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αIg-NORMAL AND αIg-REGULAR SPACES IN IDEAL TOPOLOGICAL SPACE

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Abstract

In this paper, αIg-normal spaces, αIg*-normal spaces, αIg-regular spaces and mildly αIg-normal spaces are introduced. Characterizations and properties of such new notions are studied. Some preservation theorems for these normal spaces are obtained.

Keywords:

αIg-closed sets;
αIg-normal spaces;
αIg*-normal spaces;
αIg-regular spaces;
mildly αIg-normal spaces.

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1. Introduction

An Ideal I on a topological space (X,τ,I) is defined as a non-empty collection I of subsets of X satisfying the following two conditions (i) if A ∈ I and B ⊂ A, then B ∈ I (ii) If A ∈ I and B ∈ I ,then A ∪ B ∈ I. We will make use of the basic facts about the local functions without mentioning it explicitly. A Kuratowski closure operator $cl^*(.)$ for a topology $\tau^*(\tau,I)$called the *-topology, finer than τ is defined by$cl^*(A) = A\cup A^*(\tau,I)$. When there is no chance for confusion, we simply write A^* instead of $A^*(\tau,I)$ and τ^* for $\tau^*(\tau,I)$. For a subset A ⊂X, $A^*(\tau, I) = \{x\in X / U \cap A \notin I$ for each neighborhood U of x$\}$. For every ideal topological space (X,τ,I), there exists a topology generated by β(I,τ)={U− J/ U ∈τ and J ∈ I}. In general β(I, τ) is not always a topology[5]. If I is an ideal on X, then it is called ideal space. By an ideal space, we always mean an ideal topological space with no separation properties assumed.

The notions of the normal spaces in ideal topological spaces are highly developed and used extensively in many practical and engineering problems, computational topology

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for geometric design, computer-aided geometric design, engineering design research and mathematical sciences. Hence we studied new types of normal spaces and regular spaces and obtained some of their properties in ideal topological spaces. Navaneethakrishanan M, Paulraj joseph J and SivarajD[8] were introduced Ig-normal spaces and Ig-regular spaces in ideal topological spaces. Ravia O, Rajasekaranb I, Vijayac S, Murugesand S [11] were introduced mildly *-normal spaces in ideal topological spaces. In this chapter, we introduce the concept of αIg-normal spaces, αIg*-normal spaces, αIg-regular spaces and mildly αIg-normal spaces and discuss about their properties.

2. Preliminaries

Definition 1.1:[11] Let (X, τ) be a topological space. A subset A of X is called

(i) regular open if A = int(cl(A)).

(ii) regular closed if A = cl(int(A)).

The complement of regular open set is regular closed.
The collection of regular open (resp. regular closed) subsets of X is denoted by RO(X) (resp. RC(X)).
Remark 1.2:[11] In any topological spaces, the following holds.
Every regular closed set is a closed set.
Definition 1.3:[11] Let (X, τ, I) be an ideal topological space. Then I is said to be completely codence [3] if PO(X) ∩ I = {∅}, where PO(X) is the family of all preopen sets in (X, τ).
Lemma 1.4:[2] Let (X, τ, I) be an ideal topological space and A ⊆ X. If A ⊆ A*, then A* = cl(A*) = cl(A) = cl*(A).
Definition 1.5:[8] A subset A of an ideal topological space (X, τ, I) is Ig-closed [14], if A* ⊆ U whenever A ⊆ U and U is open.
The following Lemmas, Result, Definitions, Remarks and Theorem will be useful in the sequel.
Lemma 1.6: [3] Let (X, τ, I) be an ideal topological space and A, B subsets of X. Thenthe following propertieshold:

(i) A ⊆ B ⇒ A* ⊆ B*,

(ii) A* = cl(A*) ⊆ cl(A),

(iii)(A*)* ⊆ A*,

(iv)(A∪B)* = A* ∪B*,

(v) (A∩B)* ⊆ A* ∩B*.

Definition 1.7:[8] An ideal topological space (X, τ, I) is said to be a normal space, if for every pair of disjoint closed sets A and B, there exist disjoint open sets U and V such that A ⊆ U and B ⊆ V.
Definition 1.8: [8] An ideal topological space (X, τ, I) is said to be a Ig-normal space, if for every pair of disjoint closed sets A and B, there exist disjoint Ig-open sets U and V such that A ⊆ U and B ⊆ V.

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Definition 1.9:[8] An ideal topological space (X, τ, I) is said to be a gI-normal space, if for every pair of disjoint Ig-closed sets A and B, there exist disjoint open sets U and V such that A ⊆ U and B ⊆ V.
This is a stronger form of normal space.
Definition 1.10:[8] An ideal space (X, τ, I) is said to be an Ig-regular space if for each pair consisting of a point x and a closed set B not containing x, there exist disjoint Ig-open sets U and V such that X ∈ U and B ⊂ V.
Definition 1.11:[2] An ideal space (X, τ, I) is said to be an Irwg-normal space, if for every pair of disjoint closed sets A and B, there exist disjoint Irwg-open sets U and V such that A ⊂ U and B ⊂ V.
Definition 1.12:[2] An ideal space (X, τ, I) is said to be an Irwg-regular space if for each pair consisting of a point x and a closed set B not containing x, there exist disjoint non empty Irwg - open sets U and V such that x ∈ U and B ⊂ V.
Definition 1.13: [11] An ideal topological space (X, τ, I) is called *-normal if for any pair of disjoint closed sets A and B of X, there exist disjoint *-open sets U and V such that A ⊆ U and B ⊆ V.
Definition 1.14: [11] An ideal topological space (X, τ, I) is called mildly *-normal if for every pair of disjoint H, K ∈ RC(X), there exist disjoint *-open sets U and V such that H ⊆ U and K ⊆ V.

3. αIg-NormalandαIg-Regular Spaces

In this section, we introduce αIg-normal space, αIg*-normal space and αIg-regular spaces and study their relations with existing ones.
Definition 3.1: An ideal space (X, τ, I) is said to be an αIg-normal space, if for every pair of disjoint closed sets A and B, there exist disjoint αIg-open sets U and V in X such that A ⊂ U and B ⊂ V.
Definition 3.2: An ideal space (X, τ, I) is said to be an αIg*-normal space, if for every pair of disjoint αIg-closed sets A and B, there exist disjoint open sets U and V in X such that A ⊂ U and B ⊂ V.

This is a stronger form of normal spaces. We characterize αIg*-normal spaces and give various properties of such spaces.
Definition 3.3: An ideal space (X, τ, I) is said to be an αIg-regular space, if for each pair consisting of a point x and a closed set B not containing x, there exist disjoint αIg-open sets U and V such that x ∈ U and B ⊂ V.

Various characterizations of αIg-regular space are also given. The following example shows that an αIg-normal space is not a normal space.
Example 3.4: Let X = {a, b, c}, τ = {Φ, {b}, {a, b}, X} and I = {Φ, {b}}. Here, every open set is *-closed and so, every subset of X is αIg-closed and hence every subset of X is αIg-open. This implies that (X, τ, I) is αIg-normal, {a} and {c} are disjoint closed subsets of X which are not separated by disjoint open sets and so (X, τ) is normal.
The following theorem gives characterizations of αIg-normal spaces.
Theorem 3.5: Let (X, τ, I) be an ideal space. Then the following are equivalent.

(i) X is αIg-normal.

(ii) For every pair of disjoint closed sets A and B, there exist disjoint αIg-open sets U and V such that $A \subset U$ and $B \subset V$.

(iii)For every closed set A and an open set V containing A, there exists an αIg-open set U such that $A \subset U \subset cl^*(U) \subset V$.

Proof: (i) ⇒ (ii): The proof follows from the definition of αIg-normal spaces

(ii) ⇒ (iii): Let A be a closed set and V be an open set containing A. Since A and X – V are disjoint closed sets, there exist disjoint αIg-open sets U and W such that $A \subset U$ and $X - V \subset W$. Again $U \cap W = \Phi$ implies that $U \cap int^*(W) = \Phi$. Therefore $U \subset X - int^*(W)$ and so $cl^*(U) \subset X - int^*(W)$. Again $X - V \subset W$ implies that $X - V \subset int^*(W)$ [[3]Theorem 3.31] and so $X - int^*(W) \subset V$. Thus, we have $A \subset U \subset cl^*(U) \subset X - int^*(W) \subset V$ which proves (iii).

(iii) ⇒ (i): Let A and B be two disjoint closed subsets of X. By hypothesis, there exists and αIg-open set U such that $A \subset U \subset cl^*(U) \subset X - B$. If $W = X - cl^*(U)$, then U and W are the required disjoint αIg-open sets containing A and B respectively. So, (X, τ, I) is αIg-normal.

Theorem 3.6: Let (X, τ, I) be an αIg-normal space. If F is closed and A is a α-closed set such that $A \cap F = \Phi$, then there exist disjoint αIg-open sets U and V such that $A \subset U$ and $F \subset V$.

Proof: Since $A \cap F = \Phi$, $A \subset X - F$ where X – F is open. Therefore, by hypothesis, $cl(A) \subset X - F$. Since $cl(A) \cap F = \Phi$ and X is αIg-normal, there exist disjoint αIg-open sets U and V such that $cl(A) \subset U$ and $F \subset V$. Hence the proof.

Theorem 3.7: Let (X, τ, I) be an ideal space which is αIg-normal. Then the following hold:

(i) For every closed set A and every α-open set B containing A, there exists and αIg-open set U such that $A \subset int^*(U) \subset U \subset B$.

(ii) For every α-closed set A and every open set B containing A, there exists an αIg-closed set U such that $A \subset U \subset cl^*(U) \subset B$.

Proof: (i) Let A be a closed set and B be a α-open set containing A. Then $A \cap (X - B) = \Phi$, where A is closed and X – B is α-closed. By Theorem 3.6, there exist disjoint αIg-open sets U and V such that $A \subset U$ and $X - B \subset V$. Since $U \cap V = \Phi$, we have $U \subset X - V$ and $A \subset int^*(U)$. Therefore, $A \subset int^*(U) \subset U \subset X - V \subset B$. This proves (i).

(ii) Let A be α-closed and B be an open set containing A. Then X – B is a closed set contained in the α-open set X – A. By (i), there exists an αIg-open set V such that $X - B \subset int^*(V) \subset V \subset X - A$. Therefore, $A \subset X - V \subset cl^*(X - V) \subset B$. If $U = X - V$, then $A \subset U \subset cl^*(U) \subset B$ and so U is the required αIg-closed set. This proves (ii).

Theorem 3.8: Every αIg*-normal space is a normal spaces.

Proof: An ideal space (X, τ, I) is said to be an αIg*-normal space, if for each pair of disjoint αIg-closed sets A and B, there exist disjoint open sets U and V in X such that $A \subset U$ and $B \subset V$. Since every closed set is αIg-closed, every αIg*-normal space is normal.

Remark 3.9: The following example shows that a normal space need not be an αIg*-normal space.

Example 3.10: Let X = {a, b, c, d}, τ = {Φ, {a}, X} and I = {Φ, {a}}. Now, A = {a} and B = {b, c, d} are disjoint αIg-closed sets, but they are not separated by disjoint open sets. So, (X, τ, I) is not αIg*-normal space. Since there is no pair of disjoint closed sets, (X, τ, I) is normal.

Theorem 3.11 and 3.12 below give characterizations of αIg*-normal spaces.

Theorem 3.11: In a ideal space (X, τ, I), the following are equivalent.

(i) X is αIg*-normal.

(ii) For every αIg-closed set A and every αIg-open set B containing A, there exists an open set U of X such that A ⊂ U ⊂cl(U) ⊂ B.

Proof: (i) ⇒ (ii): Let A be an αIg-closed set and B be an αIg-open set containing A. Since A and X – B are disjoint αIg-closed sets, there exists disjoint open sets U and V such that A ⊂ U and X – B ⊂ V. Now U ∩ V = Φ implies that cl(U) ⊂ X – V. Therefore, A ⊂ U ⊂cl(U) ⊂ X – V ⊂ B. This proves (i).

(ii) ⇒ (i): Suppose A and B are disjoint αIg-closed sets , then the αIg-closed set A is contained in the αIg-open set X – B. By hypothesis, there exists an open set U of X such that A ⊂ U ⊂cl(U) ⊂ X – B. If V = X –cl(U), then U and V are disjoint open sets containing A and B respectively. Therefore, (X, τ, I) is αIg*-normal space.

Theorem 3.12: In an ideal space (X, τ, I), the following are equivalent.

(i) X is αIg*-normal.

(ii) For each pair of disjoint αIg-closed subsets A and B of X, there exists an open set U of X containing A such that cl(U) ∩ B = Φ.

(iii)For each pair of disjoint αIg-closed subsets A and B of X, there exists an open set U containing A and an open set V containing B such that cl(U) ∩ cl(V) = Φ.

Proof: (i) ⇒ (ii): Suppose that A and B are disjoint αIg-closed subsets of X. Then the αIg-closed set A is contained in the αIg-open set X – B. By Theorem 3.11, there exists an open set U such that A ⊂ U ⊂cl(U) ⊂ X – B. Therefore, U is the required open set containing A such that cl(U) ∩ B = Φ.

(ii) ⇒ (iii): Let A and B be two disjoint αIg-closed subsets of X. By hypothesis, there exists an open set U containing A such that cl(U) ∩ B = Φ. Also, cl(U) and B are disjoint αIg-closed sets of X. By hypothesis, there exists an open set V containing B such that cl(U) ∩ cl(V) = Φ.

(iii) ⇒ (i): Let A and B be two disjoint αIg-closed subsets of X. By hypothesis, there exists an open set U containing A and an open set V containing B. Therefore, X is αIg*-normal.

Theorem 3.13: Let (X, τ, I) be an αIg*-normal space. If A and B are disjoint αIg-closed subsets of X, then there exist disjoint open sets U and V such that cl*(A) ⊂ U and cl*(B) ⊂ V.

Proof: Suppose that A and B are disjoint αIg-closed sets. By Theorem 3.12, there exists an open set U containing A and an open set V containing B such that cl(U) ∩ cl(V) = Φ. Since A is αIg-closed, A ⊂ U implies that cl*(A) ⊂ U. Similarly, B is αIg-closed, B ⊂ V implies that cl*(B) ⊂ V. Hence the proof.

Theorem 3.14: Let (X, τ, I) be an αIg*-normal space. If A is an αIg-closed set and B is an αIg-open set containing A, then there exists an open set U such that $A \subset cl^*(A) \subset U \subset int^*(B) \subset B$.

Proof: Suppose A is an αIg-closed set and B is an αIg-open set containing A. Since A and X – B are disjoint αIg-closed sets, by Theorem 3.13, there exist disjoint open sets U and V such that $cl^*(A) \subset U$ and $cl^*(X - B) \subset V$. Now, $X - int^*(B) = cl^*(X - B) \subset V$ implies that $X - V \subset int^*(B) \subset B$. This completes the proof.

Definition 3.15: An ideal space (X, τ, I) is said to be an αIg-regular space, if for each pair consisting of a point x and a closed set B not containing x, there exist disjoint αIg-open sets U and V such that $x \in U$ and $B \subset V$.

Theorem 3.16: Every regular space is an αIg-regular space.

Proof: Let (X, τ, I) be a regular space. Then for each pair consisting of a points x and a closed B not containing x, there exist disjoint open sets U and V such that $x \in U$ and $B \subset V$. Since every open set is αIg-open. Therefore, (X, τ, I) is an αIg-regular space.

Remark 3.17: The following example shows that an αIg-regular space need not be regular.

Example 3.18: Let X = {a, b, c}, τ = {Φ, {b}, {a, b}, X} and I = {Φ, {b}}. Here, every open set is *-closed and so, every subset of X is αIg-closed and hence every subset of X is αIg-open. This implies that (X, τ, I) is αIg-regular. Now {c} is a closed set not containing $a \in X$. {c} and a are not separated by disjoint open sets. So (X, τ, I) is not regular.

The following theorem gives a characterization of αIg-regular space.

Theorem 3.19: In an ideal space (X, τ, I), the following are equivalent.

(i) X is αIg-regular.

(ii) For every closed set B not containing $x \in X$, there exist disjoint αIg-open sets U and V such that $x \in U$ and $B \subset V$.

(iii)For every open set V containing $x \in X$, there exists an αIg-open set U of X such that $x \subset U \subset cl^*(U) \subset V$.

Proof: (i) $\Rightarrow$ (ii): Let X is αIg-regular. Then by definition, we have for every closed set B not containing $x \in X$, there exists disjoint αIg-open sets U and V such that $x \in U$ and $B \subset V$. Hence (ii)

(ii) $\Rightarrow$ (iii): Let V be an open set such that $x \in V$. Then X – V is a closed set not containing x. Therefore, there exist αIg-open sets U and W such that $x \in U$ and $X - V \subset W$. Now, $X - V \subset W$ implies that $X - V \subset int^*(W)$ [[3] Theorem 3.31] and so $X - int^*(W) \subset V$. Again, $U \cap W = \Phi$ implies that $U \cap int^*(W) = \Phi$. Therefore $U \subset X - int^*(W)$ and so $cl^*(U) \subset X - int^*(W)$. Hence, $x \in U \subset cl^*(U) \subset X - int^*(W) \subset V$. This proves (iii).

(iii) $\Rightarrow$ (i) : Let B be a closed set not containing x. By hypothesis, there exists anαIg-open set U such that $x \in U \subset cl^*(U) \subset X - B$. If $W = X - cl^*(U)$, then U and W are disjoint αIg-open sets such that $x \in U$ and $B \subset W$. This proves (i).

Theorem 3.20: If every open subset of an ideal space (X, τ, I) is *-closed, then (X, τ, I) is αIg-regular.

Proof: Suppose every open subset of X is *-closed. Since every *-closed is αIg-closed, every subset of X is αIg-closed and hence every subset of X is αIg-open. If B is a closed set not containing x, then {x} and B are the required disjoint αIg-open sets containing x and B respectively. Therefore, (X, τ, I) is αIg-regular.

The following Example 3.21 shows that the reverse direction of the above Theorem 3.20 is not true.

Example 3.21: Consider the real line R with usual the topology. Let I = {Φ}. Then, R is regular and hence αIg-regular. But open sets are not closed and hence open sets are not *-closed.

4. MildlyαIg-NormalSpaces

We introduce and study a new class of spaces called mildly αIg-normal spaces. The relationships between mildly αIg-normal spaces and new ideal topological functions are investigated. Moreover, we obtain characterizations of mildly αIg-normal spaces, and properties of new ideal topological functions for mildly αIg-normal spaces in ideal topological spaces.

Definition 4.1: An ideal topological space (X, τ, I) is called mildly αIg-normal if for every pair of disjoint H, K ∈ RC(X), there exist disjoint αIg-open sets U and V such that H ⊆ U and K ⊆ V.

Theorem 4.2: The following are equivalent for an ideal topological space (X, τ, I):

(i) X is mildly αIg-normal.

(ii) For any disjoint H, K ∈ RC(X), there exist disjoint αIg-open sets U and V such that H ⊆ U and K ⊆ V.

(iii)For any disjoint H, K ∈ RC(X), there exist disjoint Ig-open sets U and V such that H ⊆ U and K ⊆ V.

(iv)For any H ∈ RC(X) and any V ∈ RO(X) containing H, there exists an Ig-open set U of X such that H ⊆ U ⊆ cl*(U) ⊆ V.

(v) For any H ∈ RC(X) and any V ∈ RO(X) containing H, there exists an αIg-open set U of X such that H ⊆ U ⊆ cl*(U) ⊆ V.

Proof: (i) ⇒ (ii): Let H, K ∈ RC(X), where H and K are disjoint. Since, X is mildly αIg-normal, there exist disjoint αIg-open sets U and V such that H ⊆ U and K ⊆ V. Hence (ii).

(ii) ⇒ (iii): Let H, K ∈ RC(X), where H and K are disjoint. By (ii), there exist disjoint αIg-open sets U and V such that H ⊆ U and K ⊆ V. Since every αIg-open set is Ig-open set, such that H ⊆ U and K ⊆ V where U and V are Ig-open sets. Hence (ii).

(iii) ⇒ (iv): Let H ∈ RC(X) and any V ∈ RO(X). By (iii), there exist disjoint Ig-open sets U and V such that H ⊆ U and X − V ⊆ W. Hence X − V ⊆int*(W) ⇒ X − int*(W) ⊆ V. Since U ∩ W = Φ, we have U ∩int*(W) = Φ and so cl*(U) ⊆ X − int*(W). Therefore, we obtain H ⊆ U ⊆ cl*(U) ⊆ V where U is Ig-open.

(iv) ⇒ (v): Let H and K be disjoint regular closed sets of X. Then, H ⊆ X − K where X − K ∈ RO(X). By (iv), there exists a Ig-open set G of X such that H ⊆ G ⊆ cl*(G) ⊆ X

– K. Hence H ⊆int*(G). If U = int*(G), U is αIg-open set such that H ⊆ U ⊆ cl*(U) ⊆ X – K ⊆ V.

(v) ⇒ (i): Let H and K be disjoint regular closed sets of X. Then, H ⊆ X – K where X – K ∈ RO(X). By (v), there exists an αIg-open set U of X such that H ⊆ U ⊆ cl*(U) ⊆ X – K. If V = X – cl*(U), then U and V are disjoint αIg-open sets of X such that H ⊆ U and K ⊆ V.

Theorem 4.3: Every αIg-normal space is mildly αIg-normal.

Proof: Let (X, τ, I) be an αIg-normal space and A and B be any two disjoint regular closed sets in X. Since A and B are regular closed in X, they are closed in X. (X, τ, I) is αIg-normal implies that there exis disjoint αIg-open sets U and W such that A ⊆ U and B ⊆ W. Hence (X, τ, I) is mildly αIg-normal space

Remark 4.4: The following example shows that mildly αIg-normal space is not an αIg-normal space.

Example 4.5: Let (X, τ, I) be an ideal topological space such that X = {a, b, c}, τ = {Φ, {c}, {a, c}, {b, c}, X} and I = {Φ}. Then (X, τ, I) is a mildly αIg-normal space. Now, A = {a} and B = {b} are disjoint closed sets, but they are not separated by disjoint αIg-open sets. So (X, τ, I) is not αIg-normal space.

Theorem 4.6: Every mildy normal space is mildly αIg-normal space.

Proof: Let (X, τ, I) be an ideal topological space. Suppose that A and B are disjoint regular closed sets in X. Since X is mildy normal space, there exists open sets U and V such that A ⊆ U and B ⊆ V. But, every open set is αIg-open. Therefore, U and V are αIg-opensets such that A ⊆ U and B ⊆ V. Hence, X is mildly αIg-normal space.

4. Conclusion

In this paper, a new class of spaces αIg-normal space, αIg*-normal space, mildly αIg-normal space, are defined and their properties are discussed.

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