αJ-closed sets in topological spaces

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Abstract- In this paper, a new class of closed sets namely αJ-closed sets is initiated in topological spaces. The properties and relationship with other generalized closed sets are analysed. Some important characterizations are obtained.

Keywords – αJ-closed set, J-closed set, η*-closed set, regular*-closed set and g-closed set

I. INTRODUCTION

In 1937, Stone [18] introduced regular open sets and used it to define the semi-regularization of a topological space. In 1968, Velicko [24] proposed δ-open sets which are stronger than open sets. Levine [9] has brought generalized closed sets in 1970. Dunham [6] has established a generalized closure using Levine's generalized closed sets as Cl*. In 2016, Pious Missier et. al [16] has instituted regular*-open sets using Cl*.In 2018, Meenakshi et. al [13] have introduced a class of new sets namely η*-open sets which is placed between the classes of δ-open set and open set. Its basic properties are procured and the concepts of η*-cluster point, η*-adherent point and a η*-derived set are introduced and studied in the same paper. Meenakshi et.al [14] initiated J-closed sets in topological spaces and analyzed some characterizations and properties of J-closed sets. In this paper, αJ-closed sets are introduced using η*-open sets and their features are studied.

For this paper some basic definitions and results in topological spaces are needed which are given in Section 2. Throughout this paper, (X,τ) will always denote the topological space.

II. PRELIMINARIES

2.1 Definition-

Let (X,τ) be a topological space. If U is a non-empty subset of (X,τ) then the intersection of all closed sets containing U is called closure of U and is denoted by Cl(U).The union of all open sets contained in U is called interior of U and is denoted by int(U).

2.2 Definition-

If A is a subset of a space (X,τ)
1) The generalized closure of U [6] is defined as the intersection of all g-closed sets in X containing U and is denoted by Cl*(U).
2) The generalized interior of U [6] is defined as the union of all g-open sets in X contained in U and is denoted by int*(U).

2.3 Definition-

Let (X,τ) be a topological space. A subset U of (X,τ) is called
1) regular closed set [18] if U = Cl(int(U))
2) semi-closed set [8] if $int(Cl(U)) \subseteq U$
3) α-closed set [15] if $Cl(int(Cl(U)) \subseteq U$
4) pre-closed set [12] if $Cl(int(U)) \subseteq U$
5) semi pre-closed set [1] if $int(Cl(int(U))) \subseteq U$

The complements of the above mentioned sets are called regular open, semi-open, α-open, pre-open and semi pre-open respectively.

The intersection of all regular closed (resp. semi-closed,α-closed, pre-closed and semi pre-closed) subsets of (X,τ) containing U is called the regular closure (resp.semi-closure, α-closure, pre-closure and semi pre-closure) of U and is denoted by rCl(U) (resp. sCl(U), αCl(U), pCl(U) and spCl(U)). A subset U of (X,τ) is called clopen if it is both open and closed in (X,τ).

2.4 Definition [24]-

The δ-interior of a subset U of X is the union of all regular open sets of X contained in U and is denoted by $\text{int}_\delta(U)$. The subset U is called δ-open if $U = \text{int}_\delta(U)$. i.e. a set is α-open if it is the union of regular open sets, the complement of δ-open is called δ-closed. Alternatively, a set U ∈ Y is δ-closed if U = δCl(U), where δCl(U) is the intersection of all regular closed sets of (X,τ) containing U.

2.5 Definition[16]-

Let (X,τ) be a topological space. A subset U of (X,τ) is called regular*-open (or r*-open) if U = int(Cl*(U)). The complement of regular*-open set is called regular*-closed set. The union of all regular*-open sets of Y contained in U is called regular*-interior and is denoted by r*int(U). The intersection of all regular*-closed sets of X containing U is called regular*-closure is denoted by r*Cl(U).

2.6 Definition[13]-

A subset U of a topological space (X,τ) is called η*-open set if it is a union of regular*-open sets (r*-open sets).The complement of a η*-open set is called a η*-closed set. A subset U of a topological space (X,τ) is called η*-Interior of U is the union of all η*-open sets of Y contained in U. We denote the symbol by η*-int(U).The intersection of all η*-closed sets of Y containing U is called as the η*-closure of U and denoted by η*-cl(U).

2.7 Definition-

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

1) generalized closed (briefly g-closed) [9] if cl(U) ⊆ M whenever U ⊆ M and M is open in (X,τ).
2) generalized semi-closed (briefly gs-closed) [2] if scl(U) ⊆ M whenever U ⊆ M and M is open in (X,τ).
3) semi generalized-closed (briefly sg-closed) [3] if scl(U) ⊆ M whenever U ⊆ M and M is semi-open in (X,τ).
4) δ-generalized closed (briefly δg-closed) [5] if δcl(U) ⊆ M whenever U ⊆ M and M is open in (X,τ).
5) δg* -closed [19] if δcl(U) ⊆ M whenever U ⊆ M and M is g-open in (X,τ).
6) generalized α closed (briefly gα-closed) [10] if αcl(U) ⊆ M whenever U ⊆ M and M is α-open in (X,τ).
7) α generalized closed (briefly αg-closed) [11] if αcl(U) ⊆ M whenever U ⊆ M and M is open in (X,τ).
8) generalized*α closed (briefly g*α-closed) [25] if αcl(U) ⊆ M whenever U ⊆ M and M is gα-open in (X,τ).
9) $\hat{g}$ -closed [21] if cl(U) ⊆ M whenever U ⊆ M and M is semi-open in (X,τ).
10) $^{\#}$gs –closed [23] if scl(U) ⊆ M whenever U ⊆ M and M is *g-open in (X,τ).
11) *g -closed [7] if Cl(U) ⊆ M whenever U ⊆ M and M is $\hat{g}$-open in (X,τ)
12) g* -closed [20] if Cl(U) ⊆ M whenever U ⊆ M and M is g-open in (X,τ)
13) $g^{\#}$ -closed [22] if Cl(U) ⊆ M whenever U ⊆ M and M is αg-open in (X,τ)
14) generalized semi pre-closed (briefly gsp-closed) [4] if spcl(U) ⊆ M whenever U ⊆ M and M is open in (X,τ).
15) g*s-closed [17] if scl(U) ⊆ M whenever U ⊆ M and M is gs-open in (X,τ).

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

2.8 Remark [13]-

1) regular closed (open) → δ-closed (open) → η*-closed (open) → closed (open) → semi-closed (open) → semi pre-closed(open).
2) regular closed (open) → δ-closed (open) → η *-closed (open) → closed (open) → closed (open) → g-closed (open).
3) regular closed (open) → δ-closed (open) → η *-closed (open) → closed (open) → pre-closed (open).

2.9 Remark [13]-

For every subset U of X,

1) spcl(U) ⊆ scl(U) ⊆cl(U) ⊆ η*-cl(U) ⊆ δcl(U) ⊆ rcl(U) ⊆ πcl(U).
2) gcl(U) ⊆ cl(U)) ⊆ η*-cl(U) ⊆ δcl(U) ⊆ rcl(U) ⊆ πcl(U).
3) pcl(U) ⊆ cl(U) ⊆ η*-cl(U) ⊆ δcl(U) ⊆ rcl(U) ⊆ πcl(U).

III. αJ-CLOSED SETS

In this section a new class of generalized closed sets, called αJ-closed sets are introduced. The relations between αJ-closed sets and various existing closed sets are analysed

3.1 Definition-

A subset U of a topological space (X,τ) is said to be αJ-closed set if $\alpha Cl(U) \subseteq M$ whenever $U \subseteq M$, M is η^*-open in (X,τ).
The class of all αJ-closed sets of (X,τ) is denoted by $\alpha JC(X,\tau)$

3.2 Proposition-

Every δ-closed set is αJ-closed but not conversely.

Proof: Let D be a δ-closed set and M be any η^*-open set containing U. Since U is δ-closed, $\delta cl(U) = U$. Therefore $\delta cl(U) = U \subseteq M$. As $\alpha cl(U) \subseteq \delta cl(U) \subseteq M$ and hence U is αJ-closed.

3.3 Counter Example-

Let X = {a, b, c} τ = {ϕ, X, {a}}. In this topology the subset {b} is αJ-closed but not δ-closed.

3.4 Proposition-

Every δg^*-closed set is αJ-closed but not conversely.

Proof: Let U be a δg^*-closed and M be any η^*-open set containing M in Y. By Remark 2.8(iii), every η^*-open set is a g-open set and U is δg^*-closed, $\delta Cl(U) \subseteq M$. As $\alpha Cl(U) \subseteq \delta Cl(U)$ [By Remark 2.9(i)].We get $\alpha Cl(U) \subseteq M$ implies U is αJ-closed.

3.5Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a, b}}. Then the subset {a} is αJ-closed but not δg^*-closed in (X,τ).

3.6 Proposition-

Every δg-closed set is αJ-closed but not conversely.

Proof: Let U be a δg-closed and M be any η *-open set containing U in Y. By Remark 2.8(i), every η *-open set is an open set and U is δg-closed, $\delta Cl(U) \subseteq M$. As $\alpha Cl(U) \subseteq \delta Cl(U)$ [By Remark 2.9(i)].We get $\alpha Cl(U) \subseteq M$ implies U is αJ-closed.

3.7 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {a, b}}. Then the subset {b} is αJ-closed but not δg-closed in (X,τ).

3.8 Proposition-

Every $g\alpha^*$-closed set is αJ-closed but not conversely.

Proof: Let U be a $g\alpha^*$-closed set and M be any η *-open set containing U. By Remark 2.8(i), η^*-open set is $g\alpha$-open and U is g-closed, $\alpha Cl(U) \subseteq M$. Therefore U is αJ-closed.

3.9 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {b, c}}. Then the subset {a, b} is αJ-closed but not $g\alpha^*$-closed in (X,τ).

3.10 Proposition-

Every $g^\#$-closed set is αJ-closed but not conversely.
Proof: Let U be $g^\#$-closed set and M be any η *-open set containing U. By Remark 2.8(i), η^*-open set is αg-open Since U is $g^\#$-closed, $Cl(U) \subseteq M$. Hence $\alpha Cl(U) \subseteq Cl(U) \subseteq M$. Therefore U is αJ -closed.

3.11 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {a, b}}. Then the subset {b} is αJ-closed but not $g^\#$-closed in (X,τ).

3.12 Proposition-

Every *g-closed set is αJ-closed but not conversely.
Proof: Let U be *g -closed set and M be any η^*- open set containing U in Y. Every η^*- open set is $\hat{g}$ -open and U is *g-closed, $Cl(U) \subseteq M$. Hence $\alpha Cl(U) \subseteq Cl(U) \subseteq M$ implies U is αJ-closed.

3.13 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {a, b}, {a, c}}. Then the subset {a} is αJ-closed but not *g-closed in (X,τ).

3.14 Proposition-

Every $\hat{g}$ -closed set is αJ-closed but not conversely.

Proof: Let U be $\hat{g}$ -closed set and M be any η*- open set containing U in Y. Every η*- open set is semi-open and U is $\hat{g}$ -closed, Cl(U) ⊆ M. Hence αCl(U) ⊆ Cl(U) ⊆ M implies U is αJ-closed.

3.15 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a, b}}. Then the subset {a} is αJ-closed but not $\hat{g}$ -closed in (X,τ).

3.16 Proposition-

Every g*α-closed set is αJ-closed but not conversely.
Proof: Let U be g*α-closed set and M be any η*- open set containing U in Y. Every η*- open set is gα-open and U is g*α-closed, αCl(U) ⊆ M, which implies U is αJ-closed.

3.17 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {a, b}}. Then the subset {a, b} is αJ-closed but not g*α-closed in (X,τ).

3.18 Proposition-

Every gα-closed set is αJ-closed but not conversely.
Proof: Let U be gα-closed set and M be any η*- open set containing U in Y. Every η*- open set is α-open and U is gα-closed, αCl(U) ⊆ M, which implies U is αJ-closed.

3.19 Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}}. Then the subset {a, b} is αJ-closed but not gα-closed in (X,τ).

3.20 Proposition-

Every αg-closed set is αJ-closed but not conversely.
Proof: Let U be αg-closed set and M be any η*- open set containing U in Y. Every η*- open set is open and U is αg-closed, αCl(U) ⊆ M, which implies U is αJ-closed.

3.21Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a, b}}. Then the subset {a, c} is αJ-closed but not αg-closed in (X,τ).

3.22 Proposition-

Every g*-closed set is αJ-closed but not conversely.
Proof: Let U be g*-closed set and M be any η*- open set containing U in Y. Every η*- open set is g-open and U is g*-closed, Cl(U) ⊆ M, Hence αCl(U) ⊆ Cl(U) ⊆ M, which implies U is αJ-closed.

3.23Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {a, b}}. Then the subset {b} is αJ-closed but not g*-closed in (X,τ).

3.24 Proposition-

Every g-closed set is αJ-closed but not conversely.
Proof: Let U be g-closed set and M be any η*- open set containing U in Y. Every η*- open set is open and U is g-closed, Cl(U) ⊆ M, Hence αCl(U) ⊆ Cl(U) ⊆ M, which implies U is αJ-closed.

3.25Counter Example -

Let X = {a, b, c} τ = {ϕ, X, {a}, {a, b},{a, c}}. Then the subset {a} is αJ-closed but not g-closed in (X,τ).

3.26 Remark-

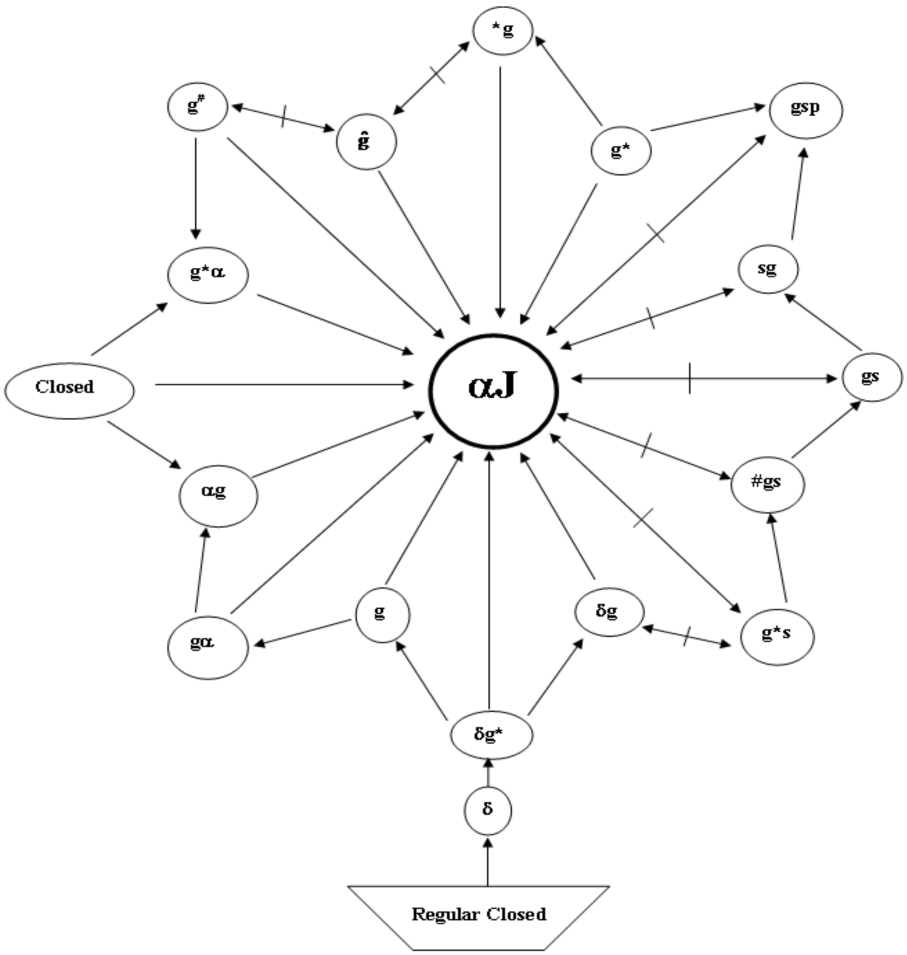
The following counter example show that αJ-closed set is independent from gsp-closed, #gs-closed, g*s-closed sg-closed and gs-closed

3.27 Counter Example -

Let X = {a,b,c} τ = {ϕ, X, {a}, {a, b},{a, c}}. Then the subset {a, b} is αJ-closed but not gsp-closed, #gs-closed, g*s-closed sg-closed and gs-closed in (X,τ).

3.28 Remark-

From the above discussions, we get αJ-closed sets is equivalent with other existing g-closed sets.



IV PROPERTIES OF αJ-CLOSED SETS IN TOPOLOGICAL SPACES

4.1Theorem -

The finite union of αJ-closed sets is J-closed

Proof : Let {Ui / i = 1,2,3…….n} be a finite class of αJ-closed sets of (X,τ). Let $U = \bigcup_{i=1}^{n} U_i$. Let M be a η*-open set containing U. This implies $U_i \subseteq M$ for every i. By assumption $\alpha cl(U_i) \subseteq M$ for every i. This implies $\bigcup_{i=1}^{n} \alpha cl(U_i) \subseteq M$. Then $\alpha cl\left(\bigcup_{i=1}^{n} (U_i)\right) \subseteq M$. Thus $\alpha cl(U) \subseteq M$. Hence finite union of αJ-closed sets is αJ-closed in (X,τ).

4.2 Remark -

The intersection of two αJ-closed sets need not be αJ-closed.

4.3 Counter Example-

Let X = {a, b, c} τ = {ϕ, X, {a}}. Here αJ-closed sets are {X, ϕ, {b}, {c}, {a, b}, {a, c}, {b, c}}. Then {a, c}∩{a, b}={a} is not a αJ-closed set.

4.4Theorem -

For $x \in X$, then the set X – {x} is αJ-closed or η*-open.
Proof : Assume that X – {x} is not η*-open. So X is the only η*-open set containing X – {x}. That is $\alpha\, cl(X - \{x\}) \subseteq X$. Then X – {x} is a αJ-closed set in X

4.5Theorem -

The subset S of X is αJ-closed in X iff αcl(S) – S contains no non empty η*-closed set in X.

Proof: Let M be a αJ-closed set in X such that $M \subseteq \alpha cl(S) - S$. Then $M \subseteq \alpha cl(S) \cap S^c$. Therefore $M \subseteq \alpha cl(S)$ & $M \subseteq S^c$, since Mc is η*-open and S is αJ-closed, $\alpha cl(S) \subseteq M^c$ (i.e) $M \subseteq \alpha cl(S)^c$. Hence $M \subseteq \alpha cl(S) \cap \alpha cl(S)^c = \phi$ (i.e) $M = \phi$. Then αcl(S) – S contains no non empty η*-closed set in X.

Conversely assume that αcl(S) – S contains no non empty η*-closed set in X. Let $S \subseteq U$, U is η*-open. Suppose αcl(S) is not contained in U. Then $\alpha cl(S) \cap S^c$ is a non empty η*-closed set in X and contained in αcl(S) – S, which is a contradiction. Therefore $\alpha cl(S) \subseteq U$. Hence S is αJ-closed.

4.6 Theorem -

If M is αJ-closed set in X and $M \subseteq N \subseteq \alpha cl(M)$, then N is αJ-closed set in X

Proof: Let U be a η*-open set in X, since M is αJ-closed, we have $\alpha cl(M) \subseteq U$. Let $M \subseteq N \subseteq \alpha cl(M) \subseteq U$. since $N \subseteq \alpha cl(M)$, we have $\alpha cl(N) \subseteq \alpha cl(M)$. Then $\alpha cl(N) - N \subseteq \alpha cl(M) - M \subseteq U$. By the above theorem αcl(M) – M contains no non empty η*-closed set in X. Therefore αcl(N) – N contains no non empty η*-closed set in X. Hence N is a αJ-closed set in X.

4.7Theorem -

Let D be a αJ-closed set in (X, τ). Then D is α-closed iff αcl(D) – D is η*-closed.

Proof: *(Necessity):* Let D be a α-closed set in X. Then αcl(D) = D and therefore αcl(D) – D = ϕ which is a η*-closed.

(Sufficiency) : Let αcl(D) – D be a η*-closed set. Since D is αJ-closed, By theorem αcl(D) – D does not contain a non-empty η*-closed set which implies αcl(D) – D = ϕ. That is αcl(D) = D. Hence D is α-closed.

Definition Let $B \subseteq A \subseteq Y$. Then B is αJ-closed relative to A if $\alpha cl_A(B) \subseteq M$, whenever $B \subseteq M$, M is η*-open in A.

4.8Theorem -

Let $B \subseteq A \subseteq Y$. and suppose that B is αJ-closed in Y, then B is αJ-closed relative to A. The converse is true if A is α-closed in Y.

Proof: Suppose that B is αJ-closed in Y. Let $B \subseteq M$, M is η*-open in A. Since M is η*-open in A, $M = V \cap A$, where V is η*-open in Y. Hence $B \subseteq M \subseteq V$. Since B is αJ-closed in Y, $\alpha cl_A(B) \subseteq M$, Hence $\alpha cl_A(B) \cap A \subseteq V \cap A$ which in turn implies that $\alpha cl_A(B) \subseteq V \cap A = M$. Therefore B is αJ-closed relative to A.

Now to prove the converse, assume that $B \subseteq A \subseteq Y$ where A is α-closed in Y and B is αJ-closed relative to A. Let $B \subseteq M$, M is η*-open in Y. Then $A \cap M$ is η*-open in A by the definition of subspace topology. Since $B \subseteq A$ and $B \subseteq M$, $B \subseteq A \cap M$, Since B is αJ-closed relative to A, $\alpha cl_A(B) \subseteq A \cap M$. Since $B \subseteq A$, $\alpha cl(B) \subseteq \alpha cl(A)$. Hence $\alpha cl(B) \subseteq A$. Therefore $\alpha cl(B) \cap A \subseteq \alpha cl(B)$ which implies $\alpha cl_A(B) = \alpha cl(B)$. Hence $\alpha cl(B) \subseteq A \cap M = M$. Thus B is αJ-closed in Y.

V.CONCLUSION

The concept of new closed set namely αJ-closed set using η*-open sets is introduced and studied. The relationship of αJ-closed sets using existing closed sets is established. Finally, some of their fundamental properties are studied. Hence I conclude that the defined set forms a topology which results this work may be entered widely.

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