E) $\tilde{\subseteq}$ s-cl(A,E) and f(G,E) $\tilde{\subseteq}$ s-cl(B,E). Since s-cl (A,E)∩ s-cl(B,E) = φ. We have (F, E)∩(G,E) = φ. Hence X is s-πgp -T_2-space.

Definition: 3.12
A space X is called soft-πgp-connected, if X is not the union of two disjoint nonempty s-πgp-open sets.

Theorem: 3.13
A space X is soft-πgp-connected, if every soft-contra-πgp-continuous function from a space X into any soft T_0-space Y is constant.

Proof
Suppose that X is not soft-πgp -connected and that every soft-contra-πgp-continuous function from X into Y is constant. Since X is not soft-πgp-connected, there exists a proper nonempty soft-πgp-clopen subset (A,E) of X. Then f is non-constant and soft-contra-πgp-continuous
such that Y is soft T_0-space, which is a contradiction. Hence, X must be soft-πgp-connected.

Theorem: 3.14
If f : X → Y is a soft-contra-πgp-continuous surjection and X is soft-πgp -connected, then Y is soft connected.

Proof
Suppose that Y is not a soft-connected space. Then there exist nonempty disjoint open sets (F,E) and (G,E) such that Y =(F,E) U (G,E). Therefore (F,E) and (G,E) are soft-clopen in Y. Since f is soft-contra-πgp-continuous, f^{-1} (F,E) and f^{-1}(G,E) are soft-πgp-open in X. Moreover, f^{-1}(F,E) and f^{-1}(G,E) are nonempty disjoint and X = f^{-1} (F,E)U(G,E). This shows that X is not soft-πgp-connected. This contradicts that Y is not soft-connected. Hence Y is soft-connected.

Definition: 3.15
A subset (A,E) of a soft space X is said to be soft-πgp-dense in X, if s-πgp-cl(A,E) = X.

Theorem: 3.16
If f : X →Y and g : X → Y are soft-contra-πgp-continuous and Y is soft-Urysohn, then (F,E) = {x ∈ X : f(x) = g(x)} is soft-πgp-closed in X.

Proof
Let x∈X \(F,E). Then f(x) ≠ g(x). Since Y is soft-Urysohn, there exist soft open sets (A,E) and (B,E) such that f(x)∈(A,E), g(x)∈(B,E) and s-cl(A,E)∩s-cl(B,E) = φ. Since f and g are soft-contra-πgp-continuous, f^{-1}(s-cl(A,E))∈SπGPO(X) and g^{-1}(s-cl(B,E))∈SπGPO(X). Let (G,E)= f^{-1}(s-cl(A,E)) and (K,E)= g^{-1}(s-cl(A,E)).Then (G,E) and (A,E) contains x. Set (V,E)=(G,E)∩(K,E).Then (V,E) is soft-πgp-open in X. Hence f(V,E)∩g(V,E)= φ and x∉s-πgp-cl(F,E).Thus (F,E) is soft-πgp-closed in X.

Theorem: 3.17
Let f: X →Y and g: X → Y is functions. If Y is soft Urysohn, f and g are soft-contra-πgp-continuous and f = g on soft-πgp-dense set (A,E) $\tilde{\subseteq}$ X, then f = g on X.

Proof
Since f and g are soft-contra-πgp-continuous and Y is soft-Urysohn, by the previous theorem (F, E) = {x∈X: f(x) = g(x)} is soft-πgp-closed in X. Then we have f = g on soft-πgp-dense set (A, E) $\tilde{\subseteq}$ X. Since (A, E) $\tilde{\subseteq}$ (F, E) and (A, E) is soft-πgp-dense set in X, then X= s-πgp-cl(A,E) $\tilde{\subseteq}$ s-πgp-cl(F,E) = (F,E). Hence f = g on X.

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