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ON R*- CLOSED SETS IN TOPOLOGICAL SPACES

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ABSTRACT

In this paper, a new class of sets called R-closed sets in topological spaces is introduced and their properties are discussed.*

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Keywords: *R*- closed sets, R*- open sets, R*-continuous, R*-irresoluteness.*

1. INTRODUCTION

Way back in 1970, Levine [11] introduced the concept of generalized closed sets. This study has been furthered by general topologists. Stone [19], Cameron [5] Gnanamabal [9], N Palaniappan and Rao [15] introduced regular open sets, regular semi open sets ,generalized pre regular closed sets, regular generalized closed sets respectively. N.

Nagaveni [14], Sundaram and SheikJohn[18], S.S. Benchalli and R.S. Wali [4], Sharmishta Battacharya [17], Sanjay Mishra[16] delved into the study of weak generalized closed sets, weakly closed sets, regular w-closed sets, regularized weak closed sets, regular generalized weakly- closed sets respectively. This paper is an attempt to study a new class of sets called R*-closed sets.

Throughout this paper, we consider spaces on which no separation axioms are assumed unless explicitly stated. The topology of a given space X is denoted by τ and (X,τ) is replaced by X if there is no confusion. For $A\subset X$, the closure and the interior of A in X are denoted by cl(A) and int(A) respectively.

2. PRELIMINARIES

Definition 2.1. A subset A of a topological space (X,τ) is called

(1) a regular open [19] if A = int(cl(A)) and regular closed [19] if A = cl(int(A))
(2) a pre open [13] if $A\subseteq$ int (cl(A)) and pre closed [13] if cl(int(A)) $\subseteq$ A.
(3) a semi open [10] if $A\subseteq$ cl(int(A)) and semi closed [10] if int(cl(A)) $\subseteq$ A.
(4) a semi-preopen [1] if A $\subseteq$ cl(int(cl(A)) and semi-pre closed [1] if int(cl(int(A))) $\subseteq$ A

The intersection of all regular closed(semi- closed, pre-closed, semi- pre-closed) subset of (X,τ) containing A is called the regular closure (semi-closure, pre-closure, semi-pre-closure resp.) of A and is denoted by rcl(A) (scl(A),pcl(A),spcl(A)resp.)

Definition 2.2. [6] A subset A of a space (X,τ) is called regular semi open set , if there is a regular open set U such that
$U\subset A\subset cl(U)$. The family of all regular semi open sets of X is denoted by RSO(X).

Lemma2.3. [5] Every regular semi open set in (X,τ) is semi open but not conversely.

Lemma2.4. [8] If A is regular semi open in (X,τ), then X\A is also an regular semi open.

Lemma2.5. [8] In a space (X,τ), the regular closed sets, regular open sets and clopen sets are regular semi open.

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Definition2.6. [8] A subset A of a space (X, τ) is said to be semi regular open if it is both semi open and semi closed.

Definition2.7. A subset of a topological space (X, τ) is called

(1) a generalized closed (briefly g- closed) [11] if cl (A) $\subseteq$ U whenever A $\subseteq$ U and U is open in X.
(2) a semi generalized closed (briefly sg-closed) [3] if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is semi open in X.
(3) a generalized semi closed (briefly gs-closed) [2] if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in X.
(4) a generalized semi preclosed (briefly gsp- closed) [6] if spcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in X.
(5) a regular generalized (briefly rg-closed) [15] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is regular open in X.
(6) a generalized pre-closed (briefly gp- closed) [12] if pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in X.
(7) a generalized pre regular closed (briefly gpr-closed) [9] if pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is regular open in X.
(8) a weakly generalized closed (briefly wg - closed) [14] if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is open in X.
(9) a weakly closed (briefly w-closed) [18] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is semi open in X.
(10) a semi weakly generalized closed (briefly swg-closed) [14] if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is semi open.
(11) a regular weakly generalized closed (briefly rwg-closed) [14] if cl(int(A)) $\subseteq$ U whenever A $\subseteq$ U and U is regular open in X.
(12) a regular w-closed (briefly rw-closed)[4] if cl(A) $\subset$ U whenever A $\subset$ U and U is regular semi open in X.
(13) a regular generalized weak closed set (briefly rgw-closed) [16] if cl(int(A)) $\subset$ U whenever A $\subset$ U and U is regular semi open.

The complements of the above mention closed sets are their respective open sets.

3. R*-CLOSED SETS AND R*-OPEN SETS

Definition 3.1. A subset A of a space (X, τ) is called R*-closed if rcl(A) $\subset$ U whenever A $\subset$ U and U is regular semi open in (X, τ).

We denote the set of all R*- closed sets in (X, τ) by R*C(X).

Example 3.2. Let X= {a, b, c} τ = {X, ϕ {a},{c}{a, c}}

R*-closed sets are {X, ϕ ,{b},{a, b},{a, c}.{b ,c}}.

Remark 3.3. Closed sets and R*-closed sets are independent of each other.

Example 3.4. Let X= {a, b ,c ,d} τ = {X, ϕ ,{a},{b},{a ,b},{a ,b ,c}} R*-closed sets are {X, ϕ ,{a, b},{c, d},{a, b, c},{a b, d},{b ,c, d},{a, c ,d}} Closed sets are {X, ϕ ,{d},{c ,d},{a, c, d},{b, c, d}}

Theorem 3.5.

(1).Every R*-closed sets is rg- closed.
(2).Every R*-closed set is gpr- closed.
(3) Every R*-closed set is rwg-closed.
(4).Every R*- closed sets is rw-closed.
(5).Every R*-closed set is pr-closed.
(6).Every R*-closed sets is rgw- closed.

Proof: Straight forward.

Converse of the theorem need not be true as seen in the following example.

Example 3.6
a) Let X= {a, b, c, d} and τ ={X, ϕ , {a},{b}{a, b},{a, b, c}}

Let A={c}. A is rg-closed, gpr closed, rwg closed, but not R*-closed set.

b) Let X= {a, b, c, d} and τ ={X, ϕ ,{a},{b}{a, b},{a, b, c}}

Let A= {d} is rw-closed set but not R*-closed set.

c) Let X= {a, b, c, d,} and τ ={X, ϕ, {a},{b}{a, b},{a, b, c}}

R*C(X) = {{a, b}, {c, d}, {a, b, c}, {a, b, d,}, {a, c, d}, {b, c, d}, X, ϕ }

Let A={c}. A is pr-closed set but not R*-closed set.

d) Let X={a, b, c, d} τ = {X. ϕ ,{a},{d},{a, d},{a, b},{a, b, d}}

R*C(X) ={ X, ϕ ,{c},{c,d},{a,c},{a,d},{b,c},{b,d},{a,b,c},{a,b,d},{b,c,d},{a,c,d}}

A= {b} is rgw closed set but not R*-closed set.

Remark 3.7. g-closed ,gs-closed, gp-closed, gsp- closed sets are independent with R*-closed sets.

Example 3.8. In example 3.4. A = {a, b} is R*-closed set but it is not g-closed, gs-closed, gp-closed and gsp-closed.

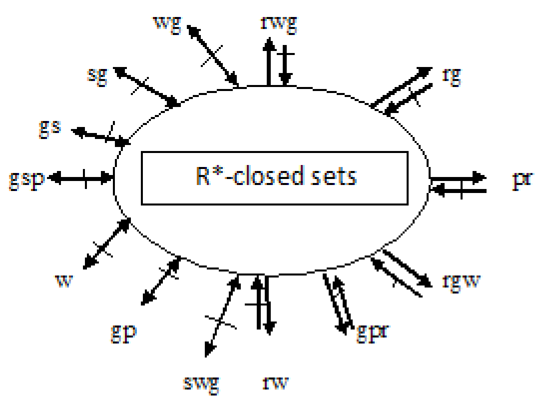
B= {d} is g-closed, gs-closed, gp-closed and gsp-closed but not R*-closed set.

Remark 3.9. The following example shows that R*-closed sets are independent of wg-closed, w-closed, sg-closed, swg-closed.

Example 3.10. Let X= {a, b, c, d} and τ = {X, ϕ, {a},{b},{a, b},{a, b, c}}.

(1) Closed sets are {X, ϕ , {b, c, d},{a, c, d},{c, d},{d}}
(2) R*-closed set are {X, ϕ, {a, b},{c, d},{a, b, c},{a, b, d},{a, c, d},{b, c, d}}.
(3) wg-closed sets are {{c},{d}, {a, d},{b, d},{c, d},{a, b, d}{b, c, d},{a, c, d}, X, ϕ }.
(4) w-closed sets are {{d}, {c, d}, {b, c, d}, {a, c, d}, X, ϕ }.
(5) sg-closed sets are {{a},{b},{c},{d},{a, c},{a, d},{b, c},{b, d},{c, d},{b, c, d},{a, c, d}, X, ϕ }.
(6) swg-closed sets are {{c}, {d}, {c, d}, {b, c, d}, {a, c, d}, X, ϕ }.

Remark 3.11 From the above discussion we have the following diagram.



Theorem 3.12. The union of the two R*-closed sets is an R*-closed subset of X.

Proof: Assume that A and B are R*-closed sets in X. Let U the regular semi open in X such that (A $\cup$ B) $\subset$ U. Then A $\subset$ U and B $\subset$ U. Since A and B are R*-closed, rcl(A) $\subset$ U and rcl(B) $\subset$ U respectively. Hence rcl (A $\cup$ B) $\subset$ U. Therefore A $\cup$ B is R*-closed.

Remark 3.13 The intersection of two R*-closed sets in X need not be R*-closed in X.

Example 3.14. Let X= {a, b, c, d}, τ ={X, ϕ, {a}.{c, d},{a, c, d}}. R*-closed sets are {X, ϕ ,{b},{a, b},{a, d}, {b, c},{b, d},{a, b, c},{a, b, d},{b, c, d},{a, c, d}}

Let A= {a, d} and B = {a, b}

Therefore $A \cap B$= {a} $\notin$ R*- closed set.

Theorem 3.15. If a subset A of X is R *-closed set in X , then rcl(A)\A does not contain any non-empty regular semi open set in X.

Proof: Suppose that A is R*-closed set in X. Let U be a regular semi open set such that rcl(A)\A $\supset$ U and U $\neq \phi$. Now U $\subset$ X\A implies A $\subset$ X\U. Since U is regular semi open, by Lemma 2.4 . X\U is also regular semi open in X. Since A is R *-closed in X, by definition rcl(A) $\subset$ X\U. So U $\subset$ X\rcl(A), hence U $\subset$ rcl(A) $\cap$ X\rcl(A)= ϕ. This shows that U= ϕ, which is a contradiction.

Hence rcl(A)\A does not contain any non-empty regular semi open set in X.

Remark 3.16. If rcl(A) \A contain no non-empty regular semi open subset of X, then A need not to be R*-closed

Example.3.17. .In example 3.1 X= {a, b, c, d} and τ ={X, ϕ ,{a},{b},{a ,b ,c}}

Let A = {a}. rcl (A)\A= {c, d} does not contain a non empty regular semi open set, but A={a} is not R*-closed.

Corollary3.18. If a subset A of X is R* -closed in X, then rcl(A) \A does not contain any non empty regular open set in X .

Proof: Follows from theorem 3.13, since every regular open set is regular semi open.

Corollary 3.19. If a subset A of X is R *- closed set in X then rcl(A)\A does not contain any non empty regular closed set in X .

Proof: Follows the theorem 3.13 and the fact that every regular closed set is regular semi open.

Theorem 3.20. For any element $x \in X$. The set X \{x} is R*-closed or regular semi open.

Proof: Suppose X\{x} is not regular semi open, then X is the only regular semi open set containing X\{x}. This implies rcl{X\{x}} $\subset$ X. Hence X\{x} is R*-closed or regular semi open set in X.

Theorem 3.21. If A is regular open and R*-closed. Then A is regular closed and hence r-clopen.

Proof: Suppose A is regular open and R*- closed. A $\subset$ A and by hypothesis rcl(A) $\subset$ A . Also A $\subset$ rcl(A), so rcl(A)=A. Therefore A is regular closed and hence r-clopen.

Theorem 3.22. If A is an R*- closed subset of X such that $A \subset B \subset$ rcl(A),then B is an R*-closed set in X .

Proof: Let A be an R*-closed set of X such that $A \subset B \subset$ rcl(A). Let U be a regular semi open set of X such that $B \subset U$, then $A \subset U$. Since A is R*- closed, we have rcl(A) $\subset$ U. Now rcl(B) $\subset$ rcl(rcl(A)) = rcl(A) $\subset$ U, therefore B is an R*- closed set in X.

Remark 3.23. The converse of the theorem 3.22 need not be true.

Example 3.24. Consider the topological space (X, τ), where X= {a, b, c, d},
τ ={X, ϕ, {a},{b},{a ,b},{a ,b ,c}}. Let A = {c} , B={ c ,d},.rcl {c} = {c ,d}

Then A and B are such that A $\subset$ B $\subset$ rcl(A) where B is R*-closed set in (X, τ) but A is not R*-closed set in (X, τ).

Theorem 3.25. Let A be the R*- closed in (X, τ). Then A is regular closed if and only if rcl(A)\A is regular semi open.

Proof: Suppose A is regular closed in X. Then rcl(A)=A and so rcl(A)\A= ϕ ,which is regular semi open in X.

Conversely, suppose rcl(A)\A is regular semi open in X . Since A is R*-closed by theorem 3.13 rcl(A)\A does not contain any non-empty regular semi open set in X . Then rcl(A)\A = ϕ .Hence A is regular closed in X .

Theorem 3.26. If a subset A of a topological space X is both regular semi open and R*- closed, then it is regular closed.

Proof: By hypothesis, we have rcl(A) $\subset$A. Hence A is regular closed.

Theorem 3.27. In a topological space X , if RSO(X)={X, ϕ }, then every subset of X is an R*-closed set.

Proof: Let X be a topological space and RSO(X) ={X, ϕ },. Let A be any subset of X. Suppose A= ϕ, then ϕ is an R*-closed set in X. Suppose A$\neq$ ϕ, then X is the only regular semi open set containing A and so rcl(A) $\subset$X. Hence A is R*- closed set in X.

Remark 3.28.. The converse of theorem 3.27 need not to be true in general as seen from the following example.

Example 3.29. Let X= {a, b, c, d} be with the topology τ = {X, ϕ, {a, b},{c, d}}. Then every subset of X is R*-closed set in X. But RSO(X) = {X, ϕ, {a ,b},{c, d}}.

Definition 3.30. A subset A in X is called R*-open if A^c is R*-closed in X.

Theorem 3.31. A subset A of X is said to be R*-open if F$\subseteq$ rint(A) whenever F is regular semi open and F$\subseteq$ A.

Proof: Necessity .Let F be regular semi open such that F$\subseteq$ A . X-A $\subseteq$ X-F. Since X-A is R*-closed,
rcl(X-A) $\subseteq$ X-F. Thus F $\subseteq$ rint(A) .

Sufficiency. Let U be any regular semi open set such that X - A $\subseteq$U .We have X - U $\subseteq$A and by hypothesis
X - U $\subseteq$ rint (A). That is rcl(X-A) = X- rint A$\subseteq$ U .Therefore (X-A) is R*-closed and hence A is R*-open.

Theorem 3.32. Finite intersection of R*-open sets is R*-open.

Proof: Let A and B be R*-open sets in X . Then $A^c \cup B^c$ is R*-closed set. This implies $(A\cap B)^c$ is R*-closed set. Therefore A$\cap$B is R*-open.

Theorem 3.33. If A is R*-closed subset of (X, τ) and F be a regular closed set in rcl(A)\A, then R*-open set.

Proof: Let A be an R*-closed subset of (X, τ) and F be a regular closed subset such that F $\subseteq$ rcl (A) – A. By corollary 3.19. , F = ϕ and thus F $\subseteq$ rint (rcl (A) – A).

By Theorem 3.31, .rcl(A) - A is R*- open.

Lemma 3.34. If the regular open and regular closed sets of X coincide, then all subset of X are R*-closed (and hence all are R*-open).

Proof: Let A be a subset of X which is regular open such that A$\subseteq$U and U is regular open, then
rcl(A) $\subseteq$rcl(U) $\subseteq$ U.

Therefore A is R*-closed.

4. R*-CONTINUOUS AND R*-IRRESOLUTE FUNCTIONS

Definition 4.1. A function f : (X, τ) → (Y, σ) is called R*-continuous function if every f^{-1}(V) is R*closed in (X, τ) for every closed set V in (Y, σ).

Definition 4.2. A function f : (X, τ) → (Y, σ) is called R*-irresolute if f^{-1}(V) is R*-closed in (X, τ) for every R*-closed set V in (Y ,σ).

Example 4.3. Let X={a, b ,c, d} τ ={X, ϕ,{a},{c},{a, c},{a, b},{a ,b, c}} and Y= X
σ = {Y, ϕ, {a},{b},{a ,b}}. f : (X, τ)→ (Y, σ) be the identity mapping, then f is R*-continuous.

Example.4.4. X={a, b ,c ,d} τ ={X, ϕ,{a},{d},{a, d},{a b},{a ,b ,d}}Y=X and σ = {Y, ϕ,{a},{c ,d},{a ,c ,d}} Define the function f: (X, τ)→ (Y, σ) by f(a) = d, f(b) = a, f(c) = b, f(d) = c.

The inverse image of every R*-closed sets is R*-closed under f. Hence f is R*-irresolute.

Remark 4.5. The composition of two R*-continuous function need not be R*-continuous.

Example 4.6 . Let X= {a, b, c, d} =Y=Z τ ={X, ϕ,{a},{c ,d},{a, c, d}}
σ ={X, ϕ,{a},{a, b},{a, b, c}}, η ={X, ϕ,{a},{d},{a, d},{a, b},{a, b, d}}.

Define f : (X, τ)→ (Y, σ) by f (a) = a, f(b) =d, f(c)= b, f(d) = c and g : (Y, σ) →(Z, η) by g (a) = a, g (b) = d, g (c) = b, g (d) = c. Here both f and g are R*-continuous but $g \circ f$ is not R*-continuous.

Remark 4.7. R*-continuity and continuity are independent concepts.

Example 4.8. Let X={a, b, c, d} τ ={X, ϕ ,{a},{c},{a, c},{a, b},{a, b, c}} and Y = {a, b, c, d} σ ={Y, ϕ, {a}, {b},{a, b}} defined by the function f: (X, τ)→ (Y, σ) , the identity mapping. f is R*- continuous function but not continuous .

Example 4.9. Let X={a, b, c, d} τ ={X, ϕ,{a},{b}, {a, b},{a, b, c}} Y={a, b, c, d} σ ={Y, ϕ,{a, b, c}} f: X → Y, the identity mapping . f is continuous but not R*-continuous .

Remark 4.10. Every R*-irresolute function is R*-continuous but not conversely.

Example 4.11. Let X = {a, b, c, d} τ ={ {a},{c},{a, c},{a, b},{a, b, c}, X , ϕ }Y={a, b, c, d} σ ={Y, ϕ,{a},{b},{a, b}}. Define f: X → Y, the identity mapping. f is R*-continuous but not R*-irresolute.

Theorem 4.12.

(a) Every R*-continuous mapping is rw-continuous

(b) Every R*-continuous mapping is rg-continuous.

(c) Every R*-continuous mapping is pr-continuous

(d) Every R*-continuous mapping is rwg-continuous

(e) Every R*-continuous mapping is rgw-continuous

(f) Every R*-continuous mapping is gpr-continuous.

Proof: Obvious

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

Example 4.13. Consider X={a, b, c, d} τ ={ X, ϕ {a},{b},{a, b},{a, b, c}} and Y={a, b, c, d}, σ ={Y, ϕ {a, b, c,}}. Define f : (X, τ)→ (Y, σ) ,the identity mapping.

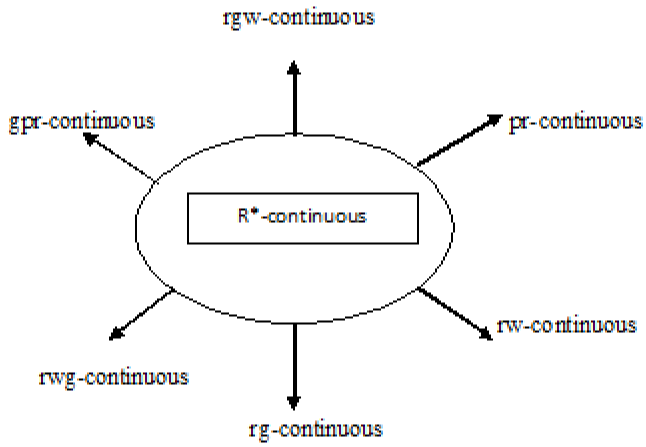
The mapping f is both rw-continuous and rg- continuous but not R*-continuous.

Example 4.14. X={a, b ,c, d},τ={X, φ,{a},{c ,d},{a, c ,d}}and Y={a, b, c, d},σ={Y, φ,{a ,b ,c}}

Define f : (X, τ)→ (Y, σ) by f(a) = a, f(b) = b, f(c) = d , f(d) = c

The function f is pr-continuous,rwg-continuous,rgw-continuous and gpr-continuous but not R*-continuous.

Remark 4.15. From the above theorem the following diagram is implicated.



Theorem:4.16.

Let f : (X, τ)→ (Y,σ) and and g : (Y,σ) →(Z,η) be any two function, then

(1). g ∘ f is R*-continuous if g is continuous and f is R*-continuous.
(2). g ∘ f is R*-irresolute if is g is R*-irresolute and f is R*-irresolute.
(3). g ∘ f is R*-continuous if g is R*-continuous and f is R*-irresolute.

Proof:

(1). Let V be closed set in (Z,η) . Then g^{-1}(V) is closed set in (Y,σ), since g is continuous and R*-continuity of f implies f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is R*-closed in (X, τ). That is $(g \circ f)^{-1}$(V) is R*-closed in (X, τ). Hence g ∘ f is R*continuous.

(2). Let V be R*-closed set in (Z,η) . Since g is irresolute, g^{-1}(V) is R*-closed set in (Y,σ) . As f is R*-irresolute f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is R*-closed in (X, τ). Hence g ∘ f is R*-irresolute.

(3). Let V be closed in (Z,η). Since g is R*-continuous, g^{-1}(V) is R*-closed in (Y,σ). As f is R*-irresolute f^{-1}(g^{-1}(V)) = $(g \circ f)^{-1}$(V) is R*-closed in (X, τ). Therefore (g ∘ f) is R*-continuous .

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