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On Soft πgr-Closed sets in Soft Topological Spaces

[1]Janaki.C and [2]Jeyanthi.V

[1]Department of Mathematics, L.R.G .Govt. College for Women, Tirupur-4

janakicsekar@yahoo.com

[2]Department of Mathematics, Sree Narayana Guru College, Coimbatore- 105.

Jeyanthi_sngc@yahoo.com

ABSTRACT

The aim of this paper is to introduce soft πgr-closed sets in soft topological space which is defined over the universe of the given set with a fixed set of parameters. Further, we investigate its properties and its relationship with other soft closed sets.

Key Words: Soft sets; Soft Topology; Soft πgr-closed sets; Soft πgr- $T_{1/2}$-space.

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1. INTRODUCTION

Molodtsov [10] initiated the concept of soft set theory in 1999 as a general mathematical tool for dealing with uncertainties. He has shown several applications of this theory in solving many practical problems in economics, engineering, social science, medical science, etc., Maji, Biswas and Roy [9] made a theoretical study of soft set theory in more detail. Maji et al[9] proposed several operations on soft sets and some basic properties. Shabir and Naz [13] introduced the notion of soft topological spaces. Tridev Jyoti Naog[14] studies a new approach to the theory of soft sets. Kannan.K [7] studied soft g-closed sets in soft topological spaces along with its properties.In topological space , the concept of generalized (g-closed) set was introduced by Levine.N[8]. The concept of π-closed sets in topological spaces was initiated by Zaitsav[16] and the concept of πg-closed set was introduced by Noiri and Dontchev.[3]. N.Palaniappan[11] studied and introduced regular closed sets in topological spaces.Jeyanthi.V and Janaki.C [6]introduced πgr-closed sets in topological spaces. The concept of πgα-closed, πgp-closed, πgs-closed, π*g-closed, πgb-closed sets in topological spaces was introduced by C.Janaki[5], Park. J.H[12], Aslim .G et al[1], Ganes M Pandya [4] and Sreeja and Janaki[14].

In this paper, we introduce and study soft πgr-closed sets in topological spaces and obtain its relationship with other soft closed sets. Further, we obtain the basic results and properties.

2. Preliminaries

Definition 2.1([2],[10],[13],[14])

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). In other words, a soft set over U is a parameterized family of subsets of the universe U. For Ɛ∈A, F(Ɛ) may be considered as the set Ɛ- 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) $\tilde{\subset}$(G,B). (F,A) is said to be a soft superset of (G,B) , if (G,B) is a soft subset of (F,A). Two soft sets (F,A) and (G,B) over a common universe U are said to be soft equal if (F,A) is a soft subset of (G,B) and (G,B) is a soft subset of (F,A).

Definition :2.2([2],[10],[13],[14])

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

Definition :2.3([2],[10],[13],[14])

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.

Definition:2.4([2],[10],[13],[14])

For a soft set (F,A) over the universe U, the relative complement of (F,A) is denoted by (F,A)′ and is defined by (F,A)′=(F′,A), where F′: A →P(U) is a mapping defined by F′(e)= U– F(e) for all e∈A.

Definition:2.5([2],[7])

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, $\tilde{X}$ 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:2.6([2],[7])

Let (X, τ, E) be soft space over X. A soft set (F,E) over X is said to be soft closed in X, if its relative complement (F,E)′ belongs to τ. The relative complement is a mapping F′:E→P(X) defined by F′(e)= X-F(e) for all e∈A.

Definition:2.7([2],[7])

Let X be an initial universe set , E be the set of parameters and τ={φ, $\tilde{X}$ }. Then τ is called the soft indiscrete topology on X and (X,τ,E) is said to be a soft indiscrete space over X. If τ is the collection of all soft sets which can be defined over X, then τ is called the soft discrete topology on X and (X,τ,E) is said to be a soft discrete space over X.

Definition:2.8 ([2],[7])

Let (X,τ, E) be a soft topological space over X and the soft interior of (F,E) denoted by Int(F,E) is the union of all soft open subsets of (F,E). Clearly, (F,E) is the largest soft open set over X which is contained in (F,E).The soft closure of (F,E) denoted by Cl(F,E) is the intersection of all closed sets containing (F,E). Clearly , (F,E) is smallest soft closed set containing (F,E).

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

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

Definition:2.9([2],[7],[9])

Let U be the common universe set and E be the set of all parameters. Let (F,A) and (G,B) be soft sets over a common universe set U and A,B ⊂ E. Then (F,A) is a subset of (G,B), denoted by (F,A) $\tilde{\subseteq}$ (G,B). (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:2.10

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

(i) a soft generalized closed (Soft g-closed)[6] 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 semi open [2]if (A,E) $\tilde{\subseteq}$ Int(Cl(A,E))

(iii) a soft regular open if (A,E)= Int(Cl(A,E)).

(iv) a soft α-open if (A,E) $\tilde{\subseteq}$ Int(Cl(Int(A,E)))

(v) a soft b-open if (A,E) $\tilde{\subseteq}$ Cl(Int(A,E)) $\cup$ Int(Cl(A,E))

(vi) a soft pre-open set if (A,E) $\tilde{\subseteq}$ Int (Cl(A,E)).

(vii) a soft clopen is (A,E) is both soft open and soft closed.

The complement of the soft semi open , soft regular open , soft α-open, soft b-open , soft pre-open sets are their respective soft semi closed , soft regular closed , soft α-closed , soft b-closed and soft pre -closed sets.

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:2.11[7]

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:2.12

The soft regular closure of (A,E) is the intersection of all soft regular closed sets containing (A,E). (i.e)The smallest soft regular closed set containing (A,E) and is denoted by srcl(A,E).

The soft regular interior of (A,E) is the union of all soft regular open set s contained in (A,E) and is denoted by srint(A,E).

Similarly , we define soft α-closure, soft pre-closure, soft semi closure and soft b-closure of the soft set (A,E) of a topological space X and are denoted by sαcl(A,E), spcl(A,E), sscl(A,E) and sbcl(A,E) respectively.

3.SOFT πGR-CLOSED SETS.

Let us introduce the following definitions.

Definition:3.1

A subset (A,E) of a soft topological space X is called

(i) 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.

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

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

(iv) a soft πgα-closed if sαcl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft π- open.

(v) a soft πgp-closed if spcl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft π- open.

(vi) a soft πgb-closed if sbcl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft π- open.

(vii) a soft πgs-closed if sscl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) and (U,E) is soft π- open.

Definition:3.2

A soft subset (A,E) of a soft topological space X is called a soft πgr-closed set in X if srcl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ (U,E) , where (U,E) is soft π- open in X. We denote the soft πgr-closed set of X by SπGRC(X) .

Result :3.3

Every soft regular closed set is soft πgr-closed but not conversely.

Example:3.4

Let X={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}, $F_6(e_2)$={a,b,c},

$F_6(e_1)$={a,c,d}, $F_7(e_2)$={a,b,d}.

Then τ ={φ, $\tilde{X}$,(F_1,E),...,(F_8,E)} is a soft topology and elements in τ are soft open sets.

The soft closed sets are its relative complements.

Here the soft set (H,E)={{b,c,d},{a,b,c}} is soft πgr-closed but not soft regular closed.

Remark:3.5

The concept of soft closed and soft πgr-closed are independent.

Example:3.6

In Example 3.4, (i) the soft set (A,E)= {{a},{d}} of a soft topological space X is soft closed but not soft πgr-closed in X.

(ii)the soft subset (H,E)={{b,c,d},{a,b,c}} is soft πgr-closed but not soft closed in X.

Remark: 3.7

The concept of soft g-closed and soft πgr-closed are independent.

Example:3.8

In Example 3.4, (i) the soft set (A,E)= {{a},{d}} of a soft topological space X is soft g-closed but not soft πgr-closed in X.

(ii) the soft subset (H,E)={{b,c,d},{a,b,c}} is soft πgr-closed but not soft g-closed in X.

Theorem : 3.9

Every soft πgr-closed set is soft πgα-closed, soft πgp-closed, soft πgb-closed, soft πgs-closed, soft πg-closed and soft soft π*g-closed but not conversely.

Proof: Straight forward.

Example : 3.10

In example 3.4, i)The soft set (A,E)= {{a},{d}} of a soft topological space X is soft πgα-closed and soft πg-closed but not soft πgr-closed.

ii)The soft set (F,E)={{a},{b}} of a soft topological space X is soft πgb-closed, soft πgp-closed and soft πgs-closed but not soft πgr-closed.

iii) The soft subset (G,E)={{c},{d}}of topological space X is soft π*g-closed but not soft πgr-closed.

Remark:3.11

Every soft πgr-closed set is soft rg-closed but not conversely.

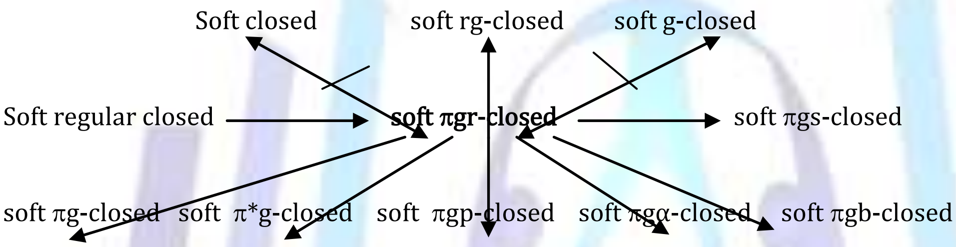
Proof: Straight forward.

Example:3.12

The soft subset (A,E)= {{a},{d}} of a soft topological space X is soft rg-closed but not soft πgr-closed in X.

Remark:3.13

The relationship between soft πgr-closed sets and soft sets are represented diagrammatically as follows:



Remark:3.14

The union of two soft πgr-closed sets is again a soft πgr-closed set.

Proof: Straight Forward.

Remark:3.15

The intersection of two soft πgr-closed sets need not be soft πgr-closed and is shown in the following example.

Example:3.16

In example 3.4,The soft sets (I,E)={{b,d},{b,d}} and (J,E)={{a,c,d},{a,b,c}} are soft πgr-closed sets in X but their intersection (K,E)={{d},{b}} is not soft πgr-closed in X.

Theorem:3.17

If the soft subset (A,E) is soft regular closed and soft πg-closed, then (A,E) is soft πgr-closed in X.

Proof: Let (A,E) be a soft regular closed set and soft πg-closed set in X.Since (A,E) is soft πg-closed in X, Cl(A,E) $\tilde{\subseteq}$ (U,E) whenever (A,E) $\tilde{\subseteq}$ ((U,E) and (U,E) is soft π-open. Since srcl(A,E) =(A,E). that is Cl(Int(A,E)) =(A,E). But Cl(Int(A,E)) $\tilde{\subseteq}$ Cl(A,E). Hence (A,E) $\tilde{\subseteq}$ Cl(A,E) $\tilde{\subseteq}$ (U,E).

$\Rightarrow$ (A,E) $\tilde{\subseteq}$ (U,E). Hence srcl(A,E)) $\tilde{\subseteq}$ (U,E) , whenever (A,E) $\tilde{\subseteq}$ (U,E) and U is soft π-open. Hence (A,E) is soft πgr-closed in X.

Theorem:3.18

If (A,E) is soft π-open and soft πgr-closed, then it is soft closed.

Proof: Suppose (A,E) is soft π-open and soft πgr-closed. Then srcl(A,E) $\tilde{\subseteq}$ (A,E). But (A,E) $\tilde{\subseteq}$ srcl(A,E). Hence srcl(A,E)=(A,E).The above implies (A,E) is soft regular closed and hence soft closed in X.

Theorem:3.19

If a soft subset (A,E) of a soft topological space X is soft πgr-closed set and (A,E) $\tilde{\subseteq}$ (B,E) $\tilde{\subseteq}$ srcl(A,E). Then (B,E) is also soft πgr-closed subset of X.

Proof: Let (A,E) be a soft πgr-closed set in X and (B,E) $\tilde{\subseteq}$ (U,E), where (U,E) is soft π-open. Since (A,E) $\tilde{\subseteq}$ (B,E), (A,E) $\tilde{\subseteq}$ (U,E). Since (A,E) is soft πgr-closed, soft srcl(A,E) $\tilde{\subseteq}$ (U,E). Given (B,E) $\tilde{\subseteq}$ srcl(A,E). Then srcl(B,E) $\tilde{\subseteq}$ srcl(A,E) $\tilde{\subseteq}$ U. Hence srcl(B,E) $\tilde{\subseteq}$ (U,E) and hence (B,E) is soft πgr-closed.

Theorem:3.20

If (A,E) is soft πgr-closed , then srcl(A,E) – (A,E) does not contain any non-empty soft π-closed set.

Proof: Let (F,E) be a non-empty soft π-closed set such that (F,E) $\tilde{\subseteq}$ srcl(A,E)–(A,E).The above implies (F,E)=X–(A,E).Since (A,E) is soft πgr-closed , X– (A,E) is soft πgr-open .Since (F,E) is soft π-closed set,X–(F,E) is soft π-open. Since srcl(A,E) $\tilde{\subseteq}$ X–(F,E), (F,E) $\tilde{\subseteq}$ X–srcl(A,E). Thus (F,E) $\tilde{\subseteq}$ φ, which is a contradiction. The above implies (F,E)=φ and hence srcl(A,E)–(A,E) does not contain non-empty soft π-closed set.

Corollary:3.21

Let (A,E) be a soft πgr-closed set. Then (A,E) is soft regular closed iff srcl(A,E)–(A,E) is soft π-closed.

Proof: Let (A,E) be soft regular closed . Then srcl(A,E)=(A,E) and srcl(A,E)–(A,E) =φ,which is soft π-closed.On the other hand ,let us suppose that srcl(A,E)–(A,E) is soft π-closed. Then by theorem 3.20, srcl(A,E)–(A,E)=φ.The above implies srcl(A,E)=(A,E).Hence (A,E) is soft regular closed.

4. SOFT πGR-OPEN SETS.

Definition:4.1

A soft set (A,E) is called a soft πgr- open set in a soft topological space X if the relative complement (A,E)′ is soft πgr-closed in X and the soft πgr-open set of X is denoted by SπRGO(X).

Remark:4.2

For a soft subset (A,E) of X, srcl(X-(A,E))= X- srint(A,E).

Theorem:4.3

The soft subset (A,E) of X is soft πgr-open iff (F,E) $\tilde{\subseteq}$ srint(A,E) whenever (A,E) is soft π-closed and (F,E) $\tilde{\subseteq}$ (A,E).

Proof: Let (A,E) be soft πgr-open. Let (F,E) be soft π-closed set and (F,E) $\tilde{\subseteq}$ (A,E). Then X− (A,E) $\tilde{\subseteq}$ X− (F,E). where X− (F,E) is soft π-open. Since (A,E) is soft πgr-open, X−(A,E) is soft πgr-closed. Then srcl(X− (A,E)) $\tilde{\subseteq}$ X−F,E).Since srcl(X− (A,E)) = X− srint(A,E).

⇒X–srint(A,E) $\tilde{\subseteq}$ X− (F,E). Hence (F,E) $\tilde{\subseteq}$ srint(A,E).

On the other hand, let (F,E) is soft π-closed and (F,E) $\tilde{\subseteq}$ (A,E) implies (F,E) $\tilde{\subseteq}$ srint(A,E). Let X- (A,E) $\tilde{\subseteq}$ (U,E), where X− (U,E) is soft π-closed. By hypothesis, X− (U,E) $\tilde{\subseteq}$ srint(A,E). Hence X-srint(A,E) $\tilde{\subseteq}$ (U,E). since srcl(X−(A,E))= X−srint(A,E).The above implies srcl(X-(A,E)) $\tilde{\subseteq}$ (U,E),whenever X-(A,E) is soft π-open.Hence X-(A,E) is soft πgr-open in X.

Theorem:4.4

If srint(A,E) $\tilde{\subseteq}$ (B,E) $\tilde{\subseteq}$ (A,E), and (A,E) is soft πgr-open , then (B,E) is soft πgr-open.

Proof: Given srint (A,E) $\tilde{\subseteq}$ (B,E) $\tilde{\subseteq}$ (A,E). Then X–(A,E) $\tilde{\subseteq}$ X–(B,E) $\tilde{\subseteq}$ srcl(X–(A,E)). Since (A,E) is soft πgr-open, X– (A,E) is soft πgr-closed. Then X–(B,E) is also soft πgr-closed. Hence (B,E) is soft πgr-open.

Remark:4.5

For any set (A,E) $\tilde{\subseteq}$ A, srint (srcl(A,E) – (A,E)) =φ.

Theorem:4.6

If (A,E) $\tilde{\subseteq}$ X is soft πgr-closed, then srcl(A,E) – (A,E) is soft πgr-open.

Proof: Let (A,E) be soft πgr-closed and let (F,E) be a soft π-closed set such that (F,E) $\tilde{\subseteq}$ srcl(A,E)-(A,E). Then (F,E) =φ. So, (F,E) $\tilde{\subseteq}$ srint(srcl(A,E) – (A,E)). Hence srcl(A,E) – (A,E) is soft πgr-open.

Theorem:4.7

The intersection of two soft πgr- open sets is again a soft πgr-open set.

Proof: Straight forward.

Remark:4.8

The union of two soft πgr-open sets need not be a soft πgr-open set and is shown in the following example.

Example:4.9

Let (B,E)={{a,c},{a,c}} and (C,E)={{b},{d}} are two soft πgr-open sets. Then their union (D,E)={{a,b,c},{a,c,d}} is not soft πgr-open in X.

5. SOFT πGR-$T_{1/2}$-SPACES.

Definition:5.1

A soft topological space X is a soft πgr- T1/2-space if every soft πgr-closed set is soft regular closed.

Theorem:5.2

For a soft topological space (X,τ,E), the following conditions are equivalent.

(i) The soft topological space X is soft πgr-T1/2-space.
(ii) Every singleton of X is either soft π-closed or soft regular open.

Proof:

(i) ⇒ (ii): Let (A,E) be a soft singleton set in X and let us assume that (A,E) is not soft π-closed. Then X-(A,E) is not soft π-open and hence X-(A,E) is trivially soft πgr-closed. Since in a soft πgr-T1/2-space , every soft πgr-closed set soft regular closed. Then X-(A,E) is soft regular closed. Hence (A,E) is soft regular open.

(ii) ⇒ (i) : Assume that every singleton of a soft topological space X is either soft π-closed or soft regular open.

Let (A,E) be a soft πgr-closed set in X . Obviously, (A,E) $\tilde{\subseteq}$ srcl(A,E).

To Prove srcl(A,E) $\tilde{\subseteq}$ (A,E)

Case (i): Let the singleton set (F,E) be soft π-closed. Suppose (F,E) does not belong to (A,E). Then (F,E) $\tilde{\subseteq}$ srcl(A,E) -(A,E) , which is a contradiction to the fact that srcl(A,E) -(A,E) does not contain any non-empty soft π-closed set. Therefore, (F,E) $\tilde{\subseteq}$ (A,E). Hence srcl(A,E) $\tilde{\subseteq}$ (A,E). The above is soft regular closed and hence every SπGRC(A,E) is soft regular closed. Hence the soft topological space X is soft πgr-T1/2-space.

Case(ii): Let (F,E) be soft regular open in X. Since (F,E) ∈srcl(A,E), we have (F,E)∩(A,E) ≠φ. Hence (F,E) $\tilde{\subseteq}$ (A,E). Therefore, srcl(A,E) $\tilde{\subseteq}$ (A,E) .Hence srcl(A,E) =(A,E).

⇒ (A,E) is soft regular closed and hence SπRG-closed in X.

Theorem:5.3

(i) Soft RO(X,τ,E) $\tilde{\subseteq}$ Soft πRGO(X,τ,E)
(ii) A soft topological space (X,τ,E) is πgr-T1/2-space iff soft RO(x,τ,E) =πGRO(X,τ,E)

Proof:

(i) Let (A,E) be soft regular open. Then X–(A,E) is soft regular closed and so soft πgr-closed.Hence (A,E) is soft πgr-open and soft RO(X,τ,E) $\tilde{\subseteq}$ πGRO(X, τ,E)

(ii) Necessity: Let (X,τ,E) be πgr-T1/2-space. Let (A,E) ∈πGRO(X,τ,E) . Then X–(A,E) is soft πgr-closed. Since the space soft πgr-T1/2-space, X–(A,E) is soft regular closed. The above implies (A,E) is soft regular open in X. Hence SπGRO(X,τ,E) =SRO(X, τ,E).

Suffiency: Let SπGRO(X,τ,E) =SRO(X, τ ,E).Let (A,E) be soft πgr-closed. Then X– (A,E) is soft πgr-open. Thus X–(A,E) ∈SRO(X,τ,E) and hence (A,E) is soft regular closed.

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