Separation Axioms in Intuitionistic Fuzzy Soft Topological space

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Abstract: **In this paper, I have studied some properties of fuzzy soft topological space. We define fuzzy soft intuitionistic separation axioms and basic definition of intuitionistic fuzzy soft normal spaces and theorems. Lastly, introduced intuitionistic fuzzy soft completely normal spaces.**

Keywords: soft sets, intuitionistic fuzzy soft sets, intuitionistic fuzzy soft topological space, intuitionistic fuzzy soft separation axioms, intuitionistic fuzzy soft completely normal space.

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I. Introduction

There are many problems encountered in real life. Various mathematical set theories such as soft set initiated by Molodtsov[2] in 1999 for modeling uncertainty present in real life. Xio[13] and Pie and Mio [3] discussed the relationship between soft sets is a parameterized classification of the objects of the universe. Atanassov [7] introduced the fundamental concept of intuitionistic fuzzy topological spaces, fuzzy continuity , fuzzy compactness and some other related concepts. Mahanta and Das[6] established the neighbourhood structures in fuzzifying topological spaces. Some others [1],[4],[8],[10].studied some separation axioms and their separation axioms are discussed on crisp points not on fuzzy points. My main aim in this paper is to develop the basic properties of intuitionistic fuzzy soft separation axioms and established several equivalent forms of fuzzy soft spaces.

II. Preliminaries

Definition2.1[9] Let U be an initial universe set and E be the set of parameters. Let $A \subseteq E$, a pair (F,A) is called a fuzzy soft set over U . Where F is a mapping given by $F : A \to I^U$ Where I^U denotes the collection of all fuzzy subset of U.

Definition 2.2[8] Let U be an initial universe set and E be the set of parameters. let IF^U denotes the collection of all intuitionistic fuzzy subset s of U. Let $A \subseteq A$, a pair (F,E) is called an intuitionistic fuzzy soft set over U. Where F is a mapping given by $F : A \to IF^U$

Definition 2.3[2] Let U be an initial universe set and E be the set of parameters. Let P(U) denotes the power set of U . A pair (F,E) is called a soft set over U .Where F is called mapping given by F:E→P(U)

Definition 2.4[2] Union of two intuitionistic fuzzy soft sets (F, A) and (G,B) over a common universe U is a fuzzy soft set (H,C) where C= AUB ∀ ε Є C

$$H(\varepsilon) = \begin{cases} F(\varepsilon) & \text{if } \varepsilon \in A-B \\ G(B) & \text{if } \varepsilon \in B-A \\ F(\varepsilon) \tilde{\cup} G(\varepsilon) & \text{if } \varepsilon \in A \cap B \end{cases}$$

And is written as F (A) $\tilde{\cup}$ (G,B) = (H,C)

Definition 2.5[9] The intersection of two intuitionistic fuzzy soft sets (F,A) and (G,B) over U is an intuitionistic fuzzy soft set denoted by (H,C) Where C=A ∩B

$$H(\varepsilon) = \begin{matrix} F(\varepsilon) & \text{if } \varepsilon \in A-B \\ G(B) & \text{if } \varepsilon \in B-A \\ F(\varepsilon) \cap G(\varepsilon) & \text{if } \varepsilon \in A\cap \end{matrix}$$

And is written as F (A) ∩ (G,B) = (H,C)

Definition 2.6[12] The complement of a fuzzy soft set (F,A) is denoted by $(F,A)^C$ and is defined by

$(F, A)^C = (F^C, A)$. Where $F^C: A \to \tilde{P}(U)$ is mapping given by

$F^C(\alpha) = U—F(\alpha)=[F(\alpha)]^C \ \forall \alpha \in A$

Definition 2.7[6] **Let** $A \subseteq E$. Then the mapping F_A: $E \to \tilde{P}(U)$, defined by $F_A(e)=\mu^e F_A$ (a fuzzy subset of U) is called fuzzy soft over (U,E), Where $\mu^e F_A=\bar{0}$ if $e \in E$-A and $\mu^e F_A \neq \bar{0}$ if $e \in A$. The set of all fuzzy soft set over (U,E) is denoted by FS(U,E)

Definition 2.8[8] The fuzzy soft set FFS (U,E) is called null fuzzy soft set and is denoted by $\bar{\phi}$. Here $F\varphi(e)=\bar{0}$ foe every $e \in E$

Definition 2.9[12]A fuzzy soft topology T on (U,E) is a family of fuzzy soft sets over (U,E) satisfying the following properties

(i)$\bar{\phi}, \bar{E} \in \tilde{T}$

(ii) If F_A, $G_B \in$ T then $F_A \tilde{\cap} G_B \in \tilde{T}$

(iii) If $F^\alpha A_\alpha \in T$ for all $\alpha \in \Delta$,then $\cup F^\alpha A_\alpha \in \tilde{T}$

Definition 2.10[2]If T is a fuzzy soft topology on (U,E) , then (U,E,T) is said to be a fuzzy soft topological space . Also each member of T is called a fuzzy soft open set in (U,E,T)

Definition 2.11[6] Let (U,E,T) be a soft topological space. A soft separation of $\tilde{U}$ is a pair of (F,E) ,(G,E) of no- null soft open sets over U such that $\tilde{U}$ =(F,E) $\tilde{U}$ (G,E) , (F,E) $\tilde{\cap}$ (G,E) =ϕ_E

III. Main Results

Definition3.1 Let(X,T,E) be a IFS topological space over X. Let (F,E) be subset of X. Then intuitionistic fuzzy soft dense is denoted by $\overline{(F,E)}$ =X

Definition3.2 let (X,T,E) be a IFST space over X is said to be IFS separable space iff there exists a countable intuitionistic fuzzy soft dense subset of (F,E) of X i. e $\overline{(F,E)}$ =X, where (F,E) is countable.

Example3.1 The usual fuzzy soft topological space (R,U) is IFS separable because (Q,E) of the rational numbers is a IFS countable subset of R. Which is also IFS dense as $\overline{(Q,E)}$ =R

Definition 3.3 Let (X,T,E) be a IFTS is said to be intuitionistic fuzzy soft hereditarily separable if each of its IFS separable is separable.

Theorem3.1 The continuous image of a fuzzy soft separable space is separable.

Proof: Let (X,T,E) and (Y,T,E) be two intuitionistic fuzzy soft topological space and f(X,E)→(Y,E) be such that f is T_1-T_2 continuous mapping of (X,E) into (Y,E). If (X,T_1,E) be IFS separable space then we are to prove that (X,T_2,E) be IFS separable .

Now (X,T_1,E) be IFS separable then there exists a countable subset (A,E) of (X,E) such that $\overline{(A,E)} = (X,E)$

Since (A,E) is countable so f(A,E) is also countable.

Let (y,E) be any element of (Y,E) then there exists (x,E) ∈ (X,E) such that (y, E) = f(x,E). Let (G,E) be a T_2- open nbd of y so that f(x,E) ∈ (G,E) $\Rightarrow (x,E) \in f^{-1}(G,E)$. But f being continuous and (G,E)being T_2-open nbd of (y,E) follows that $f^{-1}(G,E)$ is T_1-nbd of (X,E). Now (A,E) is IFS dense in (X,E) i.e $\overline{(A,E)}$ =(X,E) therefore every point $(x,E) \in (X,E)$ is an every T1-nbd of (X,E) contain at least one point of (A,E)

Hence $f^{-1}(G,E) \tilde{\cap} (A,E) \neq \tilde{\phi}$, therefore $f[f^{-1}(G,E) \tilde{\cap} (A,E)] \neq \tilde{\phi}$,implies $(G,E) \tilde{\cap} (A,E) \neq \tilde{\phi}$ as f being onto i. e $f[f^{-1}(G,E)]=(G,E)$

So, (G,E) of (y,E) is open nbd of T_2. Since (G,E) is an arbitrary nbd of (y,E) it follows every T2-nbd of (y,E) contains at least one point of f(A,E). So (y,E) is an adherent point of f(A,E).

Hence $(y,E) \in (Y,E) \Rightarrow (y,E) \in f\overline{(A,E)}$

Therefore, $(y,E) \tilde{\subseteq} \overline{(A,E)}$ but $f\overline{(A,E)} \tilde{\subseteq} (Y,E)$ so $f\overline{(A,E)} = (Y,E)$ .Hence (Y, T_2, E) be a IFS separable.

IV. Separable Axioms in Intuitionistic Fuzzy Topological Space.

Definition 4.1Let (X,τ,E) be a intuitionistic fuzzy soft topological space over X and x, y∈X such that x≠y if there exists two open sets (F,E) and (G,E) such that x∈(F,E) and y ∉ (G,E) or y∈(F,E) and x ∉ (G,E), then (X,τ,E) is said to be intuitionistic fuzzy soft T_0- space.

Example 4.1 Every discrete IFS topological space (X,T,D) is a T_0- space because there exists a open set {x} containing x but not containing y. This is distinct from x.

Example 4.2Indiscrete IFS topological space (X,T,I) there only T-open sets are X, ϕ.There no open set which contains x but does not contains y. So it is not a IFS T_o- space.

Theorem 4.1 A IFS topological space (X,T,E) is a IFS To- space iff the closures of distinct points are distinct.

Proof: Let x,y∈ X and (X,T,E) be IFS T_O-space. We are to show that $\{\overline{x}\}$ and $\{\overline{y}\}$ are distinct. Since (X,T,E) be IFS T_O-space then there exists a open set (G,E) such that $x \in (G,E)$ but $y \notin (G,E)$. Now (G,E) being open .So X-(G,E) is closed. Also $x \notin X-(G,E)$ and $y \in X-(G,E)$. Now by definition of IFS T_O-space {A} is the intersection of all closed sets containing A and hence {y}is the intersection of all closed sets which contains y. hence $y \in \{\overline{y}\}$ but $x \notin \{\overline{y}\}$ as $x \notin X-(G,E)$ therefore $\{\overline{x}\} \neq \{\overline{y}\}$

Conversely, We are to show (X,T,E) be IFS To-space. Let $z \in X$ such that $z \in \{\overline{x}\}$ but $z \notin \{\overline{y}\}$ Since $x \notin \{\overline{y}\}$ because if $x \in \{\overline{y}\}$ then $x \tilde{\subset} \{\overline{y}\} \Rightarrow \{\overline{x}\} \tilde{\subset} \{\overline{\overline{y}}\} \Rightarrow \{\overline{x}\} \tilde{\subset} \{\overline{y}\}$ therefore $z \in \{\overline{x}\} \Rightarrow z \in \{\overline{y}\}$.But the above is a contradiction to our assumption that $z \notin \{\overline{y}\}$.This contradiction is due to our taking $x \in \{\overline{y}\}$.Hence $x \in \{\overline{y}\}$.Now $x \notin \{\overline{y}\} \Rightarrow x \in [\{\overline{y}\}]^c$ This $[\{\overline{y}\}]^c$ is open set containing x but not y. Hence(X,T,E) is a IFS T_O-space.

Theorem 4.2 A IFS subspace of a IFS To-space is a IFS To-space.

Proof: Let (X,T,E) be a IFS topological space. Let (F,E) be a IFS subgroup of (X,T,E). Let ψ_1, ψ_2 be two distinct points of (F,E) and $(F,E) \tilde{\subset} (X,T,E)$ therefore distinct points of (X,T,E).since (X,T,E) be IFS-$_{TO}$-space therefore there exists open set (G,E) such that $\psi_1 \notin (G,E)$ and $\psi_2 \notin (G,E)$.hence $(G,E) \tilde{\cap} (F,E)$ does not contain ψ_2 so (G,E) is also a IFS T_O-space.

Definition 3.2 Let (X,τ,E) be a intuitionistic fuzzy soft topological space over X and x, y∈ X such that x ≠ y if there exists two soft open sets (F,E) and (G,E) such that x∈ (F,E)and y ∉ (F,E) and y∈(G,E) and x ∉ (G,E)then (X,τ,E) is said to be IFS T_1- space.

Remarks 4.1 Every IFS T_1-space is a IFS T_O-space but every IFS T_O-space is not a IFS T_1-space.

Example 4.3 Every discrete IFS topological space (X,T,D) is a IFS T_1-space.

Solution: Let (X,T,D) be IFS topological space and let x, y∈ X and {x} and {y} be two D open sets such that $x \in \{x\}$ but $y \notin \{x\}$ and y ∈ {y} but $x \notin \{y\}$. Hence (X,T,D) is a IFS T_1-space.

Theorem 4.3 Every subspace of a IFS T_1-space is a IFS T_1-space.

Proof: let (X,T,E) be a IFS T_1-space and (Y,T^*,E) is a T-relative topology. Let $y_1, y_2 \in Y$ and y_1, y_2 are also distinct points of X as $Y \tilde{\subset} X$ if (G,E) and (H,E) be two open subsets of X then (G^*,E)= $(G,E) \tilde{\cap} (Y,E)$ and $(H^*,E) = (H,E) \tilde{\cap} (Y,E)$ are T^*-open subsets of Y and

hence $y_1 \in (G,E) \Rightarrow y_1 \in (G^*,E)$

$y_1 \notin (G,E) \Rightarrow y_1 \notin (G^*,E)$

Since (X,T,E) be a IFS T_1-space and y_1,y_2 are distinct points of X and Y. As $y_1 \in (G,E)$ but $y_2 \notin (G,E)$ therefore $y_1 \notin (G^*,E)$ but $y_2 \notin (G^*,E)$ and $y_2 \in (H,E)$ but $y_1 \notin (H,E)$ therefore $y_2 \in (H^*,E)$ but $y_1 \notin (H^*,E)$.Hence (Y,T^*,E) is also a IFS T_1- space.

Theorem4.4 Let (X,T,E) be a IFS topological space then the following are equivalent

a) (X, T, E) is a IFS T_1- space.
b) Every singleton subset of X is closed.
c) Every finite subset of X is closed.
d) The intersection of neighborhood of an arbitrary point of X is a singleton.

Proposition4.1 A IFS topological space (X,T,E) is IFS T_1- space iff every finite subset of X is closed.

Proof: Every singleton subset of {x} of X is closed if (X,T,E) is IFS T_1- space. Now a finite subset of X is the union of finite number of singleton sets which is closed. Hence if (X,T,E) is IFS T_1- space then every finite subset of X is closed.

Conversely, if every finite subset of closed then every singleton subset {x} being finite is also closed. So (X,T,E) is IFS T_1- space

Definition 4.5 Let (X,τ,E) be a intuitionistic fuzzy soft topological space over X and x, y∈X such that x ≠ y then there exists two open sets (F,E) and (G,E) such that x∈(F,E) and y ∈(G,E) ,(F,E)$\tilde{\cap}$ (G,E)=ϕ, then (X,τ,E) is said to be IFS T_2- space.

Example 4.4Let (X,τ,E) be a intuitionistic fuzzy soft topological space over X and x, y∈ X so {x} and {y} be two open sets and D-open nbd of x and y such that $\{x\} \tilde{\cap} \{y\} = \phi$ .Hence (X,T,D) is IFS T_2-space.

Theorem4.6 Every subspace of IFS T_2-space is a IFS T_2-space.

Proof : Let (X,τ,E) be is a IFS T_2-space and (Y,T^*,E) be a subspace of (X,T,E). so that $T^* = \{Y \cap G, G \in T\}$

Let x, y ∈ X, Y and $Y \tilde{\subseteq} X$ .Again (X,T, E) is IFS T_2-space then there exists open nbds (G,E) and (H,E) of x and y respectively such that $(G,E) \tilde{\cap} (H,E) = \phi$

Now $x \in (G,E), x \in (Y,E) \Rightarrow x \in (Y,E) \tilde{\cap} (G,E)$ and $y \in (H,E), y \in (Y,E) \Rightarrow y \in (Y,E) \tilde{\cap} (H,E)$

Also, $((Y,E) \cap (G,E)) \tilde{\cap} ((Y,E) \cap (H,E))$ = $(Y,E) \tilde{\cap} ((G,E) \cap (H,E))$ = $(Y,E) \tilde{\cap} \phi = \phi$

We see that $(Y,E) \cap (G,E)$ and $(Y,E) \cap (H,E)$ are disjoint open nbds of x and y respectively. So (Y,T^*,E) is also a IFS T_2-space.

Proposition4.2 Every IFS T_2-space is a IFS T_1-space.

Proof: Let (X,τ,E) be is a IFS T_2-space therefore there exists (G,E) and (H,E) two open nbds of distinct points of x and y such that $(G,E) \cap (H,E)$ = ϕ therefore $x \in (G,E), y \in (H,E)$ .Also $x \in (G,E) \Rightarrow x \notin (H,E)$ as $(G,E) \cap (H,E)$ = ϕ

Similarly, $y \in (H,E) \Rightarrow y \notin (G,E)$ therefore $x \in (G,E)$ but $y \notin (G,E)$ and $y \in (H,E)$ but $x \notin (H,E)$ .Hence (X,T,E) is IFS T_1-space.

Remarks4.3 Every IFS T_2-space is T_1-space but every IFS T_1-space is not IFS T_2-space.

Definition 4.6 A IFS topological space (X,T,E) is said to be IFS regular if and only if every closed subsets (F,E) of X and each point $x \notin (F,E)$ i.e $x \in X - (F,E)$ then there exists two disjoint open nbds (G,E) and (H,E) such that $(F,E) \tilde{\subseteq} (G,E)$ and $x \in (H,E)$ and $(G,E) \tilde{\cap} (H,E) = \phi$

Remarks 4.4 A IFS topological space T_2 is IFS regular as well as a IFS T_1-space.

Theorem4.7 Every IFS T_3-space is a IFS T_2- space.

Proof: Let (X,T,E) be IFS T_3 space so it is both IFS T_1-space and IFS regular. Since (X,T,E) be IFS T_1 -space implies that every singleton subset {x} of X is a closed.(X,T,E) being IFS regular and {x}is a closed subset of x and y be any point in X-{x} then clearly y≠ x. Since it is IFS regular so there exist two open sets (G,E) and (H,E) such that $\{x\} \tilde{\subseteq} (G,E)$ .Hence(G,E) and (H,E) are two disjoint open nbds of x and y. Hence (X,T,E) is IFS T_2-space.

Definition 4.7 let (X,T,E) be IFS topological space over X and (A,E) and (B,E) be two closed subset in X then there exists open sets (G,E) and (H,E) such that $(A,E) \tilde{\subseteq} (G,E), (B,E) \tilde{\subseteq} (H,E)$ and $(G,E) \tilde{\cap} (H,E) = \phi$ therefore (X,T,E) is called IFS normal space.

Remarks 4.5 A IFS regular and IFS T_1-space is called IFS T_4-space.

Example4.5 Let X={a,b,c} and T={X, ϕ {a},{b,c}}.Hence (X,T,E) is IFS normal but not IFS T_4-space.

Theorem4.8 Every subspace of a IFS T_4-space is a IFS T_4-space..

Proof: let (X, T, E) be a IFS topological space. Since (X,T,E) be IFS T_4 space so it is IFS normal space as well as IFS T_1-space.Also every subspace of IFS T_1-space is a IFS T_1-space.

Let (A^*,E) and (B^*,E) be two T^* closed disjoint subsets of (Y,E) and let $x \in (A^*, E), y \in (B^*, E), x \neq y$ .Since (X,T,E) be IFS T_1-space. So closed subsets of X then there two open sets (G_x, E) and (H_y, E) such that

$\{x\} \tilde{\subseteq} (G_x, E), \{y\} \tilde{\subseteq} (H_y, E), (G_x, E) \tilde{\cap} (H_y, E) = \phi$. Let (G,E) and (H,E) are two open sets and $(G, E) \tilde{\cap} (H, E) = \phi$ because $(G_x, E) \tilde{\cap} (H_y, E) = \phi$

Now $(A^*, E) \tilde{\subseteq} (G, E) and (B^*, E) \tilde{\subseteq} (H, E), (G, E) \tilde{\cap} (H, E) = \phi$

$$(A^*, E) \tilde{\subseteq} (G, E) \Rightarrow (A^*, E) \tilde{\subseteq} (Y, E) \cap (G, E) as (A^*, E) \tilde{\subseteq} (Y, E) ....(3)$$

$$(B^*, E) \tilde{\subseteq} (H, E) \Rightarrow (B^*, E) \tilde{\subseteq} (Y, E) \cap (H, E)$$

$$(G, E) \cap (H, E) = \phi \Rightarrow ((Y, E) \tilde{\cap} (G, E)) \cap ((Y, E) \cap (H, E))$$

$$= (Y, E) \tilde{\cap} ((G, E) \cap (H, E))$$

$$= (Y, E) \cap \phi = \phi$$

Therefore (X,T,E) be IFS normal space it is IFS T_1-space also .So it is IFS T_4-space.

Definition 4.8 Let (X,T,E) be IFS topological space and (A,E) and (B,E) be two separated subsets of X and there exists two open sets (G,E) and (H,E) such that $(A, E) \tilde{\subseteq} (G, E), (B, E) \tilde{\subseteq} (H, E) and (G, E) \tilde{\cap} (H, E) = \phi$ then (X,T,E) is called IFS completely normal space.

Remarks 4.6 A IFS completely normal space is also a IFS T1-space is called IFS T5-space.

Theorem4.9 Every IFS completely normal space is a IFS normal and hence every IFS T4 space is IFS T_5-space.

Proof: Let (X,T,E) be IFS topological space which is IFS normal space. Let (A,E) and (B,E) be two closed disjoint subsets of X i. e $\overline{(A, E)} = (A, E), \overline{(B, E)} = (B, E), (A, E) \cap (B, E) = \phi$ so $\overline{(A, E)}$ ∩(B,E)=(A,E)∩(B,E)= ϕ and $(A, E) \cap \overline{(B, E)} = (A, E) \cap (B, E) = \phi$ since (X,T,E) be IFS completely normal then there exists two open sets (G,E) and (H,E) such that $(A, E) \tilde{\subseteq} (G, E), (B, E) \tilde{\subseteq} (H, E) and (G, E) \tilde{\cap} (H, E) = \phi$ So (X,T,E) is IFS normal space. Again IFS T_5-Space= IFS completely normal +IFS T_1-space $\Rightarrow$ IFS normal+ IFS T_1-space=IFS T_4-space. Hence every IFS T_5 space is IFS T_4-space

V. Conclusion.

Fuzzy soft topology is an important and major area of mathematics and it can give many relationships between other scientific areas and mathematical models. In this present work I have continued to study the properties of soft topological spaces. We introduced intuitionistic Fuzzy soft separable spaces and separable axioms in intuitionistic fuzzy soft topological spaces, and regular IFS-T_1, T_4-space and lastly IFS completely normal space and have established several interesting theorems, examples. I hope that the findings in this paper will help researchers enhance and promote the father study on fuzzy soft topology to carry out a general framework for their applications in practical life.

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