IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Soft r^g-Closed Sets in Soft Topological Spaces

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Abstract

This paper deals with soft r^g- closed sets, soft r^g open sets in soft topological spaces. A detail study is carried out on its properties. Also we discussed some soft r^g separation axioms.

Keywords: Soft r^g- closed sets, soft r^g- open sets, soft $R\wedge G_0$, soft $R\wedge G_1$, soft $R\wedge G_2$ spaces.
Mathematics Subject Classification: 06D72, 54A40

Introduction

Russian researcher Molodtsov [7] introduced the concept of soft set theory in order to solve complicated problems. He presented the fundamental results of soft set theory and successfully applied it in various directions such as game theory, operations research, theory of probability, Riemann integration etc. Research works on soft set theory and its applications in various fields are progressing rapidly

Shabir and Naz [11] introduced the notion of soft topological spaces. Kannan [5] studied properties of soft g closed sets. Mahantha . J [6] introduces soft semi open sets in topological spaces. After that many authors [2] , [4] , [6] , [9] extended their ideas in soft topological spaces

In this work, we introduce soft r^g closed and soft r^g open sets. Further we obtain its basic properties. And also we obtain soft r^g separation axioms.

Preliminaries

Definition 2.1 [2] : Let U be the initial universal set and P(U) be the power set of U. Let E be 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). For ε ∈ A, F(ε) may be considered as the set ε - approximate elements of the soft set (F,A). Clearly, a soft set is not a set.

For two soft sets (F,A) and (G,B) over the common universe U, we say that (F,A) is a soft subset of (G,B) if (i) A ⊆ B and (ii) for all e ∈ A, F(e) and G(e) are identical approximations. We write (F,A) $\tilde{\subseteq}$ (G,B). (F,A) is said to be a soft subset of (G,B) and (G,B) is a soft superset of (F,A). (F,A) equals (G,B) , denoted by (F,A) = (G,B) if (F,A) $\tilde{\subseteq}$ (G,B) and (G,B) $\tilde{\subseteq}$ (F,A).

Definition 2.2 [4]

The union of two soft sets (F,A) and (G,B) over a common universe U is a soft set (H,C) where C = A∪B and for all e∈ C, H(e) = F(e) if e ∈ A- B, H(e) = G(e) if e ∈ B-A and H(e) = F(e) ∪ H(e) if e ∈ A∩B. We write (F,A) ∪ (G,B) = (H,C).

Definition 2.3 [4]:

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.

ISSN: 2277-9655
Impact Factor: 1.852

Definition 2.4 [4]

A soft set (F,A) over U is called a null soft set, denoted by φ, if e∈A, F(e) = φ.

Definition 2.5 [4]:

A soft set (F,A) over U is called an absolute soft set, denoted by $\tilde{A}$, if e∈A, F(e) = U.

Definition 2.6 [2]:

For a soft set (F,A) over U, the relative complement of (F,A) is denoted by $(F,A)'$ and is defined by $(F,A)' = (F',A)$, where $F' : A \to P(U)$ is a mapping given by $F'(e) = U - F(e)$ for all e∈A.

Definition 2.7 [4]:

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:

(i) φ, $\tilde{X}$ belong to τ.
(ii) The union of any number of soft sets in τ belongs to τ.
(iii) The intersection of any two soft closed sets is a soft closed set over X.
The triplet (X, τ, E) is called a soft topological space over X.

Definition 2.8 [2]:

Let (X,τ,E) be a soft space over X, then the members of τ are said to be soft open sets of X.

Definition 2.9 [4]:

Let (X,τ,E) be a soft space over 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.

Definition 2.10 [2]:

Let (X,τ,E) be a soft topological space and (A,E) be a soft set over X
(i) The soft interior of (A,E) is the soft set

$$Int\,(A,E) = \cup\{(O,E) : (O,E) \text{ is soft open and } (O,E) \tilde{\subseteq} (A,E)\}$$

(ii) The soft closure of (A,E) is the soft set

$$Cl\,(A,E) = \cap\,\{(F,E) : (F,E) \text{ is soft closed and } (A,E) \tilde{\subseteq} (F,E)\}.$$

Definition 2.11 [4]:

A soft subset (A,E) of X is called

(i) a soft semi closed [ ] if Int(Cl(A,E)) $\tilde{\subseteq}$ (A,E).
(ii) a soft regular open if (A,E) = Int(Cl(A,E)).
(iii) a soft α - closed if Int (Cl(Int(A,E))) $\tilde{\subseteq}$ (A,E)
(iv) a soft pre-closed set if Int (Cl(A,E)) $\tilde{\subseteq}$ (A,E).
(v) a soft semi-preclosed if Int(Cl(int(A))) $\tilde{\subseteq}$ (A,E)

The complements of above mentioned sets are their respective open sets.

Definition 2.12[2]:

The soft gclosure of (A,E) is the intersection of all soft gclosed sets containing (A,E), i.e., the smallest soft gclosed set containing (A,E) and is denoted by sgcl(A,E).

The soft ginterior of (A,E) is the union of all soft g-open sets contained in (A,E) and is denoted by sgint(A,E).

 ISSN: 2277-9655
Impact Factor: 1.852

In the same manner, we define soft pre-closure, soft semi closure and soft semi-preclosure by spcl(A,E), sscl(A,E), sspcl(A,E) respectively.

Definition 2.13[2]:

A soft subset (A,E) of X is called

(i) a soft generalized closed set (Soft g 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 open in X.

(ii) a soft g* closed set if Cl (A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft g-open.

(iii) a soft rg closed set if Cl (A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft regular open.

(iv) a soft sg closed set if sscl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft semi- open.

(v) a soft gs closed set if sscl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft open.

(vi) a soft rwg closed set if cl(Int(A,E)) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft regular open.

(vii) a soft rgw closed set if cl(Int(A,E)) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft regular semi-open.

(viii) a soft wg closed set if cl(Int(A,E)) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft open.

SOFT R^G Closed Sets

Let us introduce the following definition.

Definition 3.1:

A soft subset (A,E) of a topological space X is called a soft r^g closed set in X if sgcl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) where (U,E) is soft regular open in X.

We denote the family of soft r^g closed sets of X by SR^G(X).

Theorem 3.2:

(i) Every soft closed set is soft r^g closed.
(ii) Every soft g-closed set is soft r^g closed.
(iii) Every soft g*-closed set is r^g closed.

Proof: Obvious.

Remark 3.3:

The converse of the above theorem need not be true as seen in the following example.

Example 3.4:

Let X = {a,b,c}, E = {e_1,e_2}. Let A,B,C be functions from E to P(X) and are defined as follows:

A(e_1) = {b}, A(e_2) = {a}
B(e_1) = {b,c}, B(e_2) = {a,b}
C(e_1) = {a,b}, C(e_2) = {a,c}.

Then τ = { φ, $\tilde{X}$,(A,E),(B,E),(C,E) } is a soft topology over X. the elements of τ are soft open sets and its relative complements are soft closed sets. In the soft topology (X,τ,E) ,

(i) The soft set (F,E) = {{b,c},{b}} is soft r^g closed set but it is not soft closed set.
(ii) The soft set (G,E) = {{b},{a,b}}is soft r^g closed set but it is not soft g closed set.
(iii) The soft set (H,E) = {φ,{a}} is soft r^g closed set but not soft g*-closed set.

Theorem 3.5:

Every soft r^g closed set is soft rwg closed set and soft rgw closed set but not conversely.

Proof:

ISSN: 2277-9655
Impact Factor: 1.852

Straight Forward.

Example 3.6:

Let X = {a,b,c,d}, E = {e_1,e_2}. Let F_1,F_2,F_3,F_4,F_5,F_6 be 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}
$F_4(e_1)$ = {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}

Lτ = { φ, $\widetilde{X}$, (F_1,E) , (F_2,E) , (F_3,E) , (F_4,E) , (F_5,E), (F_6,E)} is a soft topology.

In the soft topological space (X,τ) the soft subset {φ,{a}} is both soft rwg and soft rgw closed sets but it is not soft r^g closed set.

Remark 3.7:

The concept of soft semi-closed sets and soft r^g closed sets are independent.

Example 3.8:

In example 3.6, the soft subset (H_1,E) = {φ,{c}} is soft semi-closed set but it is not soft r^g closed and the soft subset (H_2,E) = {{c},{a}} is soft semi-closed but it is not soft r^g closed.

Remark 3.9:

The concept of soft pre-closed sets and soft r^g closed sets are independent.

Example 3.10:

In example 3.6, the subset {φ, {a}} is soft preclosed set but it is not soft r^g closed set and the subset {{a,c},{a,b,c}} is soft r^g closed set but it is not soft pre-closed set.

Remark 3.11:

The concept of soft semi-preclosed sets and soft r^g closed sets are independent.

Example 3.12:

In example 3.6, Let (I,E) = {φ,{b,d}}then (I,E) is soft semi-preclosed set but it is not soft r^g closed set and the soft subset (J,E) = {{b,d},{a,b,d}} is soft r^g closed set but it is not soft semi-preclosed set.

Remark 3.13:

The concept of soft α closed sets and soft r^g closed sets are independent.

Example 3.14:

In example 3.6, Let (K,E) = {{a},{b,c}} then (K,E) is soft r^g closed but it is not soft α closed set. (J,E) = {{c},{a}} then (J,E) is soft α closed set but it is not soft r^g closed set.

Remark 3.15:

The soft gs closed sets and soft r^g closed sets are independent to each other as seen in the following example.

Example 3.16:

Let X = {a,b}, E = {e_1,e_2}. Let F_1, F_2, F_3 be functions from E to P(X) and are defined as follows:

$F_1(e_1)$ = {a} , $F_1(e_2)$ = {φ}
$F_2(e_1)$ = {a} , $F_2(e_2)$ = {b}
$F_3(e_1)$ = {a} , $F_3(e_2)$ = {a,b}

Let τ = { φ, $\widetilde{X}$, (F_1,E) , (F_2,E) , (F_3,E) } be a soft topology over X.

- In (X,τ,E) , the soft subset (G_1,E) = {{a},{a,b}} is soft r^g closed but it is not soft gs closed set.
- In example 3.6, the soft subset {{c},{a}} is soft gs closed but it is not soft r^g closed set.

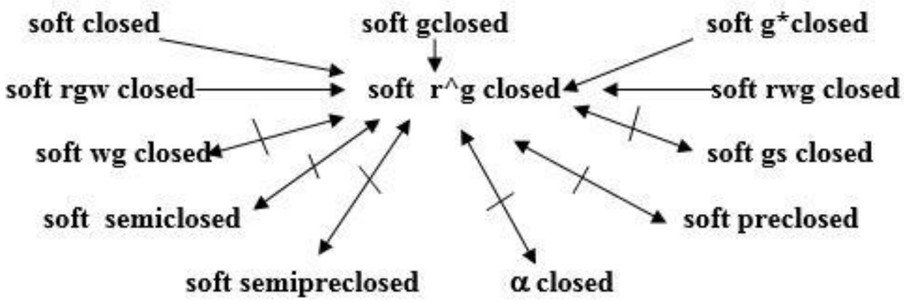
Remark 3.17:

The soft wg closed sets and soft r^g closed sets are independent to each other as seen in the following example.

Example 3.18:

In example 3.6, let (H_3,E) = {φ,{a}} , then (H_3,E) is soft wg closed set but it is not soft r^g closed set and (H_4,E) = {{a,c,d}{b}} is soft r^g closed set but it is not soft wg closed.

The above discussions are summarized in the following diagram



Remark 3.19:
The finite union of soft r^g closed set is soft r^g closed.
Proof:
Straight forward.
Remark 3.20:
The intersection of two soft r^g closed sets need not be a soft r^g closed set as seen in the following example.
Example 3.21:
In example 3.6, the soft subset {{b},{a}} and {{d},{a}} are soft r^g closed sets but their intersection {φ,{a}} is not soft r^g closed set.
Theorem 3.22:
Let (A,E) be a soft r^g closed set in a soft topological space. Then sgcl(A,E) - (A,E) contains no non-empty soft regular closed set.
Proof:

Let (F,E) be a non-empty soft regular closed set such that (F,E) $\tilde{\subseteq}$ sgcl(A,E) - (A,E). Then (F,E) $\tilde{\subseteq}$ X - (A,E) implies (A,E) $\tilde{\subseteq}$ (X,E) - (F,E), since (A,E) is soft regular closed set and (X,E) - (F,E) is regular open. Then sgcl(A,E) $\tilde{\subseteq}$ (X,E) - (F,E) i.e., (F,E) $\tilde{\subseteq}$ (X,E) - sgcl(A,E) . Hence [(F,E) - sgcl(A,E)] ∩ [(X-E) - sgcl(A,E)] = φ. Thus (F,E) = φ whence sgcl(A,E)-(A,E) does not contain non-empty soft regular closed set.
Remark 3.23:
The converse of the above theorem need not be true, i.e., if sgcl(A,E) - (A,E) contains no non-empty soft regular closed set, then (A,E) need not be a soft r^g closed set as seen in the following example.
Example 3.24:
In example 3.6, let (B,E) = {{d},{b}}. sgcl(B,E) - (B,E) = {φ,{a,d}}, it does not contain any non-empty soft regular closed set. But (B,E) is not a soft r^g closed set.
Theorem 3.25:
Let (A,E) be soft r^g closed set. Then (A,E) is soft gclosed set iff sgcl(A,E) - (A,E) is soft regular closed.
Proof:
Let (A,E) be soft gclosed. Then sgcl(A,E) - (A,E) = φ which is a soft regular closed set.
Conversely, if sgcl(A,E) - (A,E) is soft regular closed, then sgcl(A,E) - (A,E) = φ (by theorem 3.22). Hence (A,E) is soft gclosed.

SOFT R^G Open Sets

Definition 4.1:
A soft set (A,E) is called a soft regular ^ generalized (**soft r^g**) open set if the relative complement (A,E) is soft r^g closed set in (X,E). The family of soft open sets of X is denoted by SR^GO(X).
Remark 4.2:
For a soft subset (A,E) of X, sgcl(X-(A,E)) = X - sgint(A,E).

Theorem 4.3:

The soft subset (A,E) of X is soft r^g open iff (F,E) $\tilde{\subseteq}$ sgint(A,E) whenever (F,E) is soft regular closed and (F,E) $\tilde{\subseteq}$ (A,E) .

Proof:

Necessity: Let (A,E) be a soft r^g closed set and (F,E) $\tilde{\subseteq}$ (A,E). Then X - (A,E) $\tilde{\subseteq}$ X - (F,E) where X - (F,E) is soft regular open. Since (A,E) is soft r^g closed , sgcl(X- (A,E)) $\tilde{\subseteq}$ X- (F,E).

By remark 4.2, X - sgint(A,E) $\tilde{\subseteq}$ X - (F,E). Therefore (F,E) $\tilde{\subseteq}$ sgint(A,E).

Sufficiency: Suppose (F,E) is soft regular closed and (F,E) $\tilde{\subseteq}$ (A,E) then (F,E) $\tilde{\subseteq}$ sgint(A,E). Let X-(A,E) $\tilde{\subseteq}$ (U,E) where (U,E) is soft regular closed. By hypothesis, X-(U,E) $\tilde{\subseteq}$ sgint(A,E). Then X - sgint(A,E) $\tilde{\subseteq}$ (U,E). By remark 4.2, sgcl(X-(A,E)) $\tilde{\subseteq}$ (U,E). Hence X- (A,E) is soft r^g closed and (A,E) is soft r^g open.

Theorem 4.4:

If sgint(A,E) $\tilde{\subseteq}$ (B,E) $\tilde{\subseteq}$ (A,E) and if (A,E) is soft r^g open then (B,E) is soft r^g open.

Proof:

Given sgint(A,E) $\tilde{\subseteq}$ (B,E) $\tilde{\subseteq}$ (A,E). Then X - (A,E) $\tilde{\subseteq}$ X - (B,E) $\tilde{\subseteq}$ sgcl(X - (A,E) . Since (A,E) is soft r^g open, X - (A,E) is soft r^g closed. This implies X -(B,E) is soft r^g closed. Hence (B,E) is soft r^g open.

Remark 4.5: For any (A,E) $\tilde{\subseteq}$ sgint[sgcl(A,E) - (A,E)] = φ.

Theorem 4.6:

If (A,E) $\tilde{\subseteq}$ X is soft r^g closed , then sgcl(A,E) - (A,E) is soft r^g open.

Proof:

Let (A,E) be a soft r^G closed and let (F,E) be a soft regular closed set such that (F,E) $\tilde{\subseteq}$ sgcl(A,E) - (A,E) . Then by theorem 3.21(F,E) = φ.

Hence (F,E) $\tilde{\subseteq}$ sgint(A,E) - (A,E) is soft r^g open.

SOFT R^G - Separation Axioms

Definition 5.1:

Let (X,τ,E) be a soft topological space over X and x,y ∈X such that x≠y. If there exist soft r^g open sets (F,E) and (G,E) such that x ∈ (F,E) and y∉(F,E) or y∈(G,E) and x ∉(G,E) then (X,τ,E) is called a soft $R\wedge G_0$ space.

Remark 5.2:

Not all soft topological spaces are soft $R\wedge G_0$ - spaces as shown by the following example.

Example 5.3:

Let X = {a,b} , E = {e_1,e_2} and τ = {φ, $\tilde{X}$ }. Then (X,τ,E) is not a soft $R\wedge G_0$ space because for {a},{b} ∈ X, there exists only one r^g open soft set $\tilde{X}$ such that {a},{b} ∈ $\tilde{X}$.

Definition 5.4:

Let (X,τ,E) be a soft topological space over X and x, y ∈ X such that x≠y. If there exist soft r^g open sets (F,E) and (G,E) such that x ∈ (F,E), y∉(F,E) and y∈(G,E) , x ∉(G,E), then (X,τ,E) is called a soft $R\wedge G_1$ space.

Theorem 5.5:

Let (X,τ,E) be a soft topological space over X. If (x, E) is a soft r^g closed set in (X, τ,E) for each x∈X, then (X,τ,E) is a soft $R\wedge G_1$ space.

Proof:

Suppose that for each x∈X, (x,E) is a soft r^g closed in (X,τ,E) , then (x,E)′ is a soft r^g open set in (X,τ,E). Let x, y ∈ X such that x ≠ y. For x ∈ X, (x,E)′ is a soft r^g open set such that y ∈ (x,E)′ and x ∉(x,E)′. Similarly (y,E)′ is a soft r^g open set such that x ∈(y,E)′ and y ∉(y,E)′. Thus (X,τ,E) is a soft $R\wedge G_1$ space over X.

Definition 5.6:

Let (X,τ,E) be a soft topological space over X and x, y ∈X such that x ≠ y. If there exist soft r^g open sets (F,E) and (G,E) such that x ∈ (F,E) , y ∈ (G,E) and (F,E) ∩ (G,E) = φ, then (X,τ,E) is called a soft $R\wedge G_2$ space.

Example 5.7:

Let X = {a,b,c}, E = {e_1,e_2} and τ = { $\tilde{X}$,φ} be the discrete soft topology then (X,τ,E) is a soft $R\wedge G_2$ space.

Theorem 5.8:

Let (X,τ,E) be a soft topological space over X and x ∈ X. If (X,τ,E) is a soft $R\wedge G_2$ space, then (x,E) = ∩ (F,E) for each soft r^g open set (F,E) with x ∈ (F,E).

Proof:

For every x ∈X if y≠ x, since (X,τ,E) is a soft $R\wedge G_2$ space, there exist soft r^g open sets (F,E) and (G,E) such that x ∈(F,E) , y∈(G,E) and (F,E) ∩ (G,E) = φ and hence (F,E) ∩ (y, E) = φ. Thus (x, E) = ∩ (F,E) for each soft r^g open set(F,E) with x ∈ (F,E). This completes the proof.

Theorem 5.9:

(i) Every soft $R\wedge G_1$ space is a soft $R\wedge G_0$ space.

(ii) Every soft $R\wedge G_2$ space is a soft $R\wedge G_1$ space.

Proof:

Let (X,τ,E) be a soft topological space over X and x, y ∈X such that x ≠ y.

(i) If (X,τ,E) is a soft $R\wedge G_1$ space then there exist soft r^g open sets (F,E) and (G,E) such that x ∈ (F,E) , y ∉ (F,E) and y ∈(G,E) , x ∉ (G,E). Obviously x ∈ (G,E) , y ∉ (F,E) or y ∈(G,E) , x ∉ (G,E). Thus (X,τ,E) is a soft $R\wedge G_0$ space.

(ii) If (X, τ,E) is a soft $R\wedge G_2$ space then there exist soft r^g open sets (F,E) and (G,E) such that x ∈ (F,E) , y ∈(G,E) and (F,E) ∩ (G,E) = φ. Since (F,E) ∩ (G,E) = φ, x ∉ (G,E) , y ∉ (F,E). Hence (X,τ,E) is a soft $R\wedge G_1$ space.

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