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Regular α Generalized Open Sets In Intuitionistic Fuzzy Topological Spaces

Nivetha M [1], Jayanthi D [2]

P.G. Student, Department of Mathematics, Avinashilingam University, Coimbatore, Tamil Nadu, India[1]

Assistant Professor, Department of Mathematics, Avinashilingam University, Coimbatore, Tamil Nadu, India[2]

ABSTRACT: The purpose of this paper is to introduce and study the concept of intuitionistic fuzzy regular α generalized open sets in intuitionistic fuzzy topological spaces. We investigate some of their properties and also we introduce intuitionistic fuzzy regular α $T_{1/2}$ space and obtain some characterizations and several preservation theorems.

KEYWORDS: Intuitionistic fuzzy set, Intuitionistic fuzzy topology, Intuitionistic fuzzy topological space, Intuitionistic fuzzy regular α generalized open set, Intuitionistic fuzzy regular α $T_{1/2}$ space.

I. INTRODUCTION

The theory of fuzzy sets was introduced by Zadeh [10] in 1965. Later, Chang [2] proposed fuzzy topology in 1967. The concept of intuitionistic fuzzy sets, introduced by Atanassov [1] is a generalization of fuzzy sets. Using the notion of intuitionistic fuzzy sets, Coker [3] introduced the notion of intuitionistic fuzzy topological spaces in 1997.In this paper, we introduce intuitionistic fuzzy regular α generalized open set. We investigate some of their properties. We also introduce intuitionistic fuzzy regular α $T_{1/2}$ space and obtain some characterizations and several preservation theorems.

II. PRELIMINARIES

Definition 2.1: [1] An intuitionistic fuzzy set (IFS in short) A in X is an object having the form $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$ where the function $\mu_A : X \to [0,1]$ and $\nu_A : X \to [0,1]$ denote the degree of membership (namely $\mu_A(x)$) and the degree of non-membership (namely $\nu_A(x)$) of each element $x \in X$ to the set A, respectively, and $0 \le \mu_A(x) + \nu_A(x) \le 1$ for each $x \in X$.

Definition 2.2: [1] Let A and B be two IFSs of the form $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$ and $B = \{\langle x, \mu_B(x), \nu_B(x)\rangle / x \in X\}$. Then

(i) $A \subseteq B$ if and only if $\mu_A(x) \le \mu_B(x)$ and $\nu_A(x) \ge \nu_B(x)$ for all $x \in X$

(ii) $A = B$ if and only if $A \subseteq B$ and $B \subseteq A$

(iii) $A^c = \{\langle x, , \nu_A(x), \mu_A(x)\rangle / x \in X\}$

(iv) $A \cap B = \{\langle x, \mu_A(x) \wedge \mu_B(x), \nu_A(x) \vee \nu_B(x)\rangle / x \in X\}$

(v) $A \cup B = \{\langle x, \mu_A(x) \vee \mu_B(x), \nu_A(x) \wedge \nu_B(x)\rangle / x \in X\}$

For the sake of simplicity, we shall use the notation $A = \langle x, \mu_A, \nu_A\rangle$ instead of $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$. The IFS $0\sim = \{\langle x, 0, 1\rangle / x \in X\}$ and $1\sim = \{\langle x, 1, 0\rangle / x \in X\}$ are respectively the empty set and the whole set of X.

Definition 2.3: [3] An intuitionistic fuzzy topology (IFT in short) on X is a family τ of IFS in X satisfying the following axioms:

(i) $0\sim, 1\sim \in \tau$

(ii) $G_1 \cap G_2 \in \tau$ for any $G_1, G_2 \in \tau$

(iii) $\cup G_i \in \tau$ for any family $\{ G_i / i \in J\} \subseteq \tau$

In this case the pair (X,τ) is called an intuitionistic fuzzy topological space (IFTS in short) and any IFS in τ is known as an intuitionistic fuzzy open set (IFOS in short) in X. The complement A^c of an IFOS A in (X,τ) is called an intuitionistic fuzzy closed set (IFCS in short) in X.

Definition 2.4: [3] Let (X,τ) be an IFTS and $A = \langle x, \mu_A, \nu_A\rangle$ be an IFS in X. Then the intuitionistic fuzzy interior and intuitionistic fuzzy closure are defined by

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(i) int(A) = ∪ { G / G is an IFOS in X and G ⊆ A}
(ii) cl(A) = ∩ {K / K is an IFCS in X and A ⊆ K}

Note that for any IFS A in (X,τ), we have $cl(A^c) = (int(A))^c$ and $int(A^c) = (cl(A))^c$.

Definition 2.5: [5] An IFS A in an IFTS (X,τ) is said to be

(i) intuitionistic fuzzy semiopen if A ⊆ cl(int(A))
(ii) intuitionistic fuzzy α open if A ⊆ int(cl(int(A)))
(iii) intuitionistic fuzzy preopen if A ⊆ int(cl(A))
(iv) intuitionistic fuzzy regular open if A = int(cl(A))

Definition 2.6: [4]An intuitionistic fuzzy point (IFP in short), written as $p_{(\alpha,\beta)}$, is defined to be an IFS of X given by

$$p_{(\alpha,\beta)}(x) = \begin{cases} (\alpha, \beta) & \text{if } x = p, \\ (0, 1) & \text{otherwise.} \end{cases}$$

An IFP $p_{(\alpha,\beta)}$ is said to belong to a set A if $\alpha \leq \mu_A$ and $\beta \geq \nu_A$

Definition 2.7: [7] An IFTS (X,τ) is said to be an $IFT_{1/2}$ space if every IFGCS in (X,τ) is an IFCS in (X,τ).

Definition 2.8: [8] Let A be an IFS in an IFTS (X,τ). Then

(i) αint(A) = ∪ { G / G is an IFαOS in X and G ⊆ A }
(ii) αcl(A) = ∩ { K / K is an IFαCS in X and A ⊆ K }

Result 2.9: [8] Let A be an IFS in (X,τ). Then

(i) αcl(A) = A ∪ cl(int(cl(A)))
(ii) αint(A) = A ∩ int(cl(int(A)))

Definition 2.10: [9] An IFS A in an IFTS (X,τ) is intuitionistic fuzzy α generalized closed set (IFαGCS in short) if αcl(A) ⊆ U whenever A ⊆ U and U is an IFOS in X.

Definition 2.11: [6] An IFS A of an IFTS (X,τ) is called intuitionistic fuzzy regular α generalized closed set (IFRαGCS in short) if αcl(A) ⊆ U whenever A ⊆ U and U is an IFROS in X.

III. INTUITIONISTIC FUZZY REGULAR α GENERALIZED OPEN SETS

In this section we introduce the notion of intuitionistic fuzzy regular α generalized open sets and study some of their properties.

Definition 3.1: An IFS A of an IFTS (X,τ) is called intuitionistic fuzzy regular α generalized open set (IFRαGOS in short) if αint(A) ⊇ U whenever A ⊇ U and U is an IFRCS in X.

The family of all IFRαGOSs of an IFTS (X,τ) is denoted by IFRαGO(X).

Note that the complement A^c of an IFRαGCS A in an IFTS (X,τ) is an IFRαGOS in X.

Example 3.2: Let X = {a,b} and let τ = {0~,G_1,G_2,1~} where G_1 = ⟨x, (0.6,0.7), (0.4,0.2)⟩ where μ_a=0.6, μ_b=0.7, ν_a=0.4, ν_b=0.2 and G_2 = ⟨x, (0.1,0.2), (0.7,0.7)⟩ where μ_a=0.1, μ_b=0.2, ν_a=0.7, ν_b=0.7 let A = ⟨x, (0.6,0.7), (0.3,0.1)⟩ be any IFS in (X,τ). Then A ⊇ U where U = ⟨x, (0.4,0.2), (0.6,0.7)⟩ is an IFRCS in X. Now αint(A) = ⟨x, (0.6,0.7), (0.4,0.2)⟩ ⊇ U. Therefore A is an IFRαGOS in (X,τ).

Theorem 3.3: Every IFOS, IFROS and IFαOS is an IFRαGOS but the converses are not true in general.

Proof: Straight forward.

Example 3.4: Let X = {a,b} and let τ = {0~,G_1,G_2,1~} where G_1 = ⟨x, (0.6,0.5), (0.4,0.2)⟩ and G_2 = ⟨x, (0.2,0.1), (0.8,0.8)⟩. Let A = ⟨x, (0.6,0.6), (0.3,0.2)⟩ be any IFS in X. Then A ⊇ U where U = ⟨x, (0.4,0.2), (0.6,0.5)⟩ is an IFRCS in X. Now αint(A) = ⟨x, (0.6,0.5), (0.4,0.2)⟩ ⊇ U. A is an IFRαGOS but not an IFOS in X, since int(A) = ⟨x, (0.6,0.5), (0.4,0.2)⟩ ≠ A.

Example 3.5: Let X = {a,b} and let τ = {0~,G_1,G_2,1~} where G_1 = ⟨x, (0.6,0.7), (0.4,0.2)⟩ and G_2 = ⟨x, (0.1,0.2), (0.8,0.8)⟩. Let A = ⟨x, (0.6,0.7), (0.3,0.2)⟩ be any IFS in (X,τ). Then A ⊇ U where U = ⟨x, (0.4,0.2), (0.6,0.7)⟩ is an IFRCS in X. Now αint(A) = ⟨x, (0.6,0.7), (0.4,0.2)⟩ ⊇ U. A is an IFRαGOS but not an IFROS in X, since int(cl(A)) = ⟨x, (0.6,0.7), (0.4,0.2)⟩ ≠ A.

Example 3.6: Let X = {a,b} and let τ = {0~,G_1,G_2,1~} where G_1 = ⟨x, (0.5,0.7), (0.4,0.2)⟩ and G_2 = ⟨x, (0.2,0.2), (0.8,0.8)⟩. Let A = ⟨x, (0.5,0.7), (0.3,0.2)⟩ be any IFS in (X,τ). Then A ⊇ U where U = ⟨x, (0.4,0.2), (0.5,0.7)⟩ is an IFRCS in X. Now αint(A) = ⟨x, (0.5,0.7), (0.4,0.2)⟩ ⊇ U. A is an IFRαGOS but not an IFαOS in X, since int(cl(int(A))) = ⟨x, (0.5,0.7), (0.4,0.2)⟩ ⊉ A.

Remark 3.7: Every IFRαGOSs and every IFPOSs are independent to each other.

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Example 3.8: In Example 3.6, let A = ⟨x, (0.6,0.7), (0.2,0.2)⟩ be any IFS in X. Then A ⊇ U where U = ⟨x, (0.4,0.2), (0.5,0.7)⟩ is an IFRCS in X. Now αint(A) = ⟨x, (0.5,0.7), (0.4,0.2)⟩ ⊇ U. A is an IFRαGOS but not an IFPOS in X, since int(cl(A)) = ⟨x, (0.5,0.7), (0.4,0.2)⟩ ⊉ A.

Example 3.9: Let X = {a,b} and let τ = {0~, G_1,G_2,1~} where G_1 = ⟨x, (0.2,0.3), (0.6,0.7)⟩ and G_2 = ⟨x, (0.8,0.7), (0.1,0.1)⟩. Let A = ⟨x, (0.7,0.8), (0.1,0.2)⟩ be any IFS in (X,τ). Then int(cl(A)) = 1~ ⊇ A. Therefore A is an IFPOS in X but not an IFRαGOS in X, since A ⊇ U where U is an IFRCS in X but αint(A) = ⟨x, (0.2,0.3), (0.6,0.7)⟩ ⊉ U.

Remark 3.10: Every IFRαGOSs and every IFSOSs are independent to each other.

Example 3.11: Let X = {a,b} and let τ = {0~, G_1,G_2,1~} where G_1 = ⟨x, (0.6,0.7), (0.4,0.2)⟩ and G_2 = ⟨x, (0.1,0.2), (0.7,0.8)⟩. Let A = ⟨x, (0.8,0.7), (0.2,0.1)⟩ be any IFS in (X,τ). Then A ⊇ U where U = ⟨x, (0.4,0.2), (0.6,0.7)⟩ is an IFRCS in X. Now αint(A) = ⟨x, (0.6,0.7), (0.4,0.2)⟩ ⊇ U. A is an IFRαGOS but not an IFSOS in X, since cl(int(A)) = ⟨x, (0.7,0.8), (0.1,0.2)⟩ ⊉ A.

Example 3.12: Let X = {a,b} and let τ = {0~, G_1,G_2,1~} where G_1 = ⟨x, (0.5,0.2), (0.5,0.8)⟩ and G_2 = ⟨x, (0.2,0.2), (0.8,0.8)⟩. Let A = ⟨x, (0.5,0.8), (0.5,0.2)⟩ be any IFS in (X,τ). Then cl(int(A)) = ⟨x, (0.5,0.8), (0.5,0.2)⟩ = A. Therefore A is an IFSOS in X but not an IFRαGOS in X, since A = U where U = ⟨x, (0.5,0.8), (0.5,0.2)⟩ is an IFRCS in X but αint(A) = ⟨x, (0.5,0.2), (0.5,0.8)⟩ ⊉ U.

Remark 3.13: The intersection of two IFRαGOS in an IFTS (X,τ) need not be IFRαGOS in general.

Example 3.14: Let X = {a,b} and let τ = {0~, G_1, G_2, G_3, G_4, G_5, G_6, 1~} is an IFT on (X,τ). Where G_1 =⟨x, (0.5,0.7), (0.3,0.2)⟩, G_2 = ⟨x, (0.4,0.2), (0.4,0.8)⟩, G_3 = ⟨x, (0.2,0.2), (0.4,0.8)⟩, G_4 = ⟨x, (0.4,0.2), (0.4,0.7)⟩, G_5 = ⟨x, (0.4,0.2), (0.5,0.8)⟩ and G_6 = ⟨x, (0.2,0.2), (0.5,0.8)⟩. Let A = ⟨x, (0.4,0.2), (0.5,0.2)⟩ and B = ⟨x, (0.3,0.2), (0.3,0.7)⟩ be any two IFS in (X,τ). Then A ⊇ U where U = ⟨x, (0.3,0.2), (0.5,0.7)⟩ is an IFRCS in X. αint(A) = ⟨x, (0.4,0.2), (0.5,0.7)⟩ ⊇ U and then B ⊇ U where U = ⟨x, (0.3,0.2), (0.5,0.7)⟩ is an IFRCS in X. αint(B) = ⟨x, (0.3,0.2), (0.4,0.7)⟩ ⊇ U. Therefore A and B are IFRαGOS in X but A∩B = ⟨x, (0.3,0.2), (0.5,0.7)⟩ is not an IFRαGOS in X, since A∩B ⊇ U but αint(A∩B) = ⟨x, (0.2,0.2), (0.5,0.8)⟩ ⊉ U.

Theorem 3.15: Let (X,τ) be an IFTS. Then for every A ∊ IFRαGO(X) and for every B ∊ IFS(X), αint(A) ⊆ B ⊆ A ⟹ B ∊ IFRαGO(X).

Proof: Let A be any IFRαGOS of X and B be any IFS of X. Let αint(A) ⊆ B ⊆ A. Then A^c is an IFRαGCS and A^c ⊆ B^c ⊆ αcl(A^c). Then B^c is an IFRαGCS[6] and Therefore B is an IFRαGOS in X. Hence B ∊ IFRαGO(X).

Theorem 3.16: If A is an IFRCS and an IFRαGOS in (X,τ). Then A is an IFαOS in (X,τ).

Proof: As A ⊇ A, by the hypothesis, αint(A) ⊇ A. But we have A ⊇ αint(A). This implies αint(A) = A. Hence A is an IFRαGOS.

Theorem 3.17: Let (X,τ) be an IFTS. Then for every A ∊ IFS(X) and for every B ∊ IFRC(X), B ⊆ A ⊆ int(cl(B)) ⟹ A ∊ IFRαGO(X).

Proof: Let B be an IFRCS. Then B = cl(int(B)). By hypothesis, A ⊆ int(cl(B)) ⊆ int(cl(cl(int(B)))) ⊆ int(cl(int(B))) ⊆ int(cl(int(A))). Therefore A is an IFαOS and by Theorem 3.3, A is an IFRαGOS. Hence A ∊ IFRαGO(X).

IV. APPLICATIONS OF INTUITIONISTIC FUZZY REGULAR α GENERALIZED CLOSED SETS

In this section we provide some applications of intuitionistic fuzzy regular α generalized closed sets.

Definition 4.1: If every IFRαGCS in (X,τ) is an IFαCS in (X,τ), then the space can be called as an intuitionistic fuzzy regular α $T_{1/2}$ space ($IF_{r\alpha}T_{1/2}$ in short).

Theorem 4.2: An IFTS (X,τ) is an $IF_{r\alpha}T_{1/2}$ space if and only if IFαO(X) = IFRαGO(X).

Proof: Necessity: Let A be an IFRαGOS in (X,τ), then A^c is an IFRαGCS in (X,τ). By hypothesis, A^c is an IFαCS in (X,τ) and therefore A is an IFαOS in (X,τ). Hence IFαO(X) = IFRαGO(X).

Sufficiency: Let A be an IFRαGCS in (X,τ). Then A^c is an IFRαGOS in (X,τ). By hypothesis, A^c is an IFαOS in (X,τ) and therefore A is an IFαCS in (X,τ). Hence (X,τ) is an $IF_{r\alpha}T_{1/2}$ space.

Theorem 4.3: Let an $IF_{r\alpha}T_{1/2}$ space be an IFTS. If A is an IFS of X then the following properties are hold:

(i) A ∊ IFRαGO(X)
(ii) A ⊆ int(cl(int(A)))
(iii) There exists IFOS G such that G ⊆ A ⊆ int(cl(G)).

Proof: (i) ⟹ (ii): Let A ∊ IFRαGO(X). This implies A is an IFαOS in X, since X is an $IF_{r\alpha}T_{1/2}$ space,. Then A^c is an IFαCS in X. Therefore cl(int(cl(A^c))) ⊆ A^c. This implies A ⊆ int(cl(int(A))).

(ii) ⟹ (iii): Let A ⊆ int(cl(int(A))). Hence int(A) ⊆ A ⊆ int(cl(int(A))). Then there exists IFOS G in X such that G ⊆ A ⊆ int(cl(G)) where G = int(A).
(iii) ⟹ (i): Suppose that there exists IFOS G such that G ⊆ A ⊆ int(cl(G)). It is clear that $(int(cl(G)))^c \subseteq A^c$. That is $(int(cl(int(A))))^c \subseteq A^c$. This implies $cl(int(cl(A^c))) \subseteq A^c$. That is A^c is an IFαCS in X. This implies A is an IFαOS in X. Hence A ∊ IFRαGO(X).
Definition 4.4: An IFTS (X,τ) is said to be an intuitionistic fuzzy regular α $T^*_{1/2}$ space ($IF_{r\alpha}T^*_{1/2}$ space in short) if every IFRαGCS is an IFCS in (X,τ).
Remark 4.5: Every $IF_{r\alpha}T^*_{1/2}$ space is an $IF_{r\alpha}T_{1/2}$ space but not conversely.
Proof: Let (X,τ) be an $IF_{r\alpha}T^*_{1/2}$ space. Let A be an IFRαGCS in (X,τ). By hypothesis, A is an IFCS. Since every IFCS is an IFαCS, A is an IFαCS in (X,τ). Hence (X,τ) is an $IF_{r\alpha}T_{1/2}$ space.
Example 4.6: Let X = {a, b} and let τ = {0~, G_1, G_2, G_3, 1~} where G_1 = ⟨x, (0.5,0.5), (0.3,0.1)⟩, G_2 = ⟨x, (0.1,0.1), (0.7,0.7)⟩ and G_3 = ⟨x, (0.5,0.5), (0.4,0.2)⟩. Let A = ⟨x, (0.4,0.1), (0.5,0.5)⟩ be any IFS in (X,τ). Then A ⊆ U where U = ⟨x, (0.5,0.5), (0.3,0.1)⟩ is an IFROS in X. Now αcl(A) = ⟨x, (0.4,0.1), (0.5,0.5)⟩ ⊆ U. Therefore A is an IFRαGCS in X but not an IFCS in X, since cl(A) = ⟨x, (0.4,0.2), (0.5,0.5)⟩ ≠ A.
Theorem 4.7: For any IFS A in (X,τ) where X is an $IF_{r\alpha}T^*_{1/2}$ space, A∊ IFRαGO(X) if and only if every IFP $p_{(\alpha,\beta)}$ ∊ A, there exist an IFRαGOS B in X such that $p_{(\alpha,\beta)}$ ∊ B ⊆ A.
Proof: Necessity: If A ∊ IFRαGO(X), then we can take B = A so that $p_{(\alpha,\beta)}$ ∊ B ⊆ A. For every IFP $p_{(\alpha,\beta)}$ ∊ A.
Sufficiency: Let A be an IFS in (X,τ) and assume that there exist B ∊ IFRαGO(X) such that $p_{(\alpha,\beta)}$ ∊ B ⊆ A. Since X is an $IF_{r\alpha}T^*_{1/2}$ space, B is an IFOS. Then $A = \cup_{p(\alpha,\beta) \in A} \{ p_{(\alpha,\beta)} \} \subseteq \cup_{p(\alpha,\beta) \in A} B \subseteq A$. Therefore $A = \cup_{p(\alpha,\beta) \in A} B$, which is an IFOS in X. Hence by Theorem 3.3, A is an IFRαGOS in X.
Definition 4.8: An IFTS (X,τ) is said to be an intuitionistic fuzzy regular α generalized $T_{1/2}$ ($IF_{r\alpha g}T_{1/2}$ in short) space if every IFRαGCS in X is an IFαGCS in X.
Theorem 4.9: If an IFTS (X,τ) is an $IF_{r\alpha g}T_{1/2}$ space, then every IFRαGOS is an IFαGOS.
Proof: Let A be an IFRαGOS in X. This implies A^c is an IFRαGCS in X. Since X is an $IF_{r\alpha g}T_{1/2}$ space, A^c is an IFαGCS in X. Hence A is an IFαGOS in X.
Theorem 4.10: Let an $IF_{r\alpha g}T_{1/2}$ space be an IFTS. If A is an IFS of X then the following properties are hold:

(i) A ∊ IFRαGO(X)
(ii) U ⊆ int(cl(int(A))) whenever U ⊆ A and U is an IFCS in X
(iii) There exists IFOSs G and G_1 such that G_1 ⊆ U ⊆ int(cl(G)).

Proof: (i) ⟹ (ii): Let A ∊ IFRαGO(X). This implies A is an IFαGOS in X, since X is an $IF_{r\alpha g}T_{1/2}$ space. Then A^c is an IFαGCS in X. Therefore $\alpha cl(A^c) \subseteq V$ whenever $A^c \subseteq V$ and V is an IFOS in X. That is $cl(int(cl(A^c))) \subseteq V$. This implies $V^c \subseteq int(cl(int(A)))$ whenever $V^c \subseteq A$ and V^c is IFCS in X. Replacing V^c by U, U ⊆ int(cl(int(A))) whenever U ⊆ A and U is an IFCS in X.
(ii) ⟹ (iii): Let U ⊆ int(cl(int(A))) whenever U ⊆ A and U is an IFCS in X. Hence int(U) ⊆ U ⊆ int(cl(int(A))). Then there exists IFOSs G and G_1 in X such that G_1 ⊆ U ⊆ int(cl(G)) where G = int(A) and G_1 = int(U).
(iii) ⟹ (i): Suppose that there exists IFOSs G and G_1 such that G_1 ⊆ U ⊆ int(cl(G)). It is clear that $(int(cl(G)))^c \subseteq U^c$. That is $(int(cl(int(A))))^c \subseteq U^c$. This implies $cl(int(cl(A^c))) \subseteq U^c$, $A^c \subseteq U^c$ and U^c is an IFOS in X. This implies $\alpha cl(A^c) \subseteq U^c$. That is A^c is an IFαGCS in X. This implies A is an IFαGOS in X. Hence A ∊ IFRαGO(X).

V. CONCLUSION

Thus we have analyzed relationship between intuitionistic fuzzy regular α generalized open sets and the already existing intuitionistic fuzzy open sets and obtain many interesting theorem using the new spaces introduced above.

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