Contra Soft e-continuity in Soft Topological Spaces

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Abstract

In this paper, we investigated the concepts of contra soft e-continuous functions, contra soft e-open functions, contra soft e-irresolute and discussed their relations with contra soft continuous and other weaker forms of contra soft continuous functions.

Key words : Contra soft e-continuous functions, contra soft e-open (closed) functions and contra soft e-irresolute.
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1. Introduction

None mathematical tools can successfully deal with the several kinds of uncertainties in complicated problems in engineerig, economics, environment, sociology, medical science, etc, so Molodtsov [18] introduced the concept of a soft set in order to solve these problems in 1999. However, there are some theories such as theory of probability, theory of fuzzy sets[25] , theory of intuitionistic fuzzy sets[6], theory of vague sets[11], theory of interval mathematics [12] and the theory of rough sets19] , which can be taken into account as mathematical tools for dealing with uncertainties. But these theories have their own difficulties. Maji et al. [16] introduced a few operators for soft set theory and made a more detailed theoretical study of the soft set theory. Recently, study on the soft set theory and its applications in different fields has been making progress rapidly[9, 21, 23]. Shabir and Naz [22] introduced the concept of soft topological spaces which are defined over an inital universe with fixed set of parameter.

Later, Zorlutuna et al.[26], Aygunoglu and Aygun [7] and Hussain et al [13] are continued to study the properties of soft topological space. They got many important results in soft topological spaces. Weak forms of soft open sets were first studied by Chen[8]. He investigated soft semi-open sets in soft topological spaces and studied some properties of it. Arockiarani and Arokialancy [4] are defined soft β-open sets and continued to study weak forms of soft open sets in soft topological space. Later, Akdag and Ozkan [1, 2] defined soft α-open (resp. soft b-open) (soft α-closed (resp. soft b-closed)) sets.
In 2008, Erdal Ekici[10] , has introduced the concept of e-open sets in general topology. Recently in 2017 Anjan Mukherjee and Bishnupada Debnath [3] introduced oft e open set and soft e continuity in soft topological spaces. In this paper, we investigated the concepts of contra soft e-continuous functions, contra soft e-open functions, contra soft e-irresolute and discussed their relations with contra soft continuous and other weaker forms of contra soft continuous functions.

2. Preliminaries

In this section, we recall some definition and concepts discussed in[13, 17, 22, 26]. Throughout this study X and Y denote universal sets, E denote the set of parameters, $A,B,C,D,K,T \subseteq E$. Let X be an initial universe and E be a set of parameters. Let $\mathrm{P}(X)$ denote the power set of X and A be a nonempty subset set of E. A pair (F,A) is called a soft set over X, where F is a mapping given by $F: A \rightarrow \mathrm{P}(X)$. For two soft sets (F,A) and (G,B) over common universe X, we say that (F,A) is a soft subset (G,B) if $A \subseteq B$ and $F(e) \subseteq G(e)$, for all $e \in A$. In this case, we write $(F,A) \tilde{\subseteq} (G,B)$ and (G,B) is said to be a soft super set of (F,A). Two soft sets (F,A) and (G,B) over a common universe X are said to be soft equal if $(F,A) \tilde{\subseteq} (G,B)$ and $(G,B) \tilde{\subseteq} (F,A)$. The soft set (F,A) over X such that $F(e) = \{x\} \, \forall \, e \in E$ is called singleton soft point and denoted by x_E or (x,E). A soft set (F,A) over X is called null soft set, denoted by (Φ, A), if for each $e \in A, F(e) = \Phi$. Similarly, it is called absolute soft set, denoted by X, if for each $e \in A, F(e) = X$.

The union of two soft sets (F,A) and (G,B) over the common universe X is the soft set (H,C), where $C = A \cup B$ and for each $e \in C$,

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

We write $(F,A) \cup (G,B) = (H,C)$. Moreover, the intersection (H,C) of two soft sets (F,A) and (G,B) over a common universe X, denoted by $(F,A) \cap (G,B)$, is defined as $C = A \cap B$ and $H(e) = F(e) \cap G(e)$ for each $e \in C$. The difference (H,E) of two soft sets (F,E) and (G,E) over X, denoted by $(F,E) - (G,E)$, is defined as $H(e) = F(e) - G(e)$, for each $e \in E$. Let Y be nonempty subset of X. Then Y denotes the soft set (Y,E) over X where $Y(e) = Y$ for each $e \in E$. In particular, (X,E) will be denoted by X. Let (F,E) be a soft set over X and $x \in X$. We say that $x \in (F,E)$, whenever $x \in F(e)$, for each $e \in E$ [20].

The relative complement of a soft set (F,A) is denoted by $(F,A)'$ and is defined by $(F,A)' = (F,A)$ where $F': A \rightarrow \mathrm{P}(X)$ is defined by following

$$F'(e) = X - F(e), \ \forall e \in A$$

In this paper, for convenience, let $SS(X,E)$ be the family of soft sets over X with set of parameters E.

Let τ be the collection of soft sets over X. Then τ is called a soft topology [22] on X if τ satisfies the following axioms:

(i) (Φ, E) and X belongs 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 triple (X, τ, E) is called soft topological space over X. The members of τ are said to be soft open in X, and the soft set (F,E) is called soft closed in X if its relative complement $(F,E)'$ belongs to τ. Let (X, τ, E) be a soft topological space and (F,A) be a soft set over X. Soft closure of a soft set (F,A) in X is denoted by

$cl(F,A)=\bigcap\{(F,E)\,|\,(F,E)\supseteq(F,A),(F,E)\text{ is a soft closed set of }X\}$. Soft interior of a soft set (F,A) in X is denoted by $int(F,A)=\bigcup\{(F,B)\,|\,(F,B)\subseteq(F,A),(F,B)\text{ is a soft open set of }X\}$.

Definition 2.1 *Let (X,τ,E) be a soft topological space and $(F,A)\in SS(X,E)$. Then (F,A) is called a*

(i) soft regular open (for short, sr-open) (soft regular closed (for short, sr-closed)) set [4] if $(F,A)=int(cl(F,A))$ ($(F,A)=cl(int(F,A))$).

(ii) soft α-open (soft α-closed) set [1] if $(F,A)\subseteq int(cl(int(F,A)))$ ($cl(int(cl(F,A)))\subseteq(F,A)$).

(iii) soft pre-open (soft pre-closed) set [4] if $(F,A)\subseteq int(cl(F,A))$ ($cl(int(F,A))\subseteq(F,A)$).

(iv) soft semi-open (soft semi-closed) set [8]if $(F,A)\subseteq cl(int(F,A)$ ($int(cl(F,A))\subseteq(F,A)$).

(v) soft β-open (soft β-closed) set [4] if $(F,A)\subseteq cl(int(cl(F,A)))$ ($int(cl(int(F,A))\subseteq(F,A)$).

(vi) soft b-open (soft b-closed) set [2] if $(F,A)\subseteq int(cl(F,A))\cup cl(int(cl(F,A)))$ ($cl(int(F,A))\cap int(cl(F,A))\subseteq(F,A)$).

Definition 2.2 *[14] Let X be a universe and E a set of parameters. Then the collection $SS(X,E)$ of all soft sets over X with parameters from E is called a soft class.*

Definition 2.3 *[14] Let $SS(X,E)$ and $SS(Y,E^{'})$ be two soft classes. Then $u:X\to Y$ and $p:E\to E^{'}$ be two functions. Then a functions $f_{pu}:SS(X,E)\to SS(Y,E^{'})$ and its inverse are defined as*

(i) Let (L,A) be a soft set in $SS(X,E)$, where $A\subseteq E$. The image of (L,A) under f_{pu} written as $f_{pu}(L,A)=(f_{pu}(L),p(A))$ is a soft set in $SS(Y,E^{'})$ such that

$$f_{pu}(L,A)(\beta)=\Big(\bigcup_{\alpha\in p^{-1}(\beta)\cap A}L(\alpha)\Big)$$

for $\beta\in B=p(A)\subseteq E^{'}$.

(ii) Let (G,C) be a soft set in $SS(Y,E^{'})$, where $C\subseteq E^{'}$. Then the inverse image of (G,C) under f_{pu} written as $f_{pu}^{-1}(G,C)=(f_{pu}^{-1}(G),p^{-1}(C))$ is a soft set in $SS(X,E)$ such that

$$f_{pu}^{-1}(G,C)(\alpha)=u^{-1}(G(p(\alpha)))$$

for $\alpha\in D=p^{-1}(C)\subseteq E$.

Definition 2.4 *A soft topological space (X,τ,E).*

(i) The soft δ-interior [3] of a soft set (F,A) is denoted by, $int_{\delta}(F,A)$ is the largest sr-open set contained in (F,A).

(ii) The soft δ-closure [3] of a soft set (F,A) is denoted by, $cl_{\delta}(F,A)$ is the smallest sr-closed set containing (F,A).

Definition 2.5 *A soft set* (F,A) *in a soft topological space* X *is called*

(i)soft δ-open if $(F,A) = int_{\delta}(F,A)$.

(ii) soft δ-closed if $(F,A) = cl_{\delta}(F,A)$.

(iii) soft δ-semiopen if $(F,A)\subseteq cl(int_{\delta}(F,A))$.

(iv)soft δ-preopen if $(F,A)\subseteq int(cl_{\delta}(F,A))$.

(v) soft e-open (for short, se-open) set if $(F,A)\subseteq int(cl_{\delta}(F,A))\cup\ cl(int_{\delta}(F,A))$.

(vi) soft e-closed (for short, se-closed) set if $(F,A)\supseteq int(cl_{\delta}(F,A))\cap\ cl(int_{\delta}(F,A))$.

The family of all se-open sets and se-closed sets are denoted by $SeOS(X)$ and $SeCS(X)$.

Definition 2.6 [3] *Let* (X,τ,E) *be a soft topological space and* (F,A) *be a soft set over* X.

(i)Soft e-closure of a soft set (F,A) in X is denoted by

$secl(F,A) = \bigcap\{(F,E):(F,E)\supseteq(F,A),(F,E)\text{ is a } se-\text{closed set of } X\}$.

(ii) Soft e-interior of a soft set (F,A) in X is denoted by

$seint(F,A) = \bigcup\{(F,B):(F,B)\subseteq(F,A),(F,B)\text{ is a } se-\text{open set of } X\}$.

Clearly $secl(F,A)$ is the smallest se-closed set over X which contains (F,A) and $seint(F,A)$ is the largest se-open set over X which is contained in (F,A).

Definition 2.7 *[3] Let* (X,τ,E) *be a soft topological space and* (F,A) *be a soft set over* X.

(i) Soft δ-semiclosure of a soft set (F,A) in X is denoted by

$sscl_{\delta}(F,A) = \bigcap\{(F,E):(F,E)\supseteq(F,A),(F,E)\text{ is a soft } \delta-\text{semiclosed set of } X\}$.

(ii) Soft δ-semiinterior of a soft set (F,A) in X is denoted by

$ssint_{\delta}(F,A) = \bigcup\{(F,B):(F,B)\subseteq(F,A),(F,B)\text{ is a soft } \delta-\text{semiopen set of } X\}$.

(iii) Soft δ-preclosure of a soft set (F,A) in X is denoted by

$spcl_{\delta}(F,A) = \bigcap\{(F,E):(F,E)\supseteq(F,A),(F,E)\text{ is a soft } \delta-\text{preclosed set of } X\}$.

(iv) Soft δ-preinterior of a soft set (F,A) in X is denoted by

$spint_{\delta}(F,A) = \bigcup\{(F,B):(F,B)\subseteq(F,A),(F,B)\text{ is a soft } \delta-\text{preopen set of } X\}$.

Definition 2.8 *A soft mapping* $f: X \to Y$ *is called soft* β*-continuous [24] (resp. soft* α*-continuous[1] , soft pre-continuous [1], soft semi-continuous [15], soft b-continuou[2]) if the inverse image of each soft open set in* Y *is soft* β*-open (resp. soft* α*-open, soft preopen, soft semiopen, soft b-open) set in* X.

Definition 2.9 *[3] A soft mapping* $f: X \to Y$ *is said to be:*

(i) soft δ-continuous (resp. soft δ-semicontinuous, soft δ-precontinuous and soft regular continuous) if the inverse image of each soft open set of Y is a soft δ-open (resp. soft δ-semiopen, soft δ-preopen and sr-open) set in X.

(ii) soft e-continuous (briefly se-continuous) if the inverse image of each soft open set of Y is a se-open set in X.

Definition 2.10 *A mapping $f: X \to Y$ is said to be soft e-irresolute [3] (briefly se-irresolute) if $f^{-1}(F,K)$ is se-closed set in X, for every se-closed set (F,K) in Y.*

Definition 2.11 *A mapping $f: X \to Y$ is said to be soft e-open [3] (briefly, se-open) map if the image of every soft open set in X is se-open set in Y.*

Definition 2.12 *A mapping $f: X \to Y$ is said to be soft e-closed [3] (briefly, se-closed) map if the image of every soft closed set in X is se-closed set in Y.*

3.Contra Soft e-continuity

In this section, we introduce contra soft e-continuous maps, contra soft e-irresolute maps, contra soft e-closed maps and contra soft e-open maps and study some of their properties. A soft mapping $f: X \to Y$ stands for a mapping, where $f:(X,\tau,E) \to (Y,\eta,E)$, $u: X \to Y$ and $p: E \to E$ are assumed mappings unless otherwise stated.

Definition 3.1 *A soft mapping $f: X \to Y$ is said to be:*

(i) contra soft δ- continuous (resp. contra soft δ-semicontinuous, contra soft δ-precontinuous, contra soft and contra soft regular continuous) if the inverse image of each soft open set of Y is a soft δ- closed (resp. soft δ- semicsed, soft δ-preclosed s-closed and sr-closed) set in X.

(ii) contra soft e-continuous (briefly cse-cts) if the inverse image of each soft open set of Y is a se-closed set in X.

Theorem 3.1 *Let $f: X \to Y$ be a mapping from a soft space X to soft space Y. Then, the following statements are true:*

(i) f is contra se-continuous.

(ii) the inverse image of each soft closed set in Y is contra soft e- open in X.

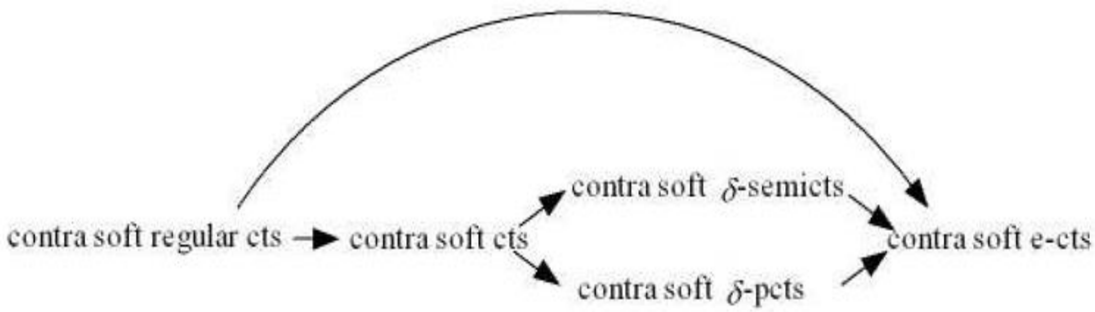
Proof. (i)$\Rightarrow$(ii): Let (G,K) be a soft closed set in Y. Then $(G,K)'$ is soft open set. Thus, $f^{-1}((G,K)') \in SeOS(X)$ i.e., $X - f^{-1}(G,K) \in SeCS(X)$. Hence $f^{-1}(G,K)$ is a se- open set in X.

(ii)$\Rightarrow$(i): Let (O,K) is soft closed set in Y. Then $(O,K)'$ is soft open set and by (ii) we have $f^{-1}((O,K)) \in SeOS(X)$, i.e., $X - f^{-1}(O,K) \in SeCS(X)$. Hence $f^{-1}(O,K)$ is a se- open set in X. Therefore, f is a contra se-continuous function.

Example 3.1 *Let $X = \{h_1,h_2,h_3\}$, $Y = \{m_1,m_2,m_3\}$, $E = \{e_1,e_2\}$. If (X,τ,E) be a soft topological space defined $\tau = \{\tilde{\Phi}, \tilde{X}, (F_1,E),(F_2,E),\ldots,(F_6,E)\}$, where $(F_1,E),(F_2,E),\ldots,(F_6,E)$ are soft sets over X, defined as follow $F_1(e_1) = \{h_1,h_2\}, F_1(e_2) = \{h_1,h_3\}$; $F_2(e_1) = \{h_2,h_3\}, F_2(e_2) = \{h_1,h_2\}$; $F_3(e_1) = \{h_1,h_3\}, F_3(e_2) = \{h_2,h_3\}$; $F_4(e_1) = \{h_2\}, F_4(e_2) = \{h_1\}$; $F_5(e_1) = \{h_3\}, F_5(e_2) = \{h_2\}$; $F_6(e_1) = \{h_1\}, F_6(e_2) = \{h_3\}$, (Y,η,E) be a soft topological space defined over Y where $\eta = \{\tilde{\Phi}, \tilde{Y}, (L,E)\}$ and (L,E) is a soft set on Y defined by: $L(e_1) = \{m_1\}, L(e_2) = \{m_1,m_2\}$. Let $f(X,\tau,E) \to (Y,\eta,E)$ be a soft function defined by $f(h_1) = m_3$, $f(h_2) = m_2$, $f(h_3) = m_1$. Then f is contra soft e-continuous.*

Example 3.2 *In Example 3.1 (i) f is contra soft e-continuous but not contra soft δ-semicontinuous. (ii) f is contra soft δ-precontinuous but not contra soft continuous. (iii) f is contra soft e-continuous but not contra soft regular continuous.*

Example 3.3 *Let $X = \{h_1, h_2, h_3, h_4\}$, $Y = \{m_1, m_2, m_3, m_4\}$, $E = \{e_1, e_2\}$. If (X, τ, E) be a soft topological space defined $\tau = \{\tilde{\Phi}, \tilde{X}, (F_1, E), (F_2, E), (F_3, E)\}$, where $(F_1, E), (F_2, E), (F_3, E)$ are soft sets over X, defined as follows: $F_1(e_1) = \{h_1\}, F_1(e_2) = \{h_1\}$ $F_2(e_1) = \{h_2\}, F_2(e_2) = \{h_2\}$* $F_3(e_1) = \{h_1, h_2\}, F_3(e_2) = \{h_1, h_2\}$, (Y, η, E) be a soft topological space defined over Y where $\eta = \{\tilde{\Phi}, \tilde{Y}, (L, E)\}$ and (L, E) is a soft set on Y defined by: $L(e_1) = \{m_1, m_2\}, L(e_2) = \{m_1, m_2\}$. Let $f : (X, \tau, E) \to (Y, \eta, E)$ be a soft function defined by $f(h_1) = m_2$, $f(h_2) = m_4$, $f(h_3) = m_3$, $f(h_4) = m_1$. Then f is contra soft e-continuous but not soft δ-precontinuous. And also f is contra soft δ-semicontinuous but not soft continuous.



Theorem 3.2 *Every contra soft continuous function is contra se-continuous function.*

Proof. Let $f : X \to Y$ be a contra soft continuous function. Let (F, K) be a soft open set in Y. Since f is contra soft continuous, $f^{-1}(F, K)$ is soft closed in X. And so $f^{-1}(F, K)$ is se- closed set in X. Therefore, f is contra se-continuous function.

Definition 3.2 *A mapping $f : X \to Y$ is said to be contra soft e-irresolute (briefly cs$e$-irresolute) if $f^{-1}(F, K)$ is se- open set in X, for every se-closed set (F, K) in Y.*

Theorem 3.3 *A mapping $f : X \to Y$ is contra se-irresolute mapping if and only if the inverse image of every se-open set in Y is se- closed set in X.*

Theorem 3.4 *Every contra se-irresolute mapping is contra se-continuous mapping.*

Proof. Let $f : X \to Y$ is contra se-irresolute mapping. Let (F, K) be a soft closed set in Y, then (F, K) is se-closed set in Y. Since f is contra se-irresolute mapping, $f^{-1}(F, K)$ is a se- open set in X. Hence, f is contra se-continuous mapping.

Theorem 3.5 *Let $f : (X, \tau, E) \to (Y, \nu, K)$, $g : (Y, \nu, K) \to (Z, \sigma, T)$ be two functions. Then:*

(i) $g \circ f : X \to Z$ is contra se-continuous, if f is contra se-continuous and g is soft continuous.

(ii) $g \circ f : X \to Z$ is contra se-irresolute, if f is contra se-irresolute and g is se

-irresolute functions.

(iii) $g \circ f : X \to Z$ is contra se-continuous if f is contra se-irresolute and g is se-continuous.

Proof. (i) Let (H,T) be soft closed set of Z. Since $g : Y \to Z$ is soft continuous, by definition $g^{-1}(H,T)$ is soft closed set of Y. Now $f : X \to Y$ is contra se-continuous and $g^{-1}(H,T)$ is soft open set of Y, so by Definition **Error! Reference source not found.**(ii), $f^{-1}(g^{-1}(H,T)) = (g \circ f)^{-1}(H,T)$ is se- open in X. Hence $g \circ f : X \to Z$ is contra se-continuous.

(ii) Let $g : Y \to Z$ is se-irresolute and let (H,T) be se-closed set of Z. Since g is se-irresolute by Definition **Error! Reference source not found.**, $g^{-1}(H,T)$ is se- closed set of Y. Also $f : X \to Y$ is contra se-irresolute, so $f^{-1}(g^{-1}(H,T)) = (g \circ f)^{-1}(H,T)$ is se-closed. Thus, $g \circ f : X \to Z$ is contra se-irresolute.

(iii) Let (H,T) be s-closed set of Z. Since $g : Y \to Z$ is se-continuous, $g^{-1}(H,T)$ is se-closed set of Y. Also $f : X \to Y$ is contra se-irresolute, so every se- closed set of Y is se- open in X. Therefore, $f^{-1}(g^{-1}(H,T)) = (g \circ f)^{-1}(H,T)$ is se-open set of X. Thus, $g \circ f : X \to Z$ is contra se-continuous.

Definition 3.3 *A mapping $f : X \to Y$ is said to be contra soft e-open (briefly, cs$e$-open) map if the image of every soft closed set in X is se-open set in Y.*

Definition 3.4 *A mapping $f : X \to Y$ is said to be contra soft e-closed (briefly, cse-closed) map if the image of every soft closed set in X is se- open set in Y.*

Theorem 3.6 *If $f : X \to Y$ is soft closed function and $g : Y \to Z$ is contra se-closed function, then $g \circ f$ is contra se-closed.*

Proof. For a soft closed set (F, A) in X, $f(F, A)$ is soft closed set in Y. Since $g : Y \to Z$ is contra se-closed function, $g(f(F, A))$ is contra se-closed set in Z. $g(f(F, A)) = (g \circ f)(F, A)$ is se-open set in Z. Therefore, $g \circ f$ is se-open function.

Theorem 3.7 *Let $f : X \to Y$, $g : Y \to Z$ be two maps such that $g \circ f : X \to Z$ is cse-open map.*

(i) If f is soft continuous and surjective, then g is cse-closed map.

(ii) If g is se-irresolute and injective, then f is cse-closed map.

Proof. (i) Let (H, K) be a soft closed set of Y. Then, $f^{-1}(H, K)$ is soft closed set in X as f is soft continuous. Since $g \circ f$ is cse-closed map, $(g \circ f)(f^{-1}(H, K)) = g(H, K)$ is cse-open set in Z. Hence $g : Y \to Z$ is cse-closed map.

(ii) Let (H, E) be a soft open set in X. Then, $(g \circ f)(H, E)$ is se-closed set in Z, and so $g^{-1}(g \circ f)(H, E) = f(H, E)$ is se-closed set in Y. Since g is se-irresolute and injective. Hence f is a cse-closed map.

4.Conclusion

In this paper We have introduced contra soft e-continuous, contra soft e-irresolute mapping, contra soft e-open and closed mapping and have established several interesting properties. In the end, we hope that this paper is just a beginning of a new structure, it will be necessary to carry out more theoretical research to promote a general framework for the practical application.

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