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On Soft slightly πg-continuous functions

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Abstract

In this paper, we introduce and study the concept of soft slightly πg-continuous functions which is weaker than soft πg-continuous functions and obtain its fundamental properties. The relationship between soft slightly πg-continuity and other related functions is also analyzed.

Keywords: Soft πg-closed set; soft πg-open set; soft clopen set; soft πg-Continuity; soft slightly continuity; soft slightly πg-continuity.

1. Introduction

Molodtsov [8] initiated the concept of soft set theory as a new mathematical tool and presented the fundamental results of the soft sets. Muhammad Shabir and Munazza Naz [10] introduced soft topological spaces and the notions of soft open sets, soft closed sets, soft closure, soft interior points, soft neighborhood of a point and soft separation aioms. Kharal et al. [5] introduced soft function over classes of soft sets. Cigdem Gunduz Aras et al., [1] in 2013 studied and discussed the properties of Soft continuous mappings which are defined over an initial universe set with a fixed set of parameters. In this paper, soft slightly πg-continuity is introduced and studied. Moreover, basic properties for soft slightly πg-continiuous functions are investigated and relationship between soft slightly πg-continiuious functions and its graphs are studied.

2. Preliminaries

Definition: 2.1[8]

Let U be the initial universe and P(U) denote the power set of U. Let E denote the set of all parameters. Let A be a non-empty subset of E. A pair (F, A) is called a soft set over U, where F is a mapping given by F: A→P (U).

Definition: 2.2[6]

A subset (A, E) of a topological space X is called soft generalized-closed **(**soft g -closed**),** if cl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft open in X.

Definition: 2.3[2]

A subset (A, E) of a topological space X is called soft regular closed, if cl(int(A,E)) = (A,E). The complement of soft regular closed set is soft regular open set.

Definition: 2.4[2]

The finite union of soft regular open sets is said to be soft π-open. The complement of soft π-open is said to be soft π-closed.

Definition: 2.5[2]

A subset (A, E) of a topological space X is called soft πg-closed in a soft topological space (X,τ, E), if cl(A, E) $\tilde{\subseteq}$ (U, E) whenever (A, E) $\tilde{\subseteq}$ (U, E) and (U, E) is soft π-open in X.

Definition: 2.6[1]

Let (F, E) be a soft set over X. The soft set (F, E) is called soft point, denoted by (x_e, E), if for element e ∈ E, F(e) = {x} and F(e') = ∅ for all e'∈ E−{e}.

Definition: 2.7[11]

Let (X, τ, E)and (Y, τ', E)be two topological spaces. A function f : (X, τ, E) → (Y, τ', E) is said to be Soft Semi continuous (Soft pre-continuous, Soft α -continuous, Soft β -continuous), if f^{-1}(G, E) is soft semi open(soft pre-open, soft α -open, soft β -open) in (X, τ, E) for every soft open set (G, E) of (Y, τ', E).

Definition: 2.8[3]

Let (X, τ, E) and (Y, τ', E) be two topological spaces. A function f : (X, τ, E) → (Y, τ', E) is said to be Soft regular continuous(Soft π-continuous, Soft g-continuous, Soft πg-continuous), if f^{-1}(G, E) is soft regular open(soft π-open, soft g-open, soft πg-open) in (X, τ, E) for every soft open set (G, E) of (Y, τ', E).

Definition: 2.9[3]

A function f : (X, τ, E) → (Y, τ', E) is soft πg-irresolute, if f^{-1}(G, E) is soft πg-open in (X, τ, E) for every soft πg-open set (G, E) of (Y, τ', E).

Definition: 2.10[2]

A space (X, τ, E) is called soft πg-$T_{\frac{1}{2}}$ [6], if every soft πg-closed set is soft closed, or equivalently every soft πg-open set is soft open.

Definition: 2.11[10]

A soft topological space (X, τ, E) is a soft -T_0 spce, if for each pair of distinct soft points x and y in X, there exist soft open sets (F,E) and (G,E) such that x ∈ (F,E) and y ∉ (F, E) or y ∈ (G,E) and x ∉ (G, E).

Definition: 2.12[3]

A function f: (X, τ, E) ⟶ (Y, τ', E) is called $\tilde{S}\pi$g-open, if image of each open set in X is $\tilde{S}\pi$g –open in Y.

Definition: 2.13[4]

A function f: (X, τ, E) ⟶ (Y, τ', E) is called soft contra πg-continuous, if f^{-1}(F, E) is soft πg-closed in X for every soft open set (F, E) of Y.

Definition: 2.14[4]

A space (X, τ, E) is said to be soft πg-compact, if every soft πg-open cover of X has a finite sub cover.

Definition: 2.15[4]

Soft countably πg-compact, if every soft πg-open countably cover of X has a finite subcover.

Definition: 2.16[4]

soft πg-Lindelöf, if every soft πg-open cover of X has a countable subcover.

Definition: 2.17[4]

A space (X, τ, E) is called soft πg-connected provided that X cannot be written as the union of two disjoint non-empty soft πg-open sets.

Definition: 2.18[10]

A soft topological space (X, τ, E) is a soft πg -T_0 spce, if for each pair of distinct soft points x and y in X, there exist soft open sets (F,E) and (G,E) such that x ∈ (F,E) and y ∉ (F, E) or y ∈ (G,E) and x ∉ (G, E).

3. Slightly πg-continuous functions

Definition: 3.1

A function f: (X, τ, E) → (Y, τ', E) is called soft slightly continuous, if f^{-1}(G, E) is soft open in X for each soft clopen subset (G, E) of Y.

Definition: 3.2

A function f: $(X, \tau, E) \to (Y, \tau', E)$ is said to be soft slightly πg-continuous, if f^{-1}(G, E) is soft πg-open in X for each soft clopen subset (G, E) of Y.

Theorem: 3.3

The following statements are equivalent for a function f: $(X, \tau, E) \to (Y, \tau', E)$

1. f is soft slightly πg-continuous.
2. for every soft clopen subset (G,E) of Y , f^{-1}(G, E) is soft πg-closed in X.
3. for every soft clopen subset (G,E) of Y , f^{-1}(G, E) is soft πg-clopen in X.

Proof:

(1)⟹(2)

Let (G, E) be soft clopen in Y. Then Y\ (G, E) is soft clopen in Y. Since f is soft slightly πg-continuous, f^{-1}(Y\ (G, E)) is soft πg-open in X. f^{-1}(Y\ (G, E)) = X− f^{-1} (G, E) is soft πg-open in X implies f^{-1} (G, E) is soft πg-closed in X.

(2) ⟹(3)

Let (G, E) be soft clopen in Y. Then Y\ (G, E) is soft clopen in Y. By (2) f^{-1}(Y\ (G, E)) is soft πg-closed in X. Hence f^{-1} (G, E) is soft πg-open in X implies f^{-1} (G, E) is soft πg-clopen in X.

(3) ⟹(1): obvious

Theorem: 3.4

Every soft slightly continuous function is soft slightly πg-continuous.

Proof: Obvious.

Remark: 3.5

The converse of the above theorem is not true in general as shown in the following examples.

Example 3.6

Let X = {h_1, h_2, h_3, h_4}, Y = {h_1, h_2, h_3}, E = {e_1, e_2}. Let F_1, F_2, F_3, F_4 and G_1, G_2 are functions from E to P(X) and E to P(Y) are defined as follows:

$F_1(e_1)$ = {h_3} , $F_1(e_2)$ = {h_1}; $F_2(e_1)$ = {h_4}, $F_2(e_2)$ = {h_2}; $F_3(e_1)$ = { h_3, h_4}, $F_3(e_2)$ = {h_1, h_2}; $F_4(e_1)$ = { h_1, h_4} , $F_4(e_2)$ = { h_2, h_4 } $F_5(e_1)$= { h_2, h_3, h_4}, $F_5(e_2)$ = {h_1, h_2, h_3}; $F_6(e_1)$ = { h_1, h_3, h_4 } , $F_6(e_2)$ = {h_1, h_2, h_4} and $G_1(e_1)$ = {h_1} , $G_1(e_2)$ = {h_1}; $G_2(e_1)$ = {h_2 h_3}, $G_2(e_2)$ = { h_2 ,h_3}. Then $\tau = \{\widetilde{\emptyset}, \widetilde{X}$, ($F_1$, E) ($F_2$, E), ($F_3$, E), ($F_4$, E), ($F_5$, E), ($F_6$, E)} is a soft topological space over X and τ' = {$\widetilde{\emptyset}, \widetilde{Y}$, ($G_1$, E), ($G_2$, E)} is a soft topological space over Y. If the function f : $(X, \tau, E) \to (Y, \tau', E)$ is defined as f(h_1) = h_1, f(h_3) = h_2 then f is soft slightly πg-continuous but not soft slightly continuous.

Theorem: 3.7

Let (X, τ, E) be a soft πg-$T_{\frac{1}{2}}$ space. Then the function f: $(X, \tau, E) \to (Y, \tau', E)$ is soft slightly πg-continuous if and only if it is soft slightly continuous.

Proof:

Let (G, E) be soft clopen in Y. Since f is soft slightly πg- continuous, f^{-1} (G, E) is soft πg-open in X implies f^{-1} (G, E) is soft open in X. Therefore f is soft slightly continuous. Conversely every soft slightly continuous is soft slightly πg-continuous.

Theorem: 3.8

Suppose S̃πGO(X) is soft closed under arbitrary unions. Let f: $(X, \tau, E) \to (Y, \tau', E)$ be a function. Then f is soft slightly πg-continuous if and only if for each point $x \in$ X and each soft clopen set (V,E) containing f(x), there exists a soft πg-open set (U,E) containing x such that f(U,E) $\widetilde{\subseteq}$ (V,E).

Proof:

Let $x \in$ X and (V,E) be soft clopen then $f(x) \in$ (V,E). Since f is soft slightly πg-continuous,

f^{-1} (V, E) is soft πg-open in X. If we put (U,E) = f^{-1} (V, E) then x ∈ (U,E) and f(U,E) $\tilde{\subseteq}$ (V,E). Conversely let (V,E) be a soft clopen subset of Y and let $x \in f^{-1}$(V, E). Since $f(x)$ ∈ (V,E) , there exists a soft πg-open set (U_x,E) in X containing x such that (U_x,E) $\tilde{\subseteq}$ f^{-1}(V,E). We obtain f^{-1}(V,E) = ∪{(U_x,E): $x \in f^{-1}$(V, E)}. Thus f^{-1}(V,E) is soft πg-open.

Definition: 3.9

A space (X, τ, E) is said to be soft locally indiscrete, if every soft open set of X is soft closed in X.

Theorem : 3.10

If a function f: (X, τ, E) → (Y, τ′, E)is soft slightly πg-continuous and (Y, τ′, E) is soft locally

indiscrete, then f is soft πg-continuous.

Proof:

Let (A, E) be a soft open set in Y. Since Y is soft locally indiscrete, every soft soft open set is soft closed. Since f is soft slightly πg-continuous, f^{-1}(A, E) is soft πg-open in X. Hence f is soft slightly continuous.

Theorem: 3.11

If a function f: (X, τ, E) → (Y, τ′, E)is soft slightly πg-continuous and (X, τ, E) is soft πg-$T_{\frac{1}{2}}$ space then f is soft slightly continuous.

Proof:

Let (A, E) be a soft clopen set in Y. By hypothesis f^{-1}(A, E) is soft πg-open in X. Since X is soft πg-$T_{\frac{1}{2}}$ space, f^{-1}(A, E) is soft open in X. Hence f is soft slightly continuous.

Definition: 3.12

A space (X, τ, E) is said to be soft submaximal, if each soft dense subset of X is soft open.

Definition: 3.13

A space (X, τ, E) is said to be soft extremally disconnected, if the soft closure of each soft open set of X is soft open in X.

Definition: 3.14

The graph G(f) of a function f : (X, τ, E) → (Y, τ′, E) is said to be soft slightly πg-graph, if for each (x, y) ∈ (X × Y)\ G(f), there exist a $\tilde{S}\pi$g-open set (A,E) in X containing x and a soft clopen set (B,E) in Y containing y such that (A × B, E) ∩ G(f) = ∅.

Theorem: 3.15

Let f: (X, τ, E) → (Y, τ′, E) be soft function and let g: (X, τ, E)→ (X × Y, τ×τ’, E) be the soft graph function of f, defined by $g(x) = (x, f(x))$ for every x ∈ X. Then f is soft slightly πg-continuous, if g is soft slightly πg-continuous.

Proof:

Let (V, E) ∈ S̃CO(Y) then X × (V, E) ∈ S̃CO(X × Y). Since g is soft slightly πg-continuous, f^{-1} (V, E) = g^{-1} (X × (V, E)) ∈ S̃πGO(X). Thus f is soft slightly πg-continuous.

Theorem: 3.16

Let f: (X, τ, E) → (Y, τ′, E) be soft slightly πg-continuous function and let g: (X, τ, E)→ (X × Y, τ×τ’, E) be the soft graph function of f, defined by $g(x) = (x, f(x))$ for every x ∈ X. If for each soft clopen subset (W,E) of (X × Y, τ×τ’, E) and for each $x \in g^{-1}$(W, E), the set g^{-1}(W, E) ∩ f^{-1}(W_x, E) where (W_x, E) is a vertical cut of (W,E) at x is soft πg-open relative to f^{-1}(W_x , E) then g is soft slightly πg-continuous.

Proof:

Let (W, E) be any soft clopen subset of X × Y and let $x \in g^{-1}$(W, E), be an arbitrarily chosen soft point. Then (W, E) ∩ ({x} × Y) is soft clopen in {x} × Y containing g (x). Also {x} × Y is soft homeomorphic to Y. Hence, the vertical cut W_x = {y ∈ Y: (x, y) ∈ (W, E)} is a soft clopen subset of Y. Since f is soft slightly πg-continuous, f^{-1}(W_x, E) is a soft πg-open subset of X. By hypothesis g^{-1}(W, E) ∩ f^{-1}(W_x, E) is soft πg-open relative to f^{-1}(W_x , E), so g^{-1}(W, E) ∩ f^{-1}(W_x, E) is soft πg-open in X. Therefore g^{-1}(W, E) is soft πg-open in X. Then g is soft slightly πg-continuous.

Theorem: 3.17

Let f: $(X, \tau, E) \to (Y, \tau', E)$and g: $(Y, \tau', E) \to (Z, \tau'', E)$be functions. Then the following properties hold:

1. if f is soft πg-irresolute and g is soft slightly πg-continuous, then g ∘ f: $(X, \tau, E) \to (Z, \tau'', E)$ is soft slightly πg-continuous.
2. if f is soft πg-irresolute and g is soft πg-continuous, then g ∘ f: $(X, \tau, E) \to (Z, \tau'', E)$ is soft slightly πg-continuous.
3. if f is soft πg-irresolute and g is soft slightly continuous, then g ∘ f: $(X, \tau, E) \to (Z, \tau'', E)$ is soft slightly πg-continuous.

Theorem: 3.18

Let f: $(X, \tau, E) \to (Y, \tau', E)$and g:$(Y, \tau', E) \to (Z, \tau'', E)$ be functions. If f is soft M- πg-open surjective and g ∘ f: $(X, \tau, E) \to (Z, \tau'', E)$ is soft slightly πg-continuous then g is soft slightly πg-continuous.

Proof:

Let (A, E) be any soft clopen in Z. Since g∘f is soft slightly πg-continuous, (g∘f)(f^{-1}(A, E)) = f^{-1}(g^{-1}(A, E)) is soft soft πg-open. Since f is soft M- πg-open, then f(f^{-1}(g^{-1}(A, E))) = g^{-1}(A, E) is soft soft πg-open in Y. Hence g is soft slightly πg-continuous.

Theorem: 3.19

Let f: $(X, \tau, E) \to (Y, \tau', E)$ be surjective soft πg-irresolute, soft M-πg-open and let g : $(Y, \tau', E) \to (Z, \tau'', E)$ be a function. Then g ∘ f: $(X, \tau, E) \to (Z, \tau'', E)$ is soft slightly πg-continuous if and only if g is soft slightly πg-continuous.

4. Soft πg-compact space and Soft πg-connected space

Definition: 4.1

A space (X, τ, E) is said to be soft mildly compact, if every soft clopen cover of X has a finite sub cover.

Theorem: 4.2

If a function f: $(X, \tau, E) \to (Y, \tau', E)$ is soft slightly πg-continuous and (A, E) is soft πg-compact relative to X, then f(A,E) is soft mildly compact relative to Y .

Proof:

Let {(V_i, E): i ∈ I} be any soft cover of f(A,E) by soft clopen sets of the subspace f(A,E). For each i ∈ I there exists a soft clopen set (A_i, E) of Y such that (V_i , E) = (A_i, E) ∩ f(A,E). For each x ∈ (A,E), there exists i(x) ∈ I such that f(x) ∈ ($A_{i(x)}$,E) and there exists (F_x, E) ∈ $\tilde{S}\pi$GO(X, x) such that f(F_x, E) $\tilde{\subset}$ ($A_{i(x)}$,E). Since the family {(F_x, E) : x ∈ (A,E)} is a soft cover of (A,E) by $\tilde{S}\pi$g- open sets of X, there exists a finite subset (A_0, E) of (A,E) such that (A,E) $\tilde{\subset}$ ∪{(F_x, E) : x ∈ (A_0,E)}. Hence, we obtain f(A,E) $\tilde{\subset}$ ∪ {f(F_x, E): x ∈ (A_0,E) which is a subset of ∪{($A_{i(x)}$,E): x ∈ (A_0,E)}. Thus, f(A,E) = ∪{$V_{i(x)}$,E): x ∈ (A_0,E)}. Hence f(A,E) is soft mildly compact relative to Y .

Corollary: 4.3

If f: $(X, \tau, E) \to (Y, \tau', E)$ is soft slightly πg-continuous surjection and X is soft πg-compact, then Y is soft mildly compact.

Definition: 4.4

A space (X, τ, E) is said to be:

1. Soft mildly countably compact, if every soft clopen countably cover of X has a finite subcover.
2. Soft mildly Lindelöf , if every soft cover of X by soft clopen sets has a soft countable subcover.
3. Soft πg-closed compact, if every soft πg-closed cover of X has a finite subcover.
4. Soft countably πg-closed-compact, if every countable cover of X by soft πg-closed sets has a finite subcover.

Theorem: 4.5

Let f: $(X, \tau, E) \to (Y, \tau', E)$ be a soft slightly πg-continuous surjection. Then the following statements hold:

1. If X is soft πg-Lindelöf, then Y is soft mildly Lindelöf.

2. If X is soft countably πg-compact, then Y is soft mildly countably compact.

Proof:

(1) Let $\{(V_\alpha, E): \alpha \in I\}$ be a soft clopen cover of Y. Since f is soft slightly πg-continuous, then $\{f^{-1}(V_\alpha,E) : \alpha \in I\}$ is a soft πg-open cover of X. Since X is soft πg-Lindelof, there exists a countable subset I_0 of I such that $X = \cup\{f^{-1}(V_\alpha,E) : \alpha \in I_0\}$.Thus $Y = \cup\{(V_\alpha,E) : \alpha \in I_0\}$ and hence Y is soft mildly Lindelöf. Proof of (2) Similar to (1).

Theorem: 4.6

Let $f: (X, \tau, E) \to (Y, \tau', E)$ be a soft slightly πg-continuous surjection. Then the following statements hold:

1. If X is soft πg-closed compact, then Y is soft mildly compact.
2. If X is soft πg-closed Lindelöf, then Y is soft mildly Lindelöf.
3. If X is soft countably πg-closed compact, then Y is soft mildly countably compact.

Theorem: 4.7

If $f: (X, \tau, E) \to (Y, \tau', E)$ is soft slightly πg-continuous surjective function and X is soft πg-connected, then Y is soft connected.

Proof:

Suppose Y is not soft connected. Then there exist non-empty disjoint soft clopen subsets (U, E) and (V, E) of Y such that Y = (U, E) ∪ (V, E). Since f is soft slightly πg-continuous, we have $f^{-1}(U, E)$ and $f^{-1}(V, E)$ are non-empty disjoint soft πg-open sets in X. Moreover, $f^{-1}(U, E) \cup f^{-1}(V, E) = X$. This shows that X is not soft πg-connected which is a contradiction. Hence Y is soft connected.

Theorem: 4.8

If f is a soft slightly πg-continuous function from a soft πg-connected space X onto any space Y, then Y is not a soft discrete space.

Proof:

Suppose that Y is soft discrete. Let (A, E) be a proper nonempty soft open subset of Y. Then $f^{-1}(A, E)$ is any proper nonempty soft πg-clopen subset of X, which is a contradiction to the assumption that X is soft πg-connected. Therefore Y is not a soft discrete space.

Theorem: 4.9

A space X is soft πg-connected, if every soft slightly πg-continuous function from a space X into any soft T_0-space Y is constant.

Proof:

Suppose that X is not soft πg-connected. Let every soft slightly πg-continuous function from X into any soft T_0-space then Y is constant. Since X is not soft πg-connected, there exists a proper nonempty soft πg-clopen subset (A, E) of X. Then f is a non-constant and soft slightly πg-continuous such that Y is soft $-T_0$, which is a contradiction. Hence, X is soft πg-connected.

Theorem: 4.10

If a function $f: X \to \prod Y_\alpha$ is soft slightly πg-continuous, then $P_\alpha \circ f : X \to Y_\alpha$ is soft slightly πg-continuous for each

$\alpha \in \Lambda$, where P_α is the projection of $\prod Y_\alpha$ onto Y_α.

Proof:

Let (V_α, E) be any soft clopen set of Y_α. Then $P_\alpha^{-1}(V_\alpha,E)$ is soft clopen in $\prod Y_\alpha$. Hence $(P_\alpha \circ f)^{-1}(V_\alpha,E) = (f^{-1}(P^{-1}(V_\alpha,E))$ is soft πg-open in X. Therefore, $P_\alpha \circ f$ is soft slightly πg-continuous.

Theorem: 4.11

If a function $f: \prod X_\alpha \to \prod Y_\alpha$ is soft slightly soft πg-continuous, then $f_\alpha: X_\alpha \to Y_\alpha$ is soft slightly πg-continuous for each $\alpha \in \Lambda$.

Proof:

Let (V_α, E) be any soft clopen set of Y_α. Then $P_\alpha^{-1}(V_\alpha, E)$ is soft clopen in $\prod Y_\alpha$ and $f^{-1}(P^{-1}(V_\alpha, E)) = f^{-1}(V_\alpha, E) \times \prod\{X_\alpha : \alpha \in \Lambda \setminus \{\alpha\}\}$. Since f is soft slightly πg-continuous, $f^{-1}(P^{-1}(V_\alpha, E))$ is soft πg-open in $\prod X_\alpha$. Since the projection P_α of $\prod X_\alpha$ onto X_α is soft open and soft continuous, $f_\alpha^{-1}(V_\alpha, E)$ is soft πg-open in X_α. Hence f_α is soft slightly πg-continuous.

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