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ON SOFT CONTRA-πgb-CONTINUOUS FUNCTIONS IN SOFT TOPOLOGICAL SPACES

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Abstract: The aim of this paper is to define and study the concepts of soft contra πgb-continuous function and soft almost contra πgb-continuous function in soft topological spaces.

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1. Introduction and Preliminaries

Molodtsov [12] initiated the concept of soft set theory as a new mathematical tool and presented the fundamental results of the soft sets. Soft systems provide a general framework with the involvement of parameters. Soft set theory has a wider application and its progress is very rapid in different fields. Levine

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[10] introduced g-closed sets in general topology. Kannan [8] introduced soft g-closed sets in soft topological spaces. Muhammad Shabir and Munazza Naz [14] 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 axioms. Soft semi-open sets and its properties were introduced and studied by Bin Chen [2]. Kharal et al. [9]introduced soft function over classes of soft sets. Hussain et al [5] continued to study the properties of soft topological space.In 2013, Cigdem Gunduz Aras et al., [3]studied and discussed the properties of soft continuous mappings which are defined over an initial universe set with a fixed set of parameters. Mahanta and Das [13]introduced and characterized various forms of soft functions like semi continuous, semi irresolute, semi open soft functions.

In this paper, the concept of soft contra πgb-continuous function and soft almost contra πgb-continuous function on soft topological spaces are discussed and some characterizations of these mappings are obtained.

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 $\tilde{\subset}$E.

Definition 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 parametrized 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. [4]For two soft sets (F,A) and (G,B) over a common universe U, we say that (F,A) is a soft subset of (G,B) if (i) A $\tilde{\subset}$ B, and (ii)$\forall$ e$\in$ A, F(e)$\tilde{\subset}$ G(e). We write (F,A)$\tilde{\subset}$ (G,B). (F,A) is said to be a soft super set of (G,B), if (G,B) is a soft subset of (F,A).

Definition 3. [11] A soft set (F,A) over U is said to be:

(i) null soft set denoted by ϕ if $\forall$ e $\in$ A, F(e) = ϕ.

(ii) absolute soft set denoted by A, if $\forall$ e $\in$ A, F(e) = U.

Definition 4. [14] Let τ be the collection of soft sets over X, then τ is called a soft topology on X if τ satisfies the following axioms:

1) ϕ, X belong to τ

2) The union of any number of soft sets in τ belongs to τ.

3) 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. For simplicity, we can take the soft topological space (X, τ, E) as X throughout the work.

Definition 5. A soft subset (A,E) of X is called:
(i) a soft b-open[6] if (A,E) $\widetilde{\subset}$ Cl(Int(A,E))$\cap$ Int(Cl(A,E));
(ii) a soft generalized closed (soft g-closed)[8] if Cl(A,E)$\widetilde{\subset}$ U,E) whenever (A,E)$\widetilde{\subset}$ (U,E) and (U,E) is soft open in X;
(iii) soft πgb-closed[6] in X if sbcl(A,E)$\widetilde{\subset}$ (U,E) whenever (A,E)$\widetilde{\subset}$ (U,E) and (U,E) is soft π-open in X;
(iv)a soft generalized β closed (Soft gβ-closed)[1] in a soft topological space (X, τ,E) if βCl(A,E) $\widetilde{\subset}$ (U,E) whenever (A,E)$\widetilde{\subset}$ (U,E) and (U,E) is soft open in X;
(v) a soft gsβ closed[1] if βCl(A,E)$\widetilde{\subset}$ (U,E) whenever (A,E)$\widetilde{\subset}$ (U,E) and (U,E) is soft semi open in X.

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 6. [8] A soft topological space X is called a soft $T_{1/2}$-space if every soft g-closed set is soft closed in X.

Definition 7. Let (X, τ, E) and (Y,τ',E) be two soft topological spaces. A function f : (X, τ ,E) $\rightarrow$ (Y, τ',E) is said to be:
(i) soft semi-continuous[13] if f^{-1}((G,E)) is soft semi-open in (X, τ ,E), for every soft open set (G,E) of (Y,τ',E).
(ii) soft pre-continuous [15] if f^{-1}((G,E)) is soft pre-open in (X, τ,E), for every soft open set (G,E) of (Y, τ',E).
(iii) soft πgr-continuous[6] if f^{-1}((G,E)) is soft πgr-closed in (X, τ, A) for every soft closed set (G, E) in (Y, τ',E).

Definition 8. [7] Let (X, τ , A) and (Y, τ', B) be two soft topological spaces and f : (X, τ, A) (Y, τ', B) be a function. Then the function f is soft πgb- continuous if f^{-1}(G,B) is soft πgb- closed in (X, τ, A) for every soft closed set (G,B) of (Y, τ',B).

Definition 9. [7] Let (X, τ, A) and (Y, τ', B) be soft topological spaces and f : (X, τ, A)$\rightarrow$(Y, τ', B) be a function. Then the function f is soft πgb-open if f (G,A) is soft πgb-open in (Y, τ',B) for every soft open set (G,A) of (X, τ, A).

Definition 10. [7] A soft topological space X is called soft πgb-$T_{1/2}$ space if every soft πgb- closed set is soft b-closed.

3. Soft Contra-πgb-Continuous Functions

In this section, we study the notion of soft contra πgb-continuous functions.

Definition 11. Let (X, τ, A) and (Y, τ', B) be two soft topological spaces and f : (X, τ, A)$\rightarrow$(Y, τ', B) be a function. Then the function f is:

(i)soft contra continuous if f^{-1}(G,B) is soft closed in (X, τ, A) for every soft open set (G,B) of (Y, τ',B).

(ii) soft contra b-continuous if f^{-1}(G,B) is soft b-closed in (X, τ, A) for every soft open set (G,B) of (Y, τ',B).

(iii) soft contra g-continuous if f^{-1}(G,B) is soft g-closed in (X, τ, A) for every soft open set (G,B) of (Y, τ',B).

(iv) soft contra πg-continuous if f^{-1}(G,B) is soft πg-closed in (X, τ, A) for every soft open set (G,B) of (Y, τ',B).

(v) soft contra πgr-continuous if f^{-1}(G,B) is soft πgr -closed in (X, τ, A) for every soft open set (G,B) of (Y, τ',B),

Definition 12. Let (X, τ, A) and (Y, τ', B) be two soft topological spaces and f : (X, τ, A)$\rightarrow$(Y, τ', B) be a function. Then the function f is soft contra πgb- continuous if f^{-1}(G,B) is soft πgb- closed in (X, τ, A) for every soft open set (G,B) of (Y, τ', B).

Theorem 13. *(i) Every soft contra continuous function is soft contra-πgb- continuous.*

(ii) Every soft contra-b-continuous function is soft contra- πgb- continuous.

(iii) Every soft contra-g-continuous function is soft contra- πgb- continuous.

(iv) Every soft contra-πg-continuous function is soft contra- πgb- continuous.

(v) Every soft contra- πgr -continuous function is soft contra- πgb- continuous.

Remark 14. Converse of the above statements is not true as shown in the following example.

Example 15. Let X=Y=$\{a, b, c, d\}$, E=$\{e_1, e_2\}$.Let $F_1, F_2, ., F_6$ are functions from E to P(X) and are defined as follows:

$F_1(e_1) = \{c\}\,, F_1(e_2) = \{a\}$

$F_2(e_1) = \{d\}\,, F_2(e_2) = \{b\}$

$F_3(e_1) = \{c, d\}, F_3(e_2) = \{a, b\}$
$F_4(e_1) = \{a, d\}, F_4(e_2) = \{b, d\}$
$F_5(e_1) = \{b, c, d\}, F_5(e_2) = \{a, b, c\}$
$F_6(e_1) = \{a, c, d\}, F_6(e_2) = \{a, b, d\}$
Then $\tau_1 = \{\phi, X, (F_1, E), ...(F_6, E)\}$ is a soft topology and elements in τ are soft open sets.

Let G_1, G_2, G_3, G_4 are functions from E to P(Y) and are defined as follows:
$G_1(e_1) = \{a\}, G_1(e_2) = \{d\}$
$G_2(e_1) = \{b\}, G_2(e_2) = \{c\}$
$G_3(e_1) = \{a, b\}, G_3(e_2) = \{c, d\}$
$G_4(e_1) = \{b, c, d\}, G_4(e_2) = \{a, b, c\}$
Then $\tau_2 = \{\phi, X, (G_1, E), ...(G_4, E)\}$ be a soft topology on Y.Let f:X→Y be an identity map. Here the inverse image of the soft open set

$$(A, E) = \{\{b, c, d\}, \{a, b, c\}\}$$

in Y is not soft closed, soft b-closed in X. Hence not soft contra continuous, soft contra b-continuous. Also soft open set (B,E)=$\{\{a\}, \{d\}\}$ in Y is not soft πg-closed, soft πgr-closed in X. Hence not soft contra-πg-continuous, soft contra πgr-continuous. Soft open set (C,E)=$\{\{b, c, d\}, \{a, b, c\}\}$ in Y is not soft g-closed in X. Hence not soft contra g-continuous.

Definition 16. A soft topological space X is called:
(i) soft πgb-locally indiscrete if every soft πgb-open set is soft closed.
(ii)a soft $T_{\pi_{gb}}$-space if every soft πgb-closed set is soft πg-closed.

Theorem 17. *(X, τ, A) and (Y, τ', B) be two soft topological spaces and f : (X, τ, A)→(Y, τ', B) be a function.*

(i) If a function f is soft πgb-continuous and (X, τ, A) is soft πgb-locally indiscrete, then f is soft contra-continuous.

(ii) If a function f is soft contra-πgb-continuous and (X, τ, A) is a soft πgb-$T_{1/2}$ space, then f is soft contra-b-continuous.

(iii) If a function f is soft contra-πgb-continuous and (X, τ, A) is a soft πgb-space, then f is soft contra-continuous.

(iv) If a function f is contra-πgb-continuous and (X, τ, A) is a soft $T_{\pi_{gb}}$ -space, then f is soft contra-πg-continuous.

Proof. (i) Let (B,E) be soft open in (Y, τ', B). By assumption inverse image of soft open set (B,E) is soft πgb-open in X. Since X is soft πgb-locally indiscrete, inverse image of soft open set (B,E) is soft closed in X. Hence f is soft contra-continuous.

(ii) Let (B,E) be soft open in (Y, $\tau^{'}$, B). By assumption, inverse image of soft open set (B,E) is soft πgb-closed in X. Since X is soft πgb-$T_{1/2}$ space, inverse image of soft open set (B,E) is soft b-closed in X. Hence f is soft contra-b-continuous.

(iii) Let (B,E) be soft open in (Y, $\tau^{'}$, B).By assumption, inverse image of soft open set (B,E) is soft πgb-closed in X. Since X is soft πgb-space, inverse image of soft open set (B,E) is closed in X. Hence f is soft contra-continuous.

(iv) Let (B,E) be soft open in (Y, $\tau^{'}$, B). By assumption, inverse image of soft open set (B,E) is soft πgb-closed in X. Since X is soft $T_{\pi_{gb}}$-space, inverse image of soft open set (B,E) is soft πg-closed in X. Hence f is soft contra-πg-continuous.

Theorem 18. *Let A $\tilde{\subset}$ Y$\tilde{\subset}$ X.*

(i) If Y is soft open in X, then A $\in\pi$GBC(X) implies A$\in\pi$GBC(Y).

(ii)If Y is soft regular open and soft πgb-closed in X, then A $\in\pi$GBC(Y) implies A$\in\pi$GBC(X).

Theorem 19. *Suppose πGBO(X) is soft closed under arbitrary union. Then the following are equivalent for a function f : (X, τ, A)$\rightarrow$(Y, $\tau^{'}$, B) .*

(i) f is soft contra-πgb-continuous.

(ii) For every soft closed subset (F,E) of Y, f^{-1}((F,E)) $\in\pi$GBO(X).

(iii) For each x$\in$X and each (F,E) $\in$ SC(Y,f(x)), there exists $(A, E) \in S\pi GBO(X, x)$ such that f((A,E))$\tilde{\subset}$ (F,E).

Proof.(i) $\Leftrightarrow$ (ii) and (ii) $\Rightarrow$ (iii) is obvious. (iii)$\Rightarrow$ (ii): Let (F,E) be any closed set of Y and $x \in f^{-1}((F, E))$. Then f(x)$\in$(F,E) and there exists $(A, E)_x$ $\in$SπGBO(X) such that f($(A, E)_x$) $\tilde{\subset}$ (F,E). Therefore we obtain

$$f^{-1}((F, E)) = \cup \left\{(A, E)x : x \in f^{-1}(F)\right\}$$

and f^{-1}((F,E)) is soft πgb-open.

Theorem 20. *Suppose SπGBO(X) is soft closed under arbitrary intersections. If a function f : (X, τ, A)$\rightarrow$(Y, $\tau^{'}$, B) is soft contra-πgb-continuous and U is soft open in X, then f / U: (U, τ, A)$\rightarrow$(Y, $\tau^{'}$, B) is soft contra-πgb-continuous.*

Proof. Let (B,E) be closed in Y. Since f : (X, τ, A)$\rightarrow$(Y, $\tau^{'}$, B) is soft contra-πgb-continuous, f^{-1}((B,E)) is soft πgb-open in (X, τ, A). $(f/U)^{-1}$((B,E)) = f^{-1}((B,E)) $\cap$ U is soft πgb-open in X. Hence $(f/U)^{-1}$((B,E)) is soft πgb-open in U.

Theorem 21. *Suppose Sπ GBO(X) is soft closed under arbitrary unions. Let (X, τ, A)$\rightarrow$(Y, τ', B) be a function and $\{Ui : i \in I\}$ be a soft cover of X such that U_i $\in$SπGBC(X) and soft regular open for each i$\in$I. If f / U_i : (U_i, τ /U_i)$\rightarrow$Y is soft contra-πgb-continuous for each i$\in$I, then f is soft contra-πgb-continuous.*

Theorem 22. *Suppose SπGBO(X) is soft closed under arbitrary unions. If f : (X, τ, A)$\rightarrow$(Y, τ', B) is soft contra-πgb-continuous and Y is soft regular open, then f is soft πgb-continuous.*

Definition 23. Let (X, τ, A) and (Y, τ', B) be soft topological spaces and f : (X, τ, A)$\rightarrow$(Y, τ', B) be a function. Then the function f is:

(i) soft contra πgb- open if f (G,A) is soft πgb-open in (Y, τ', B) for every soft closed set (G,A) of (X, τ, A).

(ii) soft contra πgb- closed if f (G,A) is soft πgb-closed in (Y, τ', B) for every soft open set (G,A) of (X, τ, A).

Theorem 24. *If f : (X, τ, A)$\rightarrow$(Y, τ', B) is a soft π-continuous and soft b-closed function, then f ((A,E)) is soft πgb-closed in Y for every soft πgb-closed set (A,E) of X.*

Proof. Let (A,E) be soft πgb-closed set in X. Let f ((A,E)) $\tilde{\subset}$ (F,E), where (F,E) is a soft π-open set in Y. Since f is soft π-continuous, f^{-1}((F,E)) is soft π-open in X and (A,E)$\tilde{\subset}$ f^{-1} ((F,E)).Then we have sbcl((A,E))$\tilde{\subset}$ f^{-1} ((F,E)) and so f(sbcl((A,E))) $\tilde{\subset}$ (F,E). Since f is soft b-closed, f (sbcl ((A,E))) is soft b-closed in Y. Hence sbcl(f((A,E))) $\tilde{\subset}$ sbclf(sbcl((A,E))) = f(sbcl((A,E))) $\tilde{\subset}$ (F,E).This shows that f((A,E)) is soft πgb closed in Y.

Definition. A map f: X$\rightarrow$Y is said to be soft contra-πgb-irresolute if f^{-1}((F,E)) is soft πgb- closed in X for each (F,E) $\in$SπGBO(Y).

Theorem 25. *Let f : (X, τ, A)$\rightarrow$(Y, τ', B) and g: f : (Y, τ', A)$\rightarrow$(Z, τ'', B) be two maps in soft topological space such that g$\circ$f: (X, τ, E) $\rightarrow$ (Z, τ'', E) .*

(i) If g is soft πgb-continuous and f is soft contra -πgb- irresolute, then g$\circ$f is soft contra πgb- continuous.

(ii) If g is soft πgb-irresolute and f is soft contra-πgb irresolute, then g$\circ$f is soft contra-πgb-irresolute.

Proof. (i) Let (F,E) be soft closed set in Z. Then g^{-1}((F,E)) is soft πgb-closed in Y. Since f is soft contra -πgb- irresolute,f^{-1}(g^{-1}((F,E))) is soft πgb-open in X. Hence g$\circ$f is soft contra πgb- continuous. (ii)Let (F,E) be soft πgb-closed in Z. Then g^{-1}((F,E)) is soft πgb-closed in Y. Since f is soft contra -πgb- irresolute, f^{-1}(g^{-1}((F,E))) is soft πgb-open in X. Hence g$\circ$f is soft contra

πgb- irresolute.

4. Soft Almost Contra-πgb-Continuous Functions

In this section, we study the concept of soft almost contra πgb-continuous functions.

Definition 26. A function f : (X, τ, A)$\rightarrow$(Y, $\tau^{'}$, B) is said to be soft almost contra- πgb- continuous if f^{-1}((F,E))$\in$ SπGBC(X) for each (F,E)$\in$SRO(Y).

Theorem 27. *Suppose SπGBO(X) is soft closed under arbitrary unions. Then the following statements are equivalent for a function f : (X, τ, A)$\rightarrow$(Y, $\tau^{'}$, B).*

(i) f is soft almost contra- πgb- continuous.

(ii) f^{-1}((F,E)) $\in$ SπGBO(X) for every (F,E)$\in$SRC(Y).

(iii) For each x$\in$X and each soft regular closed set (F,E) in Y containing f(x), there exists a soft πgb-open set (A,E) in X containing x such that f((A,E))$\widetilde{\subset}$ (F,E).

(iv)For each x$\in$X, and each soft regular open set (B,E) in Y not containing f(x),there exists a soft πgb-closed set (G,E) in X not containing x such that f^{-1}((B,E))$\widetilde{\subset}$ (G,E).

(v) f^{-1}(s-int(cl((G,E))))$\in$SπGBC(X) for every soft open subset (G,E) of Y.

(vi) f^{-1}(s-int(cl((F,E) F)))$\in$SπGBO(X) for every soft closed subset (F,E) of Y.

Proof. (i)$\Rightarrow$(ii).Let (F,E)$\in$SRC(Y).Then Y-(F,E) $\in$SRO(Y) by assumption. Hence f^{-1}((Y-(F,E))=X-f^{-1}((F,E))$\in$ SπGBC(X). This implies

$$f^{-1}((F,E)) \in S\pi GBO(X).$$

(ii) $\Rightarrow$ (i). Let (F,E) $\in$SRO(Y).Then by assumption (Y-(F,E))$\in$SRC(Y). Hence f^{-1}((Y-(F,E)) =X-f^{-1}((F,E))$\in$ SπGBO(X). This implies

$$f^{-1}((F,E)) \in S\pi GBC(X).$$

(ii)$\Rightarrow$(iii).Let (F,E) be any soft regular closed set in Y containing f(x). f^{-1}((F,E))$\in$ SπGBO(X) and x$\in$ f^{-1}((F,E)) (by (ii)).Take (A,E) =f^{-1}((F,E)).Then f((A,E))$\widetilde{\subset}$ (F,E).

(iii)$\Rightarrow$ (ii) Let (F,E) $\in$SRC(Y) and x$\in$$f^{-1}$((F,E)). From (iii), there exists a soft πgb-open set $(A,E)_x$ in X containing x such that $(A,E)_x$ $\widetilde{\subset}$ f^{-1}((F,E)).

We have $f^{-1}((F,E)) = \cup\{(A,E)_x : x \in f^{-1}((F,E))\}$. Then f^{-1}((F,E)) is soft πgb-open.

(iii)⇒(iv) Let (B,E) be any soft regular open set in Y containing f(x).Then Y-(B,E) is a soft regular closed set containing f(x).By (iii), there exists a soft πgb-open set (A,E) in X containing x such that f((A,E))$\tilde{\subset}$ Y-(B,E). Hence (A,E)$\tilde{\subset}$ f^{-1}(Y-(B,E))$\tilde{\subset}$ X- f^{-1}((B,E)).Then f^{-1}((B,E))$\tilde{\subset}$ X-(A,E). Let us set $(G,E) = X - (A,E)$.

We obtain a soft ?gb-closed set in X not containing x such that f^{-1}((B,E))$\tilde{\subset}$ (G,E).

(iv)⇒(iii). Let (F,E) be soft regular closed set in Y containing f(x).Then Y-(F,E) is soft regular open set in Y containing f(x).By (iv), there exists a soft πgb-closed set (G,E) in X not containing x such that f^{-1}(Y-(F,E))$\tilde{\subset}$ (G,E). Then X- f^{-1}((F,E))$\tilde{\subset}$ (G,E) implies X-(G,E)$\tilde{\subset}$ f^{-1}((F,E)).Hence f (X-(G,E))$\tilde{\subset}$ (F,E). Take (A,E) =X-(G,E).Then (A,E) is a soft πgb-open set in X containing x such that f((A,E))$\tilde{\subset}$ (F,E).

(i)⇒(v). Let (G,E) be a soft open subset of Y. Since s-int(cl((G,E))) is soft regular open, then by (i),f^{-1} (s-int(cl((G,E)))∈SπGBC(X).

(v)⇒(i).Let (G,E)∈SRO(Y).Then (G,E) is soft open in Y. By (v), f^{-1}(s-int(cl((G,E)))∈SπGBC(X).This implies f^{-1}((G,E))∈SπGBC(X)

(ii)⇔(vi) is similar as (i)⇔(v).

Theorem 28. *If f : (X, τ, A)→(Y, τ', B) is an soft almost contra- πgb-continuous function and (A,E) is a soft open subset of X, then the restriction f/ (A,E) : (A,E)→Y is soft almost contra- πgb- continuous.*

Proof. Let (F,E) ∈SRC(Y). Since f is soft almost contra- πgb- continuous, f^{-1}((F,E))∈ SπGBO(X).Since (A,E) is soft open, it follows that

$$(f/(A,E))^{-1}((F,E)) = (A,E) \cap f^{-1}((F,E)) \in S\pi GBO((A,E)).$$

Therefore f/(A,E) is an soft almost contra- πgb- continuous.

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