

Soft s^*g -continuous functions

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Abstract

The concept of soft topological space is a very recent developed area having many research scope. In the present paper, we investigate the new varieties of soft continuous maps, namely Soft s^*g -continuous function and discussed some of their properties. Further we introduce the class of soft s^*gc -irresolute maps which is included in the class of soft s^*g -continuous maps and some of their basic properties. In particular we have proved that the set of soft s^*gc -irresolute maps is closed under the composition of maps.

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1 Introduction

The concept of soft set was introduced by Molodtsov [1] to overcome the difficulties of fuzzy sets [2], intuitionistic fuzzy sets [3], vague sets, interval mathematics [4, 5] and rough sets [6]. Maji et al. [7, 8] found an application of soft sets in decision making problems, whereas Chen [9] gave a parametrization reduction of soft sets and a comparison of it with attribute reduction in rough set theory. Further, soft sets are a class of special information [10].

Muhammad Shabir and Munazza Naz introduced soft topological spaces, the notions of soft open sets, soft closed sets, soft closure, soft interior points, soft neighborhood of a point and soft separation axioms and investigated their basic properties [11]. Meanwhile, generalized closed sets [12, 13] in topological spaces were introduced by Levine in 1970 which is extended to soft topological spaces in the year 2012 [14]. Further soft s^*g -closed sets [15] have been studied in 2015.

In the present paper, we investigate the new varieties of soft continuous maps, namely soft s^*g -continuous function, soft s^*gc -irresolute function in soft topological spaces and investigated their properties.

2 Preliminaries

Let U , E be an initial universe and a set of parameters, respectively. Let $P(U)$, E_1 denote the power set of U and a non-empty subset of E , respectively. A pair (F, E_1) is called a soft set over U , where $F : E_1 \rightarrow P(U)$ is a function. For $\varepsilon \in E_1$, $F(\varepsilon)$ may be considered as the set of ε -approximate elements of the soft set (F, E_1) . For two soft sets (F, E_1) and (G, E_2) over a common universe U , we say that (F, E_1) is a soft subset of (G, E_2) if (1) $E_1 \subseteq E_2$ and (2) for all $e \in E_1$, $F(e)$ and $G(e)$ are identical approximations. We write $(F, E_1) \widetilde{\subseteq} (G, E_2)$. (F, E_1) is said to be a soft superset of (G, E_2) , if (G, E_2) is a soft subset of (F, E_1) . We denote it by $(F, E_1) \widetilde{\supseteq} (G, E_2)$. Two soft sets (F, E_1) and (G, E_2) over a common universe U are said to be soft equal if (F, E_1) is a soft subset of (G, E_2) and (G, E_2) is a soft subset of (F, E_1) .

The union of two soft sets of (F, E_1) and (G, E_2) over the common universe U is the soft set (H, E_3) , where $E_3 = E_1 \cup E_2$ and for all $e \in E_3$, $H(e) = F(e)$ if $e \in E_1 - E_2$, $G(e)$ if $e \in E_2 - E_1$ and $F(e) \cup G(e)$ if $e \in E_1 \cap E_2$. We write $(F, E_1) \widetilde{\cup} (G, E_2) = (H, E_3)$. The intersection (H, E_3) of two soft sets (F, E_1) and (G, E_2) over a common universe U , denoted by $(F, E_1) \widetilde{\cap} (G, E_2)$, is defined as $E_3 = E_1 \cap E_2$, and $H(e) = F(e) \cap G(e)$ for all $e \in E_3$. The relative complement of a soft set (F, E_1) is denoted by $(F, E_1)'$ and is defined by $(F, E_1)' = (F', E_1)$ where $F' : E_1 \rightarrow P(U)$ is a mapping given by $F'(e) = U - F(e)$ for all $e \in E_1$.

Let X be an initial universe set, E be the set of parameters. Let τ be the collection of soft sets over X , then is said to be a soft topology on X if (a) $\tilde{\phi}, \tilde{X}$ belong to τ , (b) the union of any number of soft sets in τ belongs to τ , (c) 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 . A soft set (F, E) over X is said to be a soft closed set in X , if its relative complement $(F, E)'$ belongs to τ .

Let (X, τ, E) be a soft topological space over X and (F, E) be a soft set over X . Then, the soft closure of (F, E) , denoted by $\overline{(F, E)}$ is the intersection of all soft closed supersets of (F, E) . Clearly $\overline{(F, E)}$ is the smallest soft closed set over X which contains (F, E) . The soft interior of (F, E) , denoted by $(F, E)^o$ is the union of all soft open subsets of (F, E) . Clearly $(F, E)^o$ is the largest soft open set over X which is contained in (F, E) . Further, $cl_Y(A, E)$ and $int_Y(A, E)$ are the soft closure and soft interior of (A, E) with respect to the subspace Y of X , respectively.

Definition 1. A soft subset (A, E) of a soft topological space (X, τ, E) is called

- (a) soft g -closed [14] if $\overline{(A, E)} \widetilde{\subseteq} (U, E)$ whenever $(A, E) \widetilde{\subseteq} (U, E)$ and (U, E) is soft open in X .
- (b) soft g -open [14] if $(A, E)'$ is soft g -closed in X .
- (c) soft s^*g -closed if $\overline{(A, E)} \widetilde{\subseteq} (U, E)$ whenever $(A, E) \widetilde{\subseteq} (U, E)$ and (U, E) is soft semi open in X .
- (d) soft s^*g -open if $(A, E)'$ is soft s^*g -closed in X .

Definition 2. A soft map $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ from a soft topological space X into a soft topological space Y is called

- (a) soft continuous [16] (resp. soft g -continuous) if the inverse image of every soft closed set in Y is soft closed (resp. soft g -closed) in X .
- (b) soft irresolute (resp. gc -irresolute) if the inverse image of every soft closed set (resp. soft g -closed set) in Y is soft closed (resp. g -closed) in X .

3 Soft s^*g -continuous maps

Definition 3. A soft map $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is called soft s^*g -continuous if the inverse image of every soft closed set in Y is soft s^*g -closed in X .

Example 4. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (L, E), (M, E), (N, E), (O, E)\}$, $Y = \{h_1, h_2\}$, $\sigma = \{\phi, X, (K, E)\}$ where the soft sets $(L, E), (M, E), (N, E), (O, E), (K, E)$ are defined as follows $L(e_1) = \{b\}$, $L(e_2) = \{\phi\}$, $M(e_1) = \{b\}$, $M(e_2) = \{a, b\}$, $N(e_1) = \{b\}$, $N(e_2) = \{a\}$, $O(e_1) = \{b\}$, $O(e_2) = \{b\}$ and $K(e_1) = \{h_1\}$, $K(e_2) = \{h_2\}$. If $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is the soft mapping defined by $f(a) = \{h_1\}$, $f(b) = \{h_2\}$ then the soft mapping $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is soft s^*g -continuous.

Proposition 5. Let $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ be a soft map. Then

- (a) If f is soft continuous then it is soft s^*g continuous.
- (b) If f is soft s^*g -continuous then it is soft g -continuous.

Proof. The proof is obvious. $\square$

Remark 6. The converse of the above is not true in general as we see in the example.

Example 7. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (A, E), (B, E)\}$, $Y = \{a, b\}$, $\sigma = \{\phi, Y, (K, E)\}$ where the soft sets $(A, E), (B, E), (K, E)$ are defined as follows. $A(e_1) = \{a\}$, $A(e_2) = \{a\}$, $B(e_1) = \{b\}$, $B(e_2) = \{b\}$, $C(e_1) = \{a\}$, $C(e_2) = \{b\}$, then $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is the soft mapping defined by $f(a) = \{a\}$, $f(b) = \{b\}$ is soft s^*g continuous but not soft continuous.

Example 8. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (K, E)\}$, $Y = \{h_1, h_2\}$, $\sigma = \{\phi, X, (A, E), (B, E)\}$ where the soft sets $(K, E), (A, E), (B, E)$ are defined as follows $K(e_1) = \{a\}$, $K(e_2) = \{b\}$, $A(e_1) = \{h_1, h_2\}$, $A(e_2) = \{\phi\}$, $B(e_1) = \{\phi\}$, $B(e_2) = \{h_1, h_2\}$. If $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is the soft mapping defined by $f(a) = \{h_1\}$, $f(b) = \{h_2\}$ then the soft mapping $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is soft g continuous but not soft s^*g -continuous.

Remark 9. When X is soft T_S -space, the concepts of soft continuity and soft s^*g -continuity coincide.

Proposition 10. Let $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ be a soft map. Then the following statements are equivalent.

- (a) f is soft s^*g -continuous.
- (b) The inverse image of each soft open set in Y is soft s^*g open in X .

Proof. It is obvious from the definitions. □

Remark 11. If $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is soft s^*g -continuous, then for each $(x, E) \in X$ and open set $(V, E) \subseteq f[(x, E)]$, there exists a soft s^*g -open set (U, E) in X such that $f[(U, E)] \subseteq (V, E)$

Proposition 12. Let X and Z be any soft topological spaces and Y be a soft T_S -space. Then the composition $g \circ f : X \rightarrow Z$ of the soft s^*g -continuous map if $f : X \rightarrow Y$ and $g : Y \rightarrow Z$ are soft s^*g -continuous.

Proof. It follows from the definition. □

Proposition 13. Let X, Y and Z be any soft topological spaces. Then the composition $g \circ f : X \rightarrow Z$ is soft s^*g -continuous if $f : X \rightarrow Y$ is soft s^*g -continuous and $g : Y \rightarrow Z$ is soft continuous.

Proof. It follows from the definition. □

Proposition 14. Let X, Y and Z be any soft topological spaces. Then the composition $g \circ f : X \rightarrow Z$ is soft s^*g -continuous if $f : X \rightarrow Y$ and $g : Y \rightarrow Z$ are soft continuous.

Proof. It follows from the definition. □

Proposition 15. Let (X, τ, E) be a soft topological space where $X = A \cap B$ and (Y, σ, E) be a soft topological space. Let $f : (A, \tau_A, E) \rightarrow (Y, \sigma, E)$ and $g : (B, \tau_B, E) \rightarrow (Y, \sigma, E)$ be soft s^*g -continuous maps such that $f[(x, E)] = g[(x, E)]$ for every $(x, E) \in (A, E) \cap (B, E)$. Suppose that (A, E) and (B, E) are soft s^*g -closed sets in X then the combination $\alpha : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is soft s^*g -continuous.

Proof. Let (F, E) be any soft closed set in Y . Clearly, $\alpha^{-1}[(F, E)] = f^{-1}[(F, E)] \widetilde{\cup} g^{-1}[(F, E)] = (C, E) \widetilde{\cup} (D, E)$ where $(C, E) = f^{-1}[(F, E)]$ and $(D, E) = g^{-1}[(F, E)]$. But (C, E) is soft s^*g -closed in (A, E) and (A, E) is soft s^*g -closed in X and so (C, E) is soft s^*g -closed in X by theorem. Similarly (D, E) is soft s^*g -closed in X . Also $(C, E) \widetilde{\cup} (D, E)$ is soft s^*g -closed in X . Therefore, $\alpha^{-1}[(F, E)]$ is soft s^*g -closed in X . Hence α is soft s^*g -continuous. $\square$

4 Soft s^*gc -irresolute maps

As an analogy of soft irresolute maps [17] in soft topological spaces we introduce the class of soft s^*gc -irresolute maps which is included in the class of soft s^*g -continuous maps. The set of soft s^*gc -irresolute maps is closed under the composition of maps. In this section we investigate basic properties of soft s^*gc -irresolute maps.

Definition 16. A map $f : X \longrightarrow Y$ from a soft topological space X into a soft topological space Y is called a soft s^*gc -irresolute if the inverse image of every soft s^*g -closed set in Y is soft s^*g -closed in X . Clearly it is proved that a map $f : X \longrightarrow Y$ is soft s^*gc -irresolute if and only if the inverse image of every soft s^*g -open set in Y is soft s^*g -open in X .

Example 17. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (F_1, E), (F_2, E), (F_3, E), (F_4, E)\}$, and $Y = \{a, b\}$, $\sigma = \{\phi, Y, (G_1, E), (G_2, E), (G_3, E), (G_4, E)\}$, where the soft sets $(F_1, E), (F_2, E), (F_3, E), (F_4, E), (G_1, E), (G_2, E), (G_3, E), (G_4, E)$ are defined as follows: $F_1(e_1) = \{a\}$, $F_1(e_2) = \{\phi\}$, $F_2(e_1) = \{a\}$, $F_2(e_2) = \{a, b\}$, $F_3(e_1) = \{a\}$, $F_3(e_2) = \{a\}$, $F_4(e_1) = \{a\}$, $F_4(e_2) = \{b\}$, $G_1(e_1) = \{b\}$, $G_1(e_2) = \{\phi\}$, $G_2(e_1) = \{b\}$, $G_2(e_2) = \{a, b\}$, $G_3(e_1) = \{b\}$, $G_3(e_2) = \{a\}$, $G_4(e_1) = \{b\}$, $G_4(e_2) = \{b\}$. If $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is the mapping defined by $f(a) = \{b\}$, $f(b) = \{a\}$ then the mapping is soft s^*gc irresolute.

Proposition 18. If a soft map $f : X \longrightarrow Y$ is soft s^*gc -irresolute then it is soft s^*g -continuous.

Proof. Since every soft closed is soft s^*g -closed, it is proved that

f is soft s^*g -continuous. $\square$

Remark 19. The converse of the above proposition need not be true. The following example supports our claim.

Example 20. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (P, E), (Q, E)\}$, and $Y = \{a, b\}$, $\sigma = \{\phi, X, (R, E), (S, E), (T, E)\}$, where the soft sets $(P, E), (Q, E), (R, E), (S, E), (T, E)$ are defined as follows. $P(e_1) = \phi$, $P(e_2) = \{a, b\}$, $Q(e_1) = \{a, b\}$, $Q(e_2) = \phi$, $R(e_1) = \phi$, $R(e_2) = \{a\}$, $S(e_1) = \{b\}$, $S(e_2) = \phi$, $T(e_1) = \{b\}$, $T(e_2) = \{a\}$. Then the mapping $f : (X, \tau, E) \rightarrow (Y, \sigma, E)$ is defined by $f(a) = \{b\}$, $f(b) = \{a\}$ is soft s^*g continuous but not soft s^*gc -irresolute.

Remark 21. Let X, Y, Z be any soft topological spaces. For any soft s^*gc -irresolute map $f : X \rightarrow Y$ and any soft s^*g -continuous map $g : Y \rightarrow Z$, the composition $g \circ f : X \rightarrow Z$ is soft s^*g -continuous.

Proposition 22. If $f : X \rightarrow Y$ from a soft topological space X into a soft topological space Y is bijective, soft open and soft s^*g -continuous then f is soft s^*gc -irresolute.

Proof. Let (A, E) be a soft s^*g -closed set in Y . Let $f^{-1}[(A, E)] \subseteq (O, E)$ where (O, E) is soft open in X . Therefore $(A, E) \subseteq f[(O, E)]$ holds. Since $f[(O, E)]$ is soft open and (A, E) is soft s^*g -closed in Y , $\overline{(A, E)} \subseteq f[(O, E)]$. Since f is soft s^*g -continuous and $\overline{(A, E)}$ is soft closed in Y , $f^{-1}[\overline{(A, E)}] \subseteq (O, E)$ and so $\overline{f^{-1}[(A, E)]} \subseteq (O, E)$. Therefore $f^{-1}[(A, E)]$ is soft s^*g -closed in X . Hence f is soft s^*gc -irresolute. $\square$

Corollary 23. Under the same assumption of above proposition, if X is a soft T_S -space then Y is a soft T_S -spaces.

Proof. Since every soft s^*g -closed set in Y is soft closed the proof follows. $\square$

Remark 24. The following examples shows that the assumption “soft open” of the above proposition can not be removed.

Example 25. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (K_1, E),$

$(K_2, E), (K_3, E), (K_4, E)\}$, and $Y = \{a, b\}$, $\sigma = \{\phi, Y, (M_1, E), (M_2, E), (M_3, E)\}$, where the soft sets $(K_1, E), (K_2, E), (K_3, E), (K_4, E), (M_1, E), (M_2, E), (M_3, E)$ are defined as follows:
 $K_1(e_1) = \phi$, $K_1(e_2) = \{b\}$, $K_2(e_1) = \{b\}$, $K_2(e_2) = \{a, b\}$,
 $K_3(e_1) = \{b\}$, $K_3(e_2) = \{a\}$, $K_4(e_1) = \{a\}$, $K_4(e_2) = \{b\}$,
 $M_1(e_1) = \{b\}$, $M_1(e_2) = \phi$, $M_2(e_1) = \phi$, $M_2(e_2) = \{b\}$,
 $M_3(e_1) = \{b\}$, $M_3(e_2) = \{b\}$. Then the soft mapping $f: (X, \tau, E) \rightarrow (Y, \sigma, E)$ defined by $f(a) = \{b\}$, $f(b) = \{a\}$ is bijective, soft s^*g continuous but not soft open and also f is not soft s^*g -c irresolute

Remark 26. The following examples show that the concept of soft irresolute maps and soft s^*gc -irresolute map are independent of each other.

Example 27. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (F, E)\}$, and $Y = \{a, b\}$, $\sigma = \{\phi, Y, (A_1, E), (A_2, E), (A_3, E)\}$, where the soft sets $(F, E), (A_1, E), (A_2, E), (A_3, E)$ are defined as follows.
 $F(e_1) = \{a\}$, $F(e_2) = \{b\}$, $A_1(e_1) = \{a, b\}$, $A_1(e_2) = \{b\}$,
 $A_2(e_1) = \{a\}$, $A_2(e_2) = \{a, b\}$, $A_3(e_1) = \{a\}$, $A_3(e_2) = \{b\}$. Then the soft mapping $f: (X, \tau, E) \rightarrow (Y, \sigma, E)$ defined by $f(a) = \{a\}$, $f(b) = \{b\}$ is soft irresolute but not soft s^*gc irresolute.

Example 28. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (B_1, E), (B_2, E)\}$, and $Y = \{a, b\}$, $\sigma = \{\phi, Y, (C, E)\}$, where the soft sets $(B_1, E), (B_2, E), (C, E)$ are defined as follows. $B_1(e_1) = \phi$, $B_1(e_2) = \{a, b\}$, $B_2(e_1) = \{a, b\}$, $B_2(e_2) = \phi$, and $C(e_1) = \{b\}$, $C(e_2) = \{b\}$. Then the soft mapping $f: (X, \tau, E) \rightarrow (Y, \sigma, E)$ defined by $f(a) = \{a\}$, $f(b) = \{b\}$ is soft $s * g$ irresolute but not soft irresolute.

Remark 29. The following examples show that the concept of soft gc -irresolute maps and soft s^*gc -irresolute map are independent of each other.

Example 30. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (B_1, E), (B_2, E)\}$, $Y = \{a, b\}$, $\sigma = \{\phi, Y, (C_1, E), (C_2, E)\}$, where the soft sets $(B_1, E), (B_2, E), (C_1, E), (C_2, E)$ are defined as follows:
 $B_1(e_1) = \phi$, $B_1(e_2) = \{a, b\}$, $B_2(e_1) = \{a, b\}$, $B_2(e_2) = \phi$, and
 $C_1(e_1) = \{b\}$, $C_1(e_2) = \{b\}$, $C_2(e_1) = \{a\}$, $C_2(e_2) = \{a\}$, then

$f:(X, \tau, E) \rightarrow (Y, \sigma, E)$ is the mapping defined by $f(a) = \{b\}$, $f(b) = \{a\}$ is soft $g - c$ irresolute but not soft $s^*g - c$ irresolute.

Example 31. Let $X = \{a, b\}$, $E = \{e_1, e_2\}$, $\tau = \{\phi, X, (P_1, E), (P_2, E), (P_3, E)\}$, and $Y = \{a, b\}$, $\sigma = \{\phi, Y, (Q, E)\}$, where the soft sets $(P_1, E), (P_2, E), (P_3, E), (Q, E)$ are defined as follows. $P_1(e_1) = X$, $P_1(e_2) = \{b\}$, $P_2(e_1) = \{a\}$, $P_2(e_2) = X$, $P_3(e_1) = \{a\}$, $P_3(e_2) = \{b\}$, and $Q(e_1) = \{a\}$, $Q(e_2) = \{b\}$. Then the soft mapping $f:(X, \tau, E) \rightarrow (Y, \sigma, E)$ defined by $f(a) = \{a\}$, $f(b) = \{b\}$ is soft s^*g-c irresolute but not soft gc -irresolute.

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