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Intuitionistic Fuzzy $g_p^{\#}$-T_0 Spaces in Intuitionistic Fuzzy Topological Spaces

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ABSTRACT:

This paper aims at the study of separation axioms via intuitionistic fuzzy generalized hash pre (briefly, $I_f g_p^{\#}$) closed sets in intuitionistic fuzzy (briefly, I_f) topological spaces. The idea of $I_f g_p^{\#}$-T_0 spaces is defined in two ways, separation axioms using I_f point and I_f vanishing point. The intra-connectedness and inter-connectedness between these spaces and properties are deeply analyzed and illustrated with suitable examples.

Key Words: Intuitionistic fuzzy point, Intuitionistic fuzzy vanishing point, $I_f g_p^{\#}$-T_0 space,

1. INTRODUCTION

L.A. Zadeh [11] introduced fuzzy sets to value every member of a set in mathematics in 1965. C.L. Chang [5] introduced fuzzy topological spaces in 1968. Further, K. Atanassov [1] introduced intuitionistic fuzzy sets by adding the notion of non-membership into fuzzy sets in 1983. D. Coker [7] introduced intuitionistic fuzzy topological spaces in 1997. From then on, many research works focused on the generalization of the concepts of intuitionistic fuzzy topological spaces. Extending further, Pious Missier .S and Gabriel Raja .S [10] introduced intuitionistic fuzzy generalized hash pre-closed (briefly, $I_f g_p^{\#}$C) set with its characterization and properties with suitable examples. Park .J.H [9] introduced separation axioms int intuitionistic fuzzy topological spaces. The aim of this paper is to study and investigate the separation axiom spaces T_0. Separation axioms are defining properties which may be specified to distinguish certain types of intuitionistic fuzzy topological spaces. This paper studies and investigates separation axioms via $I_f g_p^{\#}$ closed sets in I_f-T_0 spaces with suitable examples and theorem.

2. PRELIMINARIES

Definition 2.1 [1] Let X be a universal set and let A be an intuitionistic fuzzy (briefly, I_f) subset in X, where $A = \{< x/\mu_A(x), \upsilon_A(x) > : x \in X\}$. Here, the functions $\mu_A: X \to [0,1]$ and $\upsilon_A: X \to [0,1]$ denote the degree of membership, namely $\mu_A(x)$ and the degree of non-membership, namely $\upsilon_A(x)$ of each element $x \in X$ to the set A respectively, and $0 \leq \mu_A(x) + \upsilon_A(x) \leq 1$ for each $x \in X$.

Definition 2.2 [1] Let $A = \{< x, \mu_A(x), \upsilon_A(x) >: x \in X\}$ and B= $\{< x, \mu_B(x), \upsilon_B(x) >: x \in X\}$ be two I_f subsets, then the following holds true

(a) $A \subseteq B$ iff $\mu_A(x) \leq \mu_B(x)$ and $\upsilon_A(x) \geq \upsilon_B(x)$ for all $x \in X$

(b) $A = B$ iff $A \subseteq B$ and $B \subseteq A$

(c) $A^c = \{< x/\upsilon_A(x), \mu_A(x) >: x \in X\}$

(d) $A \cup B = \{x/\mu_A(x) \vee \mu_B(x), \upsilon_A(x) \wedge \upsilon_B(x) : x \in X\}$

(e) $A \cap B = \{x/\mu_A(x) \wedge \mu_B(x), \upsilon_A(x) \vee \upsilon_B(x) : x \in X\}$

(f) $(A \cup B)^c = A^c \cap B^c$ and $(A \cap B)^c = A^c \cup B^c$

(g) the empty set $\tilde{0} =< x/0, 1 >$ and the whole set $\tilde{1} =< x/1, 0 >$

(h) $\tilde{0}^C = \tilde{1}$ and $\tilde{1}^C = \tilde{0}$

Definition 2.3 [7] An I_f topology on a non-empty set X is a family τ_{if} of intuitionistic fuzzy subsets of X, satisfying the following axioms;

(1) $\tilde{0}, \tilde{1} \in \tau_{if}$

(2) $A \cap B \in \tau_{if}$ for any $A, B \in \tau_{if}$

(3) $\cup A_i \in \tau_{if}$ for any arbitrary family $\{A_i : i \in J\} \subseteq \tau_{if}$

A non-empty set X on which an I_f topology τ_{if} has been specified is called an intuitionistic fuzzy topological space, i.e., (X, τ_{if}). Any I_f set in τ_{if} is known as an intuitionistic fuzzy open (briefly, I_fO) set in X and the complement of an I_fO set is known as an intuitionistic fuzzy closed (briefly, I_fC) set in X.

Definition 2.4 [7] Let (X, τ_{if}) be an I_f topological space and $A = \{< x/ \mu_A(x), \upsilon_A(x) >: x \in X\}$ be an I_f subset in X. Then the interior and closure of the above I_f subset are defined as follows.

(i) $int(A) = \cup \{G | G$ is an intuitionistic fuzzy open (briefly, I_fO) set in X and $G \subseteq A\}$

(ii) $cl(A) = \cap \{K | K$ is an intuitionistic fuzzy closed (briefly, I_fC) set in X and $A \subseteq K\}$

Definition 2.5 [6] Let X be a universal set and let $A = \{< x/\mu_A(x), \upsilon_A(x) >: x \in X\}$ be an I_f subset in X, let $p \in X$ be a fixed element in X and let $\alpha, \beta \in [0, 1]$ be two non-zero real numbers such that $\alpha + \beta \leq 1$, then

(i) $p = p_{(\alpha,\beta)}$, the I_f point of X, is an I_f set of X denoted by $\tilde{p} = x_{(\alpha,\beta)}$ and defined by $x_{(\alpha,\beta)}(y) = \{ (\alpha, \beta), \quad if\ y = x \ (0,1), \quad if\ y \neq x$, where α denotes the degree of membership of $x_{(\alpha,\beta)}$ and β denotes the degree of non-membership of $x_{(\alpha,\beta)}$. $\tilde{p}$ is said to be contained in A, i.e., $\tilde{p} \subseteq A$ if and only if $\alpha \leq \mu_A(b)$ and $\beta \geq \upsilon_A(b)$.

(ii) $p = p_{(\beta)}$, the I_f vanishing point of X, is an I_f vanishing set of X denoted by $\tilde{\tilde{p}} = x_{(\beta)}$ and defined by $x_{(\beta)}(y) = \{ (0, \beta), \quad if\ y = x \ (0,1), \quad if\ y \neq x$, where β denotes the degree of non-membership of $p_{(\beta)}$. $\tilde{\tilde{p}}$ is said to be contained in A, i.e., $\tilde{\tilde{p}} \subseteq A$ if and if α vanishes to 0 and $\beta \geq \upsilon_A(b)$.

Illustration 2.6 Let $X = \{a, b, c\}$ and if an I_f point at b with $\alpha = 0.6$, $\beta = 0.2$, then obviously, I_f set $\tilde{b} = x_{(\alpha,\beta)} = \{< a/0,1 >, < b/0.6, 0.2 >, < c/0,1 >\}$, since

$$\tilde{b} = x_{(0.6,0.2)}(y) = \{ (0.6, 0.2), \quad if\ y = b \qquad (0,1), \quad if\ y = a\ (or)\ c$$

and I_f vanishing set $\tilde{\tilde{b}} = b_{(\beta)} = \{< a/0,1 >, < b/0, 0.2 >, < c/0,1 >\}$, since

$$\tilde{\tilde{b}} = b_{(0.2)}(y) = \{ (0, 0.2), \quad if\ y = b \qquad (0,1), \quad if\ y = a\ (or)\ c$$

Also, $\tilde{b}^c = \{< a/0,1 >, < b/0.2, 0.6 >, < c/0,1 >\}$ and

$\tilde{\tilde{b}}^c = \{< a/0,1 >, < b/0.2, 0 >, < c/0,1 >\}$

Moreover, if an I_f set $A = \{< a/0.3, 0.4 >, < b/0.7, 0.1 >, < c/0.2, 0.5 >\}$ then obviously, $\tilde{b} \subseteq A$ and $\tilde{\tilde{b}} \subseteq A$, since $\alpha \leq \mu_A(b)$ and $\beta \geq \upsilon_A(b)$

Definition 2.7 [2] [9] An intuitionistic fuzzy topological space (X, τ_{if}) with X being a universal set and A being an I_f subset in X is said to be

(i) an I_f-$T_0(1)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L such that either $\tilde{p} \subseteq L$ and $\tilde{q} \not\subset L$ or $\tilde{p} \not\subset L$ and $\tilde{q} \subseteq L$.

(ii) an I_f-$T_0(2)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L such that either $\tilde{\tilde{p}} \subseteq L$ and $\tilde{\tilde{q}} \not\subset L$ or $\tilde{\tilde{p}} \not\subset L$ and $\tilde{\tilde{q}} \subseteq L$.

(iii) an I_f-$T_0(3)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L such that either $\tilde{p} \subseteq L \subseteq \tilde{q}^c$ or $\tilde{q} \subseteq L \subseteq \tilde{p}^c$.

(iv) an I_f-$T_0(4)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L such that either $\tilde{\tilde{p}} \subseteq L \subseteq \tilde{\tilde{q}}^C$ or $\tilde{\tilde{q}} \subseteq L \subseteq \tilde{\tilde{p}}^C$.

(v) an I_f-$T_0(5)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L such that either $\tilde{p} \subseteq L$ or $\tilde{q} \subseteq L$.

(vi) an I_f-$T_0(6)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L such that either $\tilde{\tilde{p}} \subseteq L$ or $\tilde{\tilde{q}} \subseteq L$.

Definition 2.8 [9] An I_f topological space (X, τ_{if}) is said to be I_f-T_0 space if for each pair of I_f distinct points $p, q \in X$ there exists an I_fC set L in (X, τ_{if}) such that either $p \subseteq L$ and $q \not\subset L$ or $q \subseteq L$ and $p \not\subset L$.

Definition 2.9 An intuitionistic fuzzy set L of an intuitionistic fuzzy topological space (X, τ_{if}) is called an intuitionistic fuzzy generalized hash pre closed (briefly, $I_fg^{\#}p$ closed) set if $I_fpcl(L) \subseteq U$ whenever $L \subseteq U$ and U is intuitionistic fuzzy generalized alpha open (briefly, $I_fg\alpha$ open) set in (X, τ_{if}).

3. Intra-connectedness among $I_fg_p^{\#}$-T_0 Spaces

Definition 3.1 An intuitionistic fuzzy topological space (X, τ_{if}) with X being a universal set and A being an I_f subset in X is said to be

(i) an $I_fg_p^{\#}$-$T_0(1)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_fg_p^{\#}C$ set L such that either $\tilde{p} \subseteq L$ and $\tilde{q} \not\subset L$ or $\tilde{p} \not\subset L$ and $\tilde{q} \subseteq L$.

(ii) an $I_fg_p^{\#}$-$T_0(2)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_fg_p^{\#}C$ set L such that either $\tilde{\tilde{p}} \subseteq L$ and $\tilde{\tilde{q}} \not\subset L$ or $\tilde{\tilde{p}} \not\subset L$ and $\tilde{\tilde{q}} \subseteq L$.

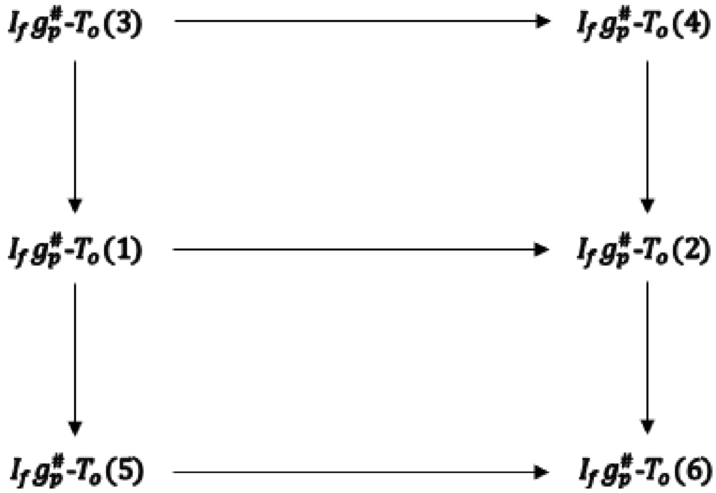
(iii) an $I_f g_p^{\#}$-$T_0(3)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_f g_p^{\#}C$ set L such that either $\tilde{p} \subseteq L \subseteq \tilde{q}^c$ *or* $\tilde{q} \subseteq L \subseteq \tilde{p}^c$.

(iv) an $I_f g_p^{\#}$-$T_0(4)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_f g_p^{\#}C$ set L such that either $\tilde{\tilde{p}} \subseteq L \subseteq \tilde{\tilde{q}}^C$ *or* $\tilde{\tilde{q}} \subseteq L \subseteq \tilde{\tilde{p}}^C$.

(v) an $I_f g_p^{\#}$-$T_0(5)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_f g_p^{\#}C$ set L such that either $\tilde{p} \subseteq L$ or $\tilde{q} \subseteq L$.

(vi) an $I_f g_p^{\#}$-$T_0(6)$ space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_f g_p^{\#}C$ set L such that either $\tilde{\tilde{p}} \subseteq L$ or $\tilde{\tilde{q}} \subseteq L$.

Theorem 3.2 The following diagram illustrates the relationship between $I_f g_p^{\#}$-T_0 spaces.



Proof: Trivial

However, the reverse implications of the above theorem are not always the case. This could be verified from the following examples.

Example 3.3 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.22, 0.6 >, < q/0.3, 0.55 >\}$. Clearly an I_f set $L = \{< p/0.2, 0.35 >, < q/0.32, 0.65 >\}$ is an $I_f g_p^{\#}C$ set in (X, τ_{if}). Let $p_{(0.3,0.38)}$ and $q_{(0.28,0.5)}$ be two I_f points in (X, τ_{if}). Now clearly $p, q \in X$, $p \neq q$, $\tilde{\tilde{p}} \subseteq L$ and $\tilde{\tilde{q}} \not\subset L$, however, $\tilde{p} \not\subset L$ and $\tilde{q} \not\subset L$. Hence, every $I_f g_p^{\#}$-$T_0(2)$ space is not an $I_f g_p^{\#}$-$T_0(1)$ space in (X, τ_{if}).

Example 3.4 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.42, 0.5 >, < q/0.4, 0.55 >\}$. Clearly an I_f set $L = \{< p/0.4, 0.34 >, < q/0.28, 0.15 >\}$ is an $I_f g_p^{\#}C$ set in (X, τ_{if}). Let $p_{(0.25,0.35)}$ and $q_{(0.27,0.5)}$ be two I_f points in (X, τ_{if}). Now clearly $p, q \in X$, $p \neq q$, and $\tilde{\tilde{p}} \subseteq L \subseteq \tilde{\tilde{q}}^C$, however, $\tilde{p} \subseteq L \not\subset \tilde{q}^c$ and $\tilde{q} \subseteq L \not\subset \tilde{p}^c$. Hence, every $I_f g_p^{\#}$-$T_0(4)$ space is not an $I_f g_p^{\#}$-$T_0(3)$ space in (X, τ_{if}).

Example 3.5 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.2, 0.65 >, < q/0.3, 0.55 >\}$. Clearly an I_f set $L = \{< p/0.22, 0.7 >, < q/0.28, 0.5 >\}$ is an $I_f g_p^{\#}C$ set in (X, τ_{if}). Let $p_{(0.25,0.35)}$ and $q_{(0.27,0.5)}$ be two I_f points in (X, τ_{if}). Then clearly $p, q \in X$, $p \neq q$, and $\tilde{\tilde{p}} \subseteq L$ however, $\tilde{p} \notin L$ and $\tilde{q} \notin L$. Hence, every $I_f g_p^{\#}$-$T_0(6)$ space is not an $I_f g_p^{\#}$-$T_0(5)$ space in (X, τ_{if}).

Example 3.6 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.4, 0.55 >, < q/0.42, 0.52 >\}$. Clearly an I_f set $L = \{< p/0.42, 0.5 >, < q/0.47, 0.53 >\}$ is an $I_f g_p^{\#}C$ set in (X, τ_{if}). Let $p_{(0.38,0.51)}$ and $q_{(0.35,0.45)}$ be two I_f points in (X, τ_{if}). Then clearly $p, q \in X$, $p \neq q$, $\tilde{p} \subseteq L$, $\tilde{q} \not\subset L$, however, $\tilde{p} \subseteq L \not\subset \tilde{q}^c$ and $\tilde{q} \not\subset L \not\subset \tilde{p}^c$. Hence, every $I_f g_p^{\#}$-$T_0(1)$ space is not an $I_f g_p^{\#}$-$T_0(3)$ space in (X, τ_{if}).

Example 3.7 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.3, 0.7 >, < q/0.4, 0.6 >\}$. Clearly an I_f set $L = \{< p/0.25, 0.75 >, < q/0.35, 0.65 >\}$ is an $I_f g_p^{\#}C$ set in (X, τ_{if}). Let $p_{(0.2,0.8)}$ and $q_{(0.3,0.7)}$ be two I_f points in (X, τ_{if}). Then clearly $p, q \in X$, and $\tilde{p} \subseteq L$, also, $\tilde{q} \subseteq L$. Hence, every $I_f g_p^{\#}$-$T_0(5)$ space is not an $I_f g_p^{\#}$-$T_0(1)$ space in (X, τ_{if}).

Example 3.8 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.4, 0.55 >, < q/0.42, 0.52 >\}$. Clearly an I_f set $L = \{< p/0.42, 0.5 >, < q/0.47, 0.53 >\}$ is an $I_f g_p^{\#}C$ set in (X, τ_{if}). Let $p_{(0.38,0.51)}$ and $q_{(0.35,0.45)}$ be two I_f points in (X, τ_{if}). Then clearly $p, q \in X$, $p \neq q$, $\tilde{\tilde{p}} \subseteq L$

and $\tilde{q} \not\subset L$, however, $\tilde{p} \subseteq L \not\subset \tilde{q}^C$ and $\tilde{q} \not\subset L \subset \tilde{p}^C$. Hence, every $I_f g_p^\#$-$T_0(2)$ space is not an $I_f g_p^\#$-$T_0(4)$ space in (X, τ_{if}).

Example 3.9 Let (X, τ_{if}) be an $I_f TS$ where $X = \{p, q\}$, $\tau_{if} = \{\tilde{0}, A, \tilde{1}\}$, $A = \{< p/0.3, 0.65 >, < q/0.4, 0.55 >\}$. Clearly an I_f set $L = \{< p/0.25, 0.7 >, < q/0.35, 0.6 >\}$ is an $I_f g_p^\# C$ set in (X, τ_{if}). Let $p_{(0.2,0.75)}$ and $q_{(0.3,0.65)}$ be two I_f points in (X, τ_{if}). Then clearly $p, q \in X$, $p \neq q$, $\tilde{q} \subseteq L$, also $\tilde{p} \subseteq L$. Hence, every $I_f g_p^\#$-$T_0(6)$ space is not an $I_f g_p^\#$-$T_0(2)$ space in (X, τ_{if}).

Definition 3.10 An I_f topological space (X, τ_{if}) is said to be $I_f g_p^\#$-T_0 space if for each pair of I_f distinct points $p, q \in X$ there exists an $I_f g_p^\# C$ set L in (X, τ_{if}) such that either $\tilde{p} \subseteq L$ and $\tilde{q} \not\subset L$ or $\tilde{q} \subseteq L$ and $\tilde{p} \not\subset L$.

Theorem 3.11 Let (X, τ_{if}) be an $I_f TS$. Then every I_f-T_0 space is an $I_f g_p^\#$-T_0 space in (X, τ_{if}).

Proof: We know that every $I_f C$ set is an $I_f g_p^\# C$ set. Hence the proof is obvious.

However, the reverse implication of the above theorem is not always the case. This could be verified from the following example.

Example 3.12 Let (X, τ_{if}) be an $I_f TS$ where $X = \{u, v\}$, $\tau_{if} = \{\tilde{o}, A, \tilde{1}\}$, $A = \{< p/0.2, 0.65 >, < q/0.3, 0.55 >\}$ and $L = \{< p/0.22, 0.6 >, < q/0.32, 0.5 >\}$ be an I_f set in (X, τ_{if}). Let $\tilde{p} = \{< p/0.2, 0.65 >\}$ and $\tilde{q} = \{< q/0.3, 0.55 >\}$ be two I_f points in (X, τ_{if}). Clearly $p, q \in X$ and $p \neq q$ such that $\tilde{p} \subseteq L$ and $\tilde{q} \not\subset L$. We also clearly observe that L is an $I_f g_p^\# C$ set but not an $I_f C$ set in (X, τ_{if}). Hence (X, τ_{if}) is an $I_f g_p^\#$-T_0 space but not an I_f-T_0 space.

4. Some Characteristics of $I_f g_p^\#$-T_0 Spaces

Theorem 4.1 Let an I_f bijective mapping $f: (X, \tau_{if}) \to (Y, \sigma_{if})$ be an $I_f g_p^\# C$ mapping. If (X, τ_{if}) is an I_f-T_0 space then (Y, σ_{if}) is an $I_f g_p^\#$-T_0 space.

Proof: Let $k, l \in (Y, \sigma_{if})$ and let $k \neq l$. Since f is an onto mapping there exist $p, q \in (X, \tau_{if})$ such that $f(p) = k$ and $f(q) = l$. Then $f(p) \neq f(q)$ which implies $p \neq q$ as f is a one-one mapping. Since $p, q \in (X, \tau_{if})$, $p \neq q$, and (X, τ_{if}) is an I_f-T_0 space, there exists an $I_f C$ set L in (X, τ_{if}) such that $p \in L$ and $q \notin L$. As f is an $I_f g_p^\# C$ mapping, $f(L)$ is an $I_f C$ set in (Y, σ_{if}) which implies $k = f(p) \in f(L)$ and $l = f(q) \notin f(L)$. Thus, we get $k, l \in (Y, \sigma_{if})$ with $k \neq l$. Therefore, there exists an $I_f g_p^\# C$ set $f(L) \in (Y, \sigma_{if})$ such that $k = f(p) \in f(L)$ and $l = f(q) \notin f(L)$. Hence (Y, σ_{if}) is an $I_f g_p^\#$-T_0 space.

Theorem 4.2 Let an I_f bijective mapping $f: (X, \tau_{if}) \to (Y, \sigma_{if})$ be an $I_f g_p^\# c$ mapping. If (Y, σ_{if}) is an I_f-T_0 space then (X, τ_{if}) is an $I_f g_p^\#$-T_0 space.

Proof: Let $p, q \in (X, \tau_{if})$ and let $p \neq q$. Since f is a one-one mapping $f(p), f(q) \in (Y, \sigma_{if})$ with $f(p) \neq f(q)$. Since (Y, σ_{if}) is an I_f-T_0 space, there exist an $I_f C$ set L in (Y, σ_{if}) such that either $f(p) \in L$, $f(q) \notin L$ or $f(q) \in L_1$ and $f(p) \notin L_1$. Now $f(p) \in L$ implies that $f^{-1}(f(p)) \in f^{-1}(L)$ and so $p \in f^{-1}(L)$. Similarly, $f(q) \in L_1$ implies that $f^{-1}(f(q)) \in f^{-1}(L)$ and so $q \in f^{-1}(L)$. This would be same with $p \notin f^{-1}(L)$ and $q \notin f(L)$. Thus if $p, q \in (X, \tau_{if})$ with $p \neq q$, there exists an $I_f g_p^\# C$ set $f^{-1}(L)$ such that either $p \in f^{-1}(L)$, $q \notin f^{-1}(L)$ or $q \in f^{-1}(L)$ and $p \notin f^{-1}(L)$. Hence (X, τ_{if}) is an $I_f g_p^\#$-T_0 space.

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