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ON INTUITIONISTIC FUZZY πgb AND πgb*-SETS

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ABSTRACT
In this paper, two kinds of intuitionistic fuzzy sets called πgb and πgb^* sets in intuitionistic fuzzy topological spaces are introduced and some of their basic properties are studied. In addition the relationships between πgb and πgb^*, also the relationships between πgb and πgb^* separately with other are investigated. Furthermore the πgb and πgb^* continuous functions are introduced which resulted in obtaining some interesting properties of both.
Key words: *Intuitionistic fuzzy πgb-closed set, intuitionistic fuzzy πgb*-closed set.*

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1. Intruduction

The concept of fuzzy set was introduced by L. A. Zadah [21]. The fuzzy concept has invaded almost all branches of mathematics. The concept of fuzzy topological space was introduced and developed by C. L. Chang [4]. Atanasov [3] was introduced the concept of intuitionistic fuzzy set, as a generalization of fuzzy set. This approach provided a wide field to the generalization of various concepts of fuzzy mathematics. In 1997 Coker[9] defined intuitionistic fuzzy topological spaces. Recently many concepts of fuzzy topological space have been extended in intuitionistic fuzzy (IF) topological spaces. D. Sreeja and C. Janaki [18] introduced the concepts of πgb-closed set. Dhanya and A. Parvath [7] introduced the concept of πgb∗ sets. Amal M. Al-Dowais and AbdulGawad A. Al-Qubati [2] have studied the slightly πgb-continuous functions in intuitionistic fuzzy topological spaces. In this paper we introduce two kinds of intuitionistic fuzzy sets which are called πgb and πgb∗ sets and discuss the relationship be- tween them and several kinds of intuitionistic fuzzy sets such as intuitionistic fuzzy πgb closed set and other. Also, we study two kinds of continuity which are intuitionistic fuzzy πgb-continuous functions and intuitionistic fuzzy πgb*- continuous functions. Lastly, our discussion focuses on the relationship between intuitionistic fuzzy πgb and πgb∗ sets.

2. Preliminaries

Definition2.1[3]LetXbeanon-emptyfixedset.Anintuitionisticfuzzyset (IFS in short) A in X is an object having the form $A = \{<x,\mu_A(x), \nu_A(x) >: x\in X\}$, where the function $\mu_A(x):X\to[0,1]$ and $\nu_A(x):X\to[0,1]$ 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 setA, respectively, and$0\le\mu_A(x) + \nu_A(x)\le 1$ for each $x\in X$. Denote by IFS(X), the set of all intuitionistic fuzzy sets in X.

Definition 2.2[3] Let A and B be IFSs of the form $A =\{<x,\mu_A(x),\nu_A(x)>: x \in X\}$ and $B = \{<x,\mu_B(x), \nu_B(x) >: x \in X\}$. Then:

(a) $A \subseteq B$ if and only if $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for all $x \in X$.
(b) $A = B$ if and only if $A \subseteq B$ and $B \subseteq A$.
(c) $A^c = \{< x, \nu_A(x), \mu_A(x) >: x \in X\}$.
(d) $A \cap B = \{<x, \mu_A(x) \wedge \mu_B(x), \nu_A(x) \vee \nu_B(x) >: x \in X\}$.
(e) $A \cup B = \{<x, \mu_A(x) \vee \mu_B(x), \nu_A(x) \wedge \nu_B(x) >: x \in X\}$.
(f) $0_\sim = \{< x, 0, 1 >: x \in X\}$ and $1_\sim = \{< x, 1, 0 >: x \in X\}$.
(g) $0_\sim^c = 1_\sim$ and $1_\sim^c = 0_\sim$

Definition 2.3 [5] Let $\alpha, \beta \in [0, 1]$ such that $\alpha + \beta \leq 1$. An intuitionistic fuzzy point (IFP) $p_{(\alpha,\beta)}$ is intuitionistic fuzzy set defined by

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

In this case, p is called the support of $p_{(\alpha,\beta)}$ and α, β are called the value and no value of $p_{(\alpha,\beta)}$ respectively.

Clearly an intuitionistic fuzzy point can be represented by an ordered pair of fuzzy point as follows: $p_{(\alpha,\beta)} = (p_\alpha, p_{(1-\beta)})$

In IFP$p_{(\alpha,\beta)}$ is said to belong to an IFS $A = \{<x, \mu_A(x), \nu_A(x) >: x \in X\}$ denoted by $p_{(\alpha,\beta)} \in A$, if $\alpha \leq \mu_A(x)$ and $\beta \geq \nu_A(x)$.

Definition2.4 [6] Let X and Y be two non-empty sets and f: X → Y be a function. Then:

(a) If $B=\{<y,\mu_B(y),\nu_B(y)>:y \in Y\}$ is an IFS in Y, then the pre image of B under f denoted by $f^{-1}(B)$ is the IFS in X defined by

$$f^{-1}(B) = \{< x, f^{-1}(\mu_B)(x), f^{-1}(\nu_B)(x) >: x \in X\}, \text{ where}$$

$$f^{-1}(\mu_B(x) = \mu_B(f(x)) \text{ and } f^{-1}(\nu_B(x) = \nu_B(f(x)).$$

(b) If $A = \{<x, \mu_A(x), \nu_A(x) >: x \in X\}$ is an IFS in X, then the image of A under f denoted by $f(A)$ is the IFS in Y defined by

$$f(A) = \{<y, f(\mu_A)(y), 1 - f(1 - \nu_A)(y) >: y \in Y\}$$

where,

$$f(\mu_A)(y) = \begin{cases} \sup\limits_{x \in f^{-1}(y)} \mu_A(x) & if\ f^{-1}(y) \neq \varnothing \\ 0, & \text{if otherwise} \end{cases}$$

$$1 - f(1-\nu_A)(y) = \begin{cases} \inf\limits_{x \in f^{-1}(y)} \nu_A(x) & if\ f^{-1}(y) \neq \varnothing \\ 1, & \text{if otherwise} \end{cases}$$

Replaying fuzzy sets [21] by intuitionistic fuzzy sets in Chang definition of fuzzy topological space [4] we get the following;

Definition 2.5[6] *Anintuitionistic fuzzy topology (IFT in short) on X is a family τ of IFSs in X satisfying the following axioms:*

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

(ii) If $G_1, G_2 \in \tau$, then $G_1 \cap G_2 \in \tau$

(iii) If $G_\lambda \in \tau$ for each λ in Λ, then $\bigcup_{\lambda \in \Lambda} G_\lambda \in \tau$.

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

Definition 2.6[9] *A subset A of an intuitionistic fuzzy space X is said to be cl open if it is intuitionistic fuzzy open set and intuitionistic fuzzy closed set.*

Definition 2.7 [4] *Let (X, τ) be an IFTS and $A = \{<x, \mu_A(x), \nu_A(x)>: x \in X\}$ bean IFS in X. Then the intuitionistic fuzzy interior and an intuitionistic fuzzy clouser are defined by:*
$\mathrm{int}(A) = \cup\{G : G$ is an IFOS in X and $G \subseteq A.\}$,$\mathrm{cl}(A) = \cap\{K : K$ is an IFCS in X and $A \subseteq K\}$.

Definition 2.8 An IFS A of an IFTS (X, τ) is an:
1. Intuitionistic fuzzy regular open set (IFROS in short)[9] if int(cl(A))= A.[9]
2. Intuitionistic fuzzy regular closed set (IFRCS in short)[9] if cl(intl(A))= A.[9]
3. Intuitionistic fuzzy π-open set (IFπOS in short)[15] if the finite union of intuitionistic fuzzy regular open sets.[15]
4. Intuitionistic fuzzy π-closed set (IFπCS in short)[15] if the finite inter- section of intuitionistic fuzzy regular closedsets.[15]
5.Intuitionistic fuzzy generalized closed set (IFGCS in short)[20] if cl(A)$\subseteq$U whenever A $\subseteq$ U and U is an IFOS in X.[20]
6.Intuitionisticfuzzy b-open set (IFbOSin short)[10] if A $\subseteq$ cl(int(A))$\cup$ int(cl(A)).[1]
7.Intuitionisticfuzzy b-closed set (IFbCSin short)[10] if cl(int(A))$\cup$ int(cl(A)) $\subseteq$ A.[1]
8.Intuitionistic fuzzy semi-closed set (IFSCS in short) if int(cl(A)) $\subseteq$ A.[9]
9.Intuitionistic fuzzy α-closed set (IFαCS in short) if cl(int(cl(A))) $\subseteq$ A.[9]
10.Intuitionistic fuzzy pre-closed set (IFPCS in short) if cl(int(A)) $\subseteq$ A.[9]
11.Intuitionisticfuzzygb-closedset(IFgbCSinshort)[13]ifbcl(A)$\subseteq$Uwhenever A $\subseteq$ U and U is IFOS in (X, τ).
12.Intuitionistic fuzzy gs-closed set (IFgsCS in short) [16]if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is IFOS in(X, τ).
13.Intuitionistic fuzzy gp-closed set (IFgpCS in short) [14]if pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is IFOS in (X, τ).
14.Intuitionistic fuzzy αg-closed set (IFαgCS in short) [17]if αcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is IFOS in (X, τ).
15.Intuitionistic fuzzy πg-closed set (IFπgCSin short) [8]if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is an IFπOS in (X, τ).
16.Intuitionistic fuzzy πgs-closed set (IFπgsCS in short) [11]if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is an IFπOS in (X, τ).
17.Intuitionistic fuzzy πgα-closed set (IFπgαCS in short) [19]if αcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is an IFπOS in (X, τ).

18.Intuitionistic fuzzy πgp-closed set (IFπgpCS in short) [12]if pcl(A) ⊆ U whenever A ⊆ U and U is an IFπOS in (X, τ) .

Definition 2.9 [13] Let (X, τ) be an IFTS and A be an IFS in X. Then the intuitionisticfuzzyb-interiorandanintuitionisticfuzzyb-clouseraredefinedby

bint(A) = ⋃ { G : G is an IFbOS in X and G ⊆ A. } ,

cl(A) = ∩ {K : K is an IFbCS in X and A ⊆ K}

Theorem 2.10 Let A be an intuitionistic fuzzy set of an IFTS (X, τ), then :

(i) bcl(A) = A ⋃ [int(cl(A)) ∩ cl(int(A))]

bint (A) = A ∩ [int(cl(A)) ⋃ cl(int(A))]

Proof.

Since bcl(A) is an IFbCS, we have int(cl(A)) ∩ cl(int(A)) ⊆ int(cl(bc(A)))∩cl(int(bcl(A)))⊆bcl(A)andwehave,A⊆bcl(A). Then,

A ∪ (int(cl(A)) ∩ cl(int(A))) ⊆bcl(A). − − − − − − > (1)

On the other hand, Since int(cl(A ∪int(cl(A)))) ⊆ A ∪int(cl(A)), and

cl(int(A ∪ cl(int(A)))) ⊆ A ∪ cl(int(A)), also

int(cl(A ∪ (int(cl(A)) ∩ cl(int(A))))) ⊆ A ∪int(cl(A))

, cl(int(A∪(cl(int(A))∩int(cl(A)))))⊆A∪cl(int(A))

Then, int(cl(A ∪ (int(cl(A)) ∩ cl(int(A)))) ∩ cl(int(A ∪ (cl(int(A)) ∩ int(cl(A))))) ⊆ [A ∪ int(cl(A))] ∩ [A ∪ cl(int(A))] = A ∪ [int(cl(A)) ∩ cl(int(A))]. Hence A ∪ [int(cl(A)) ∩ cl(int(A))] is an IFbCS and thus bcl(A) ⊆ A ∪ [int(cl(A)) ∩ cl(int(A))] − − − − − − > (2).

From (1) and (2) it follows that bcl(A) = A ∪ [int(cl(A)) ∩ cl(int(A))] (ii) can be proved easily by taking complement in (i).

3. Intuitionistic fuzzy πgb-set and Intuitionistic fuzzyπgb*-set

Definition 3.1 [2] An IFS A of an IFTS (X, τ) is an :

1. Intuitionistic fuzzy πgb-open set (IFπgbOSin short) if F ⊆bint(A) when- ever F ⊆ A and F is an IFπCS in (X, τ).

2.Intuitionistic fuzzy πgb-closed set (IFπgbCS in short) if bcl(A) ⊆ U when- ever A ⊆ U and U is an IFπOS in (X, τ).

Definition 3.2 Let (X, τ) be an IFTS and A = {<x,μ_A(x), ν_A(x) >:x ∊ X} beanIFSin(X,τ).Thentheintuitionisticfuzzyπgb-interiorandanintuition- istic fuzzy πgb-clouser of A are defined by:

πgb-int(A) = ⋃ { G : G is an IFπgbOS in X and G ⊆ A. } ,

πgb-cl(A) = ∩ {K : K is an IFπgbCS in X and A ⊆ K} .

Theorem 3.3 If A is IFπgbCS in X, then πgb-cl(A) = A.

Proof. Since A is an IFπgbCS, πgb-cl(A) is the smallest IFπgbCSwhich contains A, which is nothing but A. Hence πgb-cl(A)=A. ■

Remark 3.4 If A = πgb-cl(A), then A need not be an IFπgbCS.

Example 3.5 Let X = {a, b, c} and let τ = {$0_\sim$, $1_\sim$, A, B, C} is IFT on X, whereA={<a,1,0>,<b,0,1>,<c,0,1>},B={<a,0,1>,<b,0.8,0.2> , < c, 0, 1 >} and C = {< a, 1, 0 >, < b, 0.8, 0.2 >, < c, 0, 1 >}. Clearly πgb-cl(C) = C but C is notIFπgbCS.

Theorem 3.6 If A is IFπgbOS in X, then πgb-int(A) = A.

Proof. Similar to the(theorem3.3)

Remark 3.7 If A = πgb-int(A), then A need not be an IFπgbOS.

Example 3.8 Let X = {a, b, c} and let τ = {$0_\sim$, $1_\sim$, A, B, C} is IFT on X, whereA={<a,1,0>,<b,0,1>,<c,0,1>},B={<a,0,1>,<b,0.8,0.2> , < c, 0, 1 >} and C = {< a, 1, 0 >, < b, 0.8, 0.2 >, < c, 0, 1 >}. let D ={< a, 0, 1 >, < b, 0.2, 0.8 >, < c, 1, 0 >}, clearly πgb-int(D) = D but D isnot IFπgbOS.

Remark 3.9 The union of two IFπgb-closed sets is generally not aIFπgb-closedsetandtheintersectionoftwoIFπgb-opensetsisgenerallynotanIFπgb- openset

Example 3.10 Let X = {a, b} and let τ = {$0_\sim$, $1_\sim$, A, B, C} is IFT on X,where A = {< a, 1, 0 >, < b, 0, 1 >}, B = {< a, 0, 1 >, < b, 0.9, 0.1 >}and C = {< a, 1, 0 >, < b, 0.9, 0.1 >}. Then the IFSs A^c, B^c are IFπgbOSs but $A^c \cap B^c = C^c$ is not an IFπgbOS of X, since $C^c \subseteq C^c$ and $C^c \not\subset$ bint(C^c) = $0_\sim$. And the IFSs A, B are IFπgbCSs but A ∪ B = C is not an IFπgbCS of X, since C ⊆ C and bcl(C) = $1_\sim \not\subset$ C.

Theorem 3.11 Every intuitionistic fuzzy closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy closed set of (X, τ) such that A⊆ U and U is an IFπ-open set in (X, τ). Since int(cl(A)) ∩cl(int(A)) ⊆int(cl(A))=cl(A) = A, A ∪ [int(cl(A)) ∩ cl(int(A))] ⊆ A ∪ A = A, then bcl(A) ⊆ A ⊆U. Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example 3.12 Let X ={a, b} and let τ ={$0_\sim$, $1_\sim$, U} is an IFT on X, where U = {< a, 0.5, 0.4 >, < b, 0.6, 0.4 >}. Let A = {< a, 0.3, 0.6 >, < b, 0.2, 0.8 >}, then A is an IFπgbCS but it is not IFCS. Since cl(A) = $U^c \neq$ A.

Theorem 3.13 Every intuitionistic fuzzy semi-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy semi-closed set of (X, τ) such that
A ⊆ U and U is an IFπ-open set in (X, τ). Since
int(cl(A))∩ cl(int(A)) ⊆ int(cl(A))
⇒ int(cl(A))∩cl(int(A))⊆ A
and A∪ (int(cl(A))∩cl(int(A)))⊆ A∪ A=A
This implies bcl(A) ⊆ A ⊆ U . Hence A is an intuitionistic fuzzy πgb-closed set.

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The converse of above theorem is not true in general, as we will see in the following example.

Example 3.14 Let $X = \{a, b\}$ and let $\tau = \{0_\sim, 1_\sim, U\}$ is an IFT on X, where $U = \{< a, 0.8, 0.2 >, < b, 0.9, 0.1 >\}$. Let $A = \{< a, 0.4, 0.6 >, < b, 0.5, 0.5 >\}$, then A is an IFπgbCS but it is not IFSCS. Since $int(cl(A)) = 1_\sim \not\subset A$.

Theorem 3.15 Every intuitionistic fuzzy α-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy α-closed set of (X, τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ). Since$A \subseteq cl(A)$, $cl(int(A)) \subseteq cl(int(cl(A))) \Rightarrow$ $cl(int(A)) \subseteq A$ and $cl(int(A)) \cap int(cl(A)) \subseteq A \cap int(cl(A))$
$cl(int(A)) \cap int(cl(A)) \subseteq A \cap cl(int(cl(A))) \Rightarrow cl(int(A)) \cap int(cl(A)) \subseteq A \cap A$ and $cl(int(A)) \cap int(cl(A)) \subseteq A$
then $A \cup (cl(int(A)) \cap int(cl(A))) \subseteq A \cup A = A$
This implies $bcl(A) \subseteq A \subseteq U$. Hence A is an intuitionistic fuzzy πgb-closedset. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example3.16 Let $X=\{a,b,c\}$ and let $\tau=\{0_\sim, 1_\sim, A, B, C\}$ is an IFT on X, where $A=\{<a,1,0>,<b,0,1>,<c,0,1>\}$,$B=\{<a,0,1>,<b,0.8,0.2>,<c,0.3,0.7>\}andC=\{<a,1,0>,<b,0.8,0.2>,<c,0.3,0.7>\}$. Then B is an IFπgbCS but it is not IFαCS. Since $cl(int(cl(B))) = A^c \not\subset B$.

Theorem 3.17 Every intuitionistic fuzzy pre-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy pre-closed set of (X, τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ). Since $int(cl(A)) \cap cl(int(A)) \subseteq cl(int(A))$ and $int(cl(A)) \cap cl(int(A)) \subseteq A$
then $A \cup (int(cl(A)) \cap cl(int(A))) \subseteq A \cup A = A$ This implies $bcl(A) \subseteq A \subseteq U$. Hence A is an intuitionistic fuzzy πgb-closedset. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example3.18 Let$X=\{a,b,c\}$ and let $\tau=\{0_\sim, 1_\sim, A, B, C\}$ is an IFT on X, where $A=\{<a,1,0>,<b,0,1>,<c,0,1>\}$,$B=\{<a,0,1>,<b,0.5,0.4>,<c,0.4,0.6>\}$ and $C=\{<a,1,0>,<b,0.5,0.4>,<c,0.4,0.6>\}$. Then B is an IFπgbCS but it is not IFPCS. Since $cl(int(B)) = A^c \not\subset B$.

Theorem 3.19 Every intuitionistic fuzzy b-closed set is an intuitionistic fuzzy πgb-closed set.

Proof.Let A be anintuitionistic fuzzy b-closed set of (X,τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ). Since $bcl(A) = A \subseteq U$. Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

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Example 3.20 Let $X = \{a, b\}$ and let $\tau = \{0_\sim, 1_\sim, U\}$ is an IFT on X, where $U=\{<a,0.8,0.2>,<b,0.9,0.1>\}$.Let$A=\{<a,0.9,0.1>,<b,1,0>\}$,then A is an IFπgbCS but it is not IFbCS, since $int(cl(A)) \cap cl(int(A)) = 1_\sim \not\subset A$.

Theorem 3.21 Every intuitionistic fuzzy g-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy g-closed set of (X,τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ), since every IFπ-open set is an intuitionistic fuzzy open set and $cl(A) \subseteq U$ .Since
$int(cl(A)) \cap cl(int(A)) \subseteq int(cl(A)) \subseteq cl(cl(A)) = cl(A)$, $A \cup (int(cl(A)) \cap cl(int(A))) \subseteq A \cup cl(A) = cl(A)$
This implies $bcl(A) \subseteq cl(A) \subseteq U$. Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example 3.22 Let $X = \{a, b\}$ and let $\tau = \{0_\sim, 1_\sim, U\}$ is an IFT on X,where $U = \{< a, 0.7, 0.3 >, < b, 0.6, 0.4 >\}$. Let $A = \{< a, 0.2, 0.8 >, < b, 0.4, 0.6 >\}$, then A is an IFπgbCS but it is not IFgCS. Since $cl(A) = U^c \not\subset U$.

Theorem 3.23 Every intuitionistic fuzzy αg-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy αg-closed set of (X, τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ). Since every IFπ-open set is an intuitionistic fuzzy open set, $\alpha cl(A) \subseteq U$ .Since
$A \subseteq cl(A)$
, $cl(int(A)) \subseteq cl(int(cl(A)))$
, $cl(int(A)) \cap int(cl(A)) \subseteq cl(int(cl(A))) \cap int(cl(A))$
$\Rightarrow$ $cl(int(A)) \cap int(cl(A)) \subseteq cl(int(cl(A))) \cap cl(int(cl(A)))$
$\Rightarrow$ $cl(int(A)) \cap int(cl(A)) \subseteq cl(int(cl(A)))$
then $A \cup (cl(int(A)) \cap int(cl(A))) \subseteq A \cup cl(int(cl(A)))$
This implies $bcl(A) \subseteq \alpha cl(A) \subseteq U$. Hence A is anintuitionistic fuzzy πgb-closed set. ■
The converse of above theorem is not true in general, as we will see in the following example.

Example3.24 Let $X=\{a,b\}$ and let $\tau=\{0_\sim,1_\sim,U\}$ is an IFT on X, where $U = \{< a, 0.3, 0.4 >, < b, 0.3, 0.4 >\}$. Let $A = \{< a, 0.1, 0.5 >, < b, 0.1, 0.6 >\}$, then A is an IFπgbCS but it is not IFαgCS, since $\alpha cl(A) = U^c \not\subset U$.

Theorem 3.25 Every intuitionistic fuzzy gs-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy gs-closed set of (X, τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ). Since every IFπ-open set is an intuitionistic fuzzy open set, $scl(A) \subseteq U$ .Since

$int(cl(A)) \cap cl(int(A)) \subseteq int(cl(A))$
then $A \cup (int(cl(A)) \cap cl(int(A))) \subseteq A \cup int(cl(A))$
This implies $bcl(A) \subseteq scl(A) \subseteq U$. Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example 3.26 Let X ={a, b} and let τ ={$0_\sim$, $1_\sim$, U} is an IFT on X,where
U = {< a, 0.7, 0.2 >, < b, 0.7, 0.3 >}. Let A = {< a, 0.5, 0.5 >, < b, 0.5, 0.5 >},
then A is an IFπgbCS but it is not IFgsCS, since scl(A) = $1_\sim \not\subset$ U.

Theorem 3.27 Every intuitionistic fuzzy gp-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A bean intuitionistic fuzzy gp-closed set of (X, τ) such that A ⊆ U and U is an IFπ-open set in (X, τ). Since every IFπ-open set is an intuitionistic fuzzy open set, pcl(A) ⊆ U .Since
int(cl(A))∩ cl(int(A)) ⊆ cl(int(A)) ,A∪ (int(cl(A))∩cl(int(A)))⊆ A∪ cl(int(A))
This implies bcl(A) ⊆pcl(A) ⊆ U . Hence A is an intuitionistic fuzzyπgb-closed set. ■
The converse of above theorem is not true in general, as we will see in the following example.

Example 3.28 Let X={a,b} and let τ={$0_\sim$,$1_\sim$,U} is an IFT on X,where U={<a,0.5,0.5>,<b,0.2,0.6>}. Let A=U, then A is an IFπgbCS but it is not IFgpCS, since pcl(A)=$U^c \not\subset$U.

***Theorem 3.29** Every intuitionistic fuzzy gb-closed set is an intuitionistic fuzzy πgb-closed set.*

Proof.Let A be an intuitionistic fuzzy gb-closed set of (X, τ) such that A ⊆ U and U is an IFπ-open set in (X, τ). Since every IFπ-open set is an intuitionistic fuzzy open set, bcl(A) ⊆ U . Hence A is an intuitionistic fuzzy πgb-closedset. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example3.30 Let X={a,b} and let τ={$0_\sim$,$1_\sim$,U} is an IFT on X, where U={<a,0.6,0.3>,<b,0.8,0.2>}. Let A=U, then A is an IFπgbCS but it is not IFgbCS, since bcl(A)=$1_\sim \not\subset$U.

Theorem 3.31 Every intuitionistic fuzzy πg-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy πg-closed set of (X,τ) such thatA ⊆ U and U is an IFπ-open set in (X, τ). Then cl(A) ⊆ U and asbcl(A)⊆cl(A) ⊆ U . Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example 3.32 Let X ={a, b} and let τ ={$0_\sim$, $1_\sim$, U} is an IFT on X, where
U = {< a, 0.1, 0.9 >, < b, 0.3, 0.7 >}. Let A = {< a, 0, 1 >, < b, 0.2, 0.7 >},
then A is an IFπgbCS but it is not IFπgCS, since cl(A) = $U^c \not\subset$U.

Theorem 3.33 Every intuitionistic fuzzy πgα-closed set is an intuitionistic fuzzy πgb-closed

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set.

Proof. Let A be an intuitionistic fuzzy πgα-closed set of (X,τ) such thatA ⊆ U and U is an IFπ-open set in (X, τ). Then αcl(A) ⊆ U , and asbcl(A)⊆αcl(A) ⊆ U . Hence A is an intuitionistic fuzzy πgb-closed set.■

The converse of above theorem is not true in general, as we will see in the following example.

Example 3.34 Let X ={a, b} and let τ ={0~ , 1~ , U} is an IFT on X,where U = {< a, 0.3, 0.6 >, < b, 0.5, 0.5 >}. Let A = {< a, 0.2, 0.8 >, < b, 0.4, 0.6 >}, then A is an IFπgbCS but it is not IFπgαCS, since αcl(A) = $U^c \not\subset U$.

Theorem 3.35 Every intuitionistic fuzzy πgp-closed set is an intuitionistic fuzzy πgb-closed set.

Proof. Let A be an intuitionistic fuzzy πgp-closed set of (X, τ) such thatA ⊆ U and U is an IFπ-open set in (X, τ). Then pcl(A) ⊆ U , and asbcl(A)⊆pcl(A) ⊆ U . Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example 3.36 Let X ={a, b} and let τ ={0~, 1~, U_1, U_2, U_3} is an IFT on X, where U_1={<a,0,1>,<b,0.7,0.3>},U_2={<a,0.8,0.2>,<b,0,1>}, U_3={<a,0.8,0.2>,<b,0.7,0.3>}.LetA=U_2,thenAisanIFπgbCS but it is not IFπgpCS, since pcl(A) = $U^c \not\subset U_3$.

Theorem 3.37 Every intuitionistic fuzzy πgs-closed set is an intuitionistic fuzzy πgb-closed set.

Proof Let A be an intuitionistic fuzzy πgs-closed set of (X,τ) such that A ⊆ U and U is an IFπ-open set in (X, τ). Then scl(A) ⊆ U , and asbcl(A)⊆scl(A) ⊆ U . Hence A is an intuitionistic fuzzy πgb-closed set. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example3.38 LetX={a,b}andletτ={0~,1~,U_1,U_2,U_3,U_4,U_5}is an IFT on X, where U_1={<a,0.1,0.4>,<b,0.3,0.2>},U_2={<a,0.3,0.2>,<b,0.2,0.3>},U_3={<a,0.1,0.4>,<b,0.2,0.3>} ,U_4={<a,0.3,0.2>,<b,0.3,0.2 >},U_6= {<a,0.4,0.2 >,<b,0.3,0.2 >}.Let A= {<a,0.3,0.4>,<b,0.3,0.4>},thenAisanIFπgbCSbutitisnotIFπgsCS,sincescl(A)= $U_5 \not\subset U_4$.

Definition 3.39 An IFS A of an IFTS (X, τ) is an :

1. Intuitionistic fuzzy πgb' -open set (IFπgb' OSinshort) if F⊆ cl(bint(A)) whenever F ⊆ A and F is an IFπCS in (X, τ).
2. Intuitionistic fuzzy πgb' -closed set (IFπgb' CSinshort) if int(bcl(A))⊆ U whenever A ⊆ U and U is an IFπOS in (X, τ).

Remark 3.40 The union off inite IFπgb' -closed sets is generally no tan IFπgb' -closed set and the intersection off initeIFπgb' -open sets is generally no tanIFπgb' -open set.

Example 3.41 Let X = {a, b} and let τ = {0~ , 1~ , A, B, C} is IFT on X, where A = {< a, 1, 0 >, < b, 0, 1 >}, B = {< a, 0, 1 >, < b, 0.9, 0.1 >} and C={<a,1,0>,<b,0.9,0.1>}. Then the IFSsA^c,B^c are IFπgb' Oss but $A^c \cap B^c = C^c$ is not an

IFπgb' O So fX, since $C^c \subseteq C^c$ and $C^c \not\subset cl(bint(C^c)) = 0_\sim$.
And the IFSs A,B are IFπgb' CSs but $A \cup B = C$ is not an IFπgb' CS of X, since $C \subseteq C$ and $int(bcl(C)) = 1_\sim \not\subset C$.

Theorem3.42

1. Every intuitionistic fuzzy closed set is an intuitionistic fuzzy πgb*-closed set.
2. Every intuitionistic fuzzy semi-closed set is an intuitionistic fuzzy πgb^* - closed set.
3. Every intuitionistic fuzzy pre-closed set is an intuitionistic fuzzy πgb^* - closedset.
4. Every intuitionistic fuzzy α- closed set is an intuitionistic fuzzy πgb^* -closed set.
5. Every intuitionistic fuzzy b- closed set is an intuitionistic fuzzy πgb^* -closed set.
6. Every intuitionistic fuzzy g- closed set is an intuitionistic fuzzy πgb^* -closed set.
7. Every intuitionistic fuzzy gs- closed set is an intuitionistic fuzzy πgb^* -closed set.
8. Every intuitionistic fuzzy gp- closed set is an intuitionistic fuzzy πgb^* -closed set.
9. Every intuitionistic fuzzy gα-closed set is an intuitionistic fuzzy πgb^* - closedset.
10. Every intuitionistic fuzzy gb- closed set is an intuitionistic fuzzy πgb^* -closed set.
11. Every intuitionistic fuzzy πg- closed set is an intuitionistic fuzzy πgb^* -closed set.
12. Every intuitionistic fuzzy πgs-closed set is an intuitionistic fuzzy πgb^* - closedset.
13. Every intuitionistic fuzzy πgα-closed set is an intuitionistic fuzzy πgb^* - closedset.
14. Every intuitionistic fuzzy πgp-closed set is an intuitionistic fuzzy πgb^* - closedset.

Proof. It is similar to that of (theorems (3.11), (3.13), (3.15), (3.17), (3.19), (3.21), (3.23), (3.25), (3.27), (3.29), (3.31), (3.33), (3.35) and (3.37)). ■

4. Intuitionistic Fuzzy πgb Continuous Functions and Intuitionistic Fuzzy πgb∗ Continuous Functions

Definition 4.1 [2] Let f be a function from an IFTS(X,τ) into an IFTS(Y,σ). Then f is said to be an intuitionistic fuzzy πgb-continuous if $f^{-1}(F)$ is an intuitionistic fuzzy πgb-closed in (X,τ) for every intuitionistic fuzzy closed set F of (Y,σ).

Theorem 4.2 A function $f: (X, \tau) \to (Y, \sigma)$ is intuitionistic fuzzy πgb- continuous if and only if the inverse image of every intuitionistic fuzzy open set of (Y,σ) is intuitionistic fuzzy πgb-open set in (X,τ).

Proof. Necessity: Let A be an IFOS in(Y, σ). Then A^c is an IFCS in (Y, σ). By hypothesis, $f^{-1}(A^c)$ is an IFπgbCSin (X, τ). Then $f^{-1}(A^c) = (f^{-1}(A))^c$, implies $f^{-1}(A)$ is an IFπgbOSin(X,τ).
Sufficiency: Let A be an IFCS in (Y, σ). Then A^c is an IFCS in (Y, σ).By hypothesis, $f^{-1}(A^c)$ is an IFπgbOSin(X,τ). But $f^{-1}(A^c)=(f^{-1}(A))^c$, which in turn implies $f^{-1}(A)$ is an IFπgbCSin(X,τ). Hence f is intuitionistic fuzzy πgb-continuous. ■

Theorem 4.3 Let $f: (X, \tau) \to (Y, \sigma)$ from a IFTS (X, τ) to another IFTS (Y, σ) is IFπgb-continuous. Then the following statements hold.

1. $f(\pi gb\text{-}cl(A)) \subseteq cl(f(A))$,for every intuitionistic fuzzy set A in (X,τ).
2. $\pi gb\text{-}cl(f^{-1}(B)) \subseteq f^{-1}(cl(B))$,foreveryintuitionisticfuzzysetBin(Y,σ).

Proof.

1. Let A beany set in (X, τ). Then cl(f (A)) is an IFCS in (Y, σ). Since $f$is an IFπgb-continuous, $f^{-1}(cl(f(A)))$ is an IFπgbCSin (X, τ). Since $A \subseteq f^{-1}(f(A)) \subseteq f^{-1}(cl((f(A)))$ and $f^{-1}(cl((f(A)))$ is anIFπgbCS,
impliesπgb-cl(A) $\subseteq \pi gb- cl(f^{-1}(cl((f(A)))) = f^{-1}(cl((f(A)))$.Hence

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f(πgb-cl(A)) ⊆ (cl((f (A))).

2. Replacing A by f^{-1}(B) in (i), we get f(πgb−cl(f^{-1}(B)))⊆ cl(f(f^{-1}(B)))⊆ cl(B) f (πgb− cl(f^{-1}(B))) ⊆ cl(B) Hence πgb-cl(f^{-1}(B))⊆ f^{-1}(cl(B)).

■

Definition 4.4 A bijection function f:(X,τ)→(Y,σ) is called an intuitionistic fuzzy πgb homeomorphism (IFπgbhomeinshort) if f and f^{-1} are IFπgb- continuous functions.

Example 4.5 Let X ={a, b}, Y ={u, v} and U_1 = {< a, 0.3, 0.6 >, < b, 0.3, 0.7 >}, U_2 = {< u, 0.4, 0.4 >, <v, 0.8, 0.2 >}, then τ = {$0_\sim$, $1_\sim$,U_1}
And σ={$0_\sim$,$1_\sim$,U_2} are IFT's on X and Y, respectively. Define a bisection function f:(X,τ)→(Y,σ) by f(a)=v and f(b)=u. Then f is an IFπgb- continuous function and f^{-1} is also an IFπgb-continuous function. Therefore f is an intuitionistic fuzzy πgb homeomorphism.

Definition 4.6 Let f be a function from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an intuitionistic fuzzy πgb*-continuous if f^{-1}(F) is an intuitionisticfuzzyπgb*-closedin(X,τ)foreveryintuitionisticfuzzyclosedset F of (Y,σ).

Theorem 4.7 Let f: (X, τ) → (Y, σ) from a IFTS (X, τ) to another IF (Y, σ) is IFπgb* -continuous. Then the following statements hold.

(i) f (πgb*-cl(A))⊆ cl(f(A)),for every intuitionistic fuzzy set A in (X,τ).
(ii) πgb*-cl(f^{-1}(B))⊆ f^{-1}(cl(B)),for every intuitionistic fuzzy set B in (Y, σ).

Proof. It is similar to that of(theorem4.3). ■

Definition 4.8 A bijection function f: (X, τ) → (Y, σ) is called an intuitionistic fuzzy πgb* homeomorphism(IFπgb*home in short) if f and $f^{-1}$are IFπgb*-continuous functions.

Theorem4.9

1. Every intuitionistic fuzzy continuous function is an intuitionistic fuzzy πgb-continuous.
2. Every intuitionistic fuzzy semi-continuous function is an intuitionistic fuzzy πgb-continuous.
3. Every intuitionistic fuzzy pre-continuous function is an intuitionistic fuzzy πgb-continuous.
4. Every intuitionistic fuzzy α-continuous function is an intuitionistic fuzzy πgb-continuous.
5. Every intuitionistic fuzzy b-continuous function is an intuitionistic fuzzy πgb-continuous.
6. Every intuitionistic fuzzy g-continuous function is an intuitionistic fuzzy πgb-continuous.
7. Every intuitionistic fuzzy gs-continuous function is an intuitionistic fuzzy πgb-continuous.
8. Every intuitionistic fuzzy gp-continuous function is an intuitionistic fuzzy πgb-continuous.
9. Every intuitionistic fuzzy gα-continuous function is an intuitionistic fuzzy πgb- continuous.
10. Every intuitionistic fuzzy gb-continuous function is an intuitionistic fuzzy

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πgb- continuous.

11. Every intuitionistic fuzzy πg-continuous function is an intuitionistic fuzzy πgb- continuous.
12. Every intuitionistic fuzzy πgs-continuous function is an intuitionistic fuzzy πgb- continuous.
13. Every intuitionistic fuzzy πgα-continuous function is an intuitionistic fuzzy πgb continuous.
14. Every intuitionistic fuzzy πgp-continuous function is an intuitionistic fuzzy πgb- continuous.

Proof.

1. Let f:(X,τ)→(Y,σ) be an intuitionistic fuzzy continuous function. Let V be an intuitionistic fuzzy closed set in (Y,σ). Since f is an intuitionistic fuzzy continuous f^{-1}(V) is an intuitionistic fuzzy closed set in (X,τ). As every intuitionistic fuzzy closed set is an intuitionistic fuzzy πgb-closed set, f^{-1}(V) is an intuitionistic fuzzy πgb-closed set. Hence f is an intuitionistic fuzzy πgb-continuous.

2. It is similar to that of above. ■

The converse of above theorem is not true in general, as we will see in the following example.

Example 4.10 Let X ={a, b}, Y ={u, v} and U_1 = {< a, 0.1, 0.8 >, < b, 0.5, 0.5 >}, U_2 = {< u, 0.6, 0.4 >, <v, 0.9, 0.1 >}, then τ = {$0_\sim$, $1_\sim$,U_1}
And σ ={$0_\sim$,$1_\sim$,U_2} are IFT's on X and Y respectively. Define A function f:(X,τ)→(Y,σ) by f (a)=v and f (b)=u. Therefore f is an intuitionistic fuzzy πgb-continuous but not an intuitionistic fuzzy continuous function, since
$f^{-1}(U_2^c)$ = {<a,0.1,0.9>,<b,0.4,0.6>}, $cl(f^{-1}(U_2^c)) = U_2^c \neq f^{-1}(U_2^c)$

Theorem 4.11

1. Every intuitionistic fuzzy continuous function is an intuitionistic Fuzzy πgb*-continuous.
2. Every intuitionistic fuzzy semi-continuous function is an intuitionistic fuzzy πgb* -continuous.
3. Every intuitionistic fuzzy pre-continuous function is an intuitionistic fuzzy πgb* -continuous.
4. Every intuitionistic fuzzy α-continuous function is an intuitionistic fuzzy πgb* -continuous.
5. Every intuitionistic fuzzy b-continuous function is an intuitionistic fuzzy πgb* -continuous.
6. Every intuitionistic fuzzy g-continuous function is an intuitionistic fuzzy πgb* -continuous.
7. Every intuitionistic fuzzy gα-continuous function is an intuitionistic fuzzy πgb* -continuous.
8. Every intuitionistic fuzzy gs-continuous function is an intuitionistic fuzzy πgb* -continuous.
9. Every intuitionistic fuzzy gp-continuous function is an intuitionistic fuzzy πgb* -continuous.
10. Every intuitionistic fuzzy gb-continuous function is an intuitionistic fuzzy πgb* -continuous.
11. Every intuitionistic fuzzy πg-continuous function is an intuitionistic fuzzy πgb* -continuous.
12. Every intuitionistic fuzzy πgs-continuous function is an intuitionistic fuzzy πgb* -

continuous.

13. Every intuitionistic fuzzy πgp-continuous function is an intuitionistic fuzzy πgb^*-continuous.
14. Every intuitionistic fuzzy πgα-continuous function is an intuitionistic fuzzy πgb^*-continuous.

Proof. It is similar to that of (theorem 4.9).■

5 Relation Between $IF\pi gb$-Sets and $IF\pi gb^*$-Sets

Theorem 5.1 Every intuitionistic fuzzy πgb-closed set is an intuitionistic fuzzy πgb^*-closed set.

Proof. Let A be an intuitionistic fuzzy πgb-closed set of (X, τ) such that $A \subseteq U$ and U is an IFπ-open set in (X, τ). Since every IFπ-open set is an IF open set, $bcl(A) \subseteq U$.
Thus $int(bcl(A)) \subseteq int(U) = U$. Hence A is an intuitionistic fuzzy πgb^*-closedset. ■

The converse of above theorem is not true in general, as we will see in the following example

Example 5.2 Let X ={a, b} and let τ ={$0_\sim$, $1_\sim$, U_1, U_2, U_3} is an IFT on X, where U_1={<a,0,1>,<b,0.7,0.3>},U_2={<a,0.8,0.2>,<b,0,1>},U_3={<a,0.8,0.2>,<b,0.7,0.3>}
.Let A={<a,0.7,0.3>,<b,0.7,0.3>},then A is an $IF\pi gb^*CS$ but it is not $IF\pi gbCS$, since bcl(A)={<a,0.7,0.3>, < b, 1, 0 >} $\not\subset U_3$.

Theorem 5.3 Every intuitionistic fuzzy πgb-continuous function is an intu- itionistic fuzzy πgb^*-continuous.

Proof. Let f: (X, τ) ⟶ (Y, σ) be an intuitionistic fuzzy πgb-continuous function. Let V be an intuitionistic fuzzy closed set in (Y, σ). Since f is an intuitionistic fuzzy πgb-continuous f^{-1}(V) is an intuitionistic fuzzy πgb-closed set in (X, τ). As every intuitionistic fuzzy πgb-closed set is an intuitionistic fuzzy πgb^*-closed set, f^{-1}(V) is an intuitionistic fuzzy πgb^*-closed set. Hence f is an intuitionistic fuzzy πgb^*-continuous.■

The converse of above theorem is not true.

Example5.4 Let X={a,b},Y={u,v} and U_1={<a,0,1>,<b,0.6,0.4>},
U_2 = {< a, 0.7, 0.3 >, <v, 0, 0.1 >}, U_3 = {< a, 0.7, 0.3 >, < b, 0.6, 0.4>},
U_4 = {< u, 0.4, 0.6 >, <v, 0.4, 0.6 >}, then τ = {$0_\sim$, $1_\sim$, U_1, U_2, U_3} and σ=
{$0_\sim$,$1_\sim$,U_4} are IFT's on X and Y respectively. Define A function f:(X,τ)⟶(Y,σ) by f(a)=u and f(b)=v. Therefore f is an intuitionistic fuzzy πgb^*- continuous but not an intuitionistic fuzzy πgb-continuous function.

Theorem 5.5 Every intuitionistic fuzzy πgb homeomorphism is an intuitionistic fuzzy πgb^* homeomorphism.

Proof. Let f: (X, τ) ⟶ (Y, σ) be an IFπgb homeomorphism. Then f and f^{-1} are IFπgb-continuous functions. This implies f and f^{-1} are $IF\pi gb^*$- continuous functions. Therefore, f is an intuitionistic fuzzy πgb^* homeomorphism. ■
The converse of above theorem is not true.

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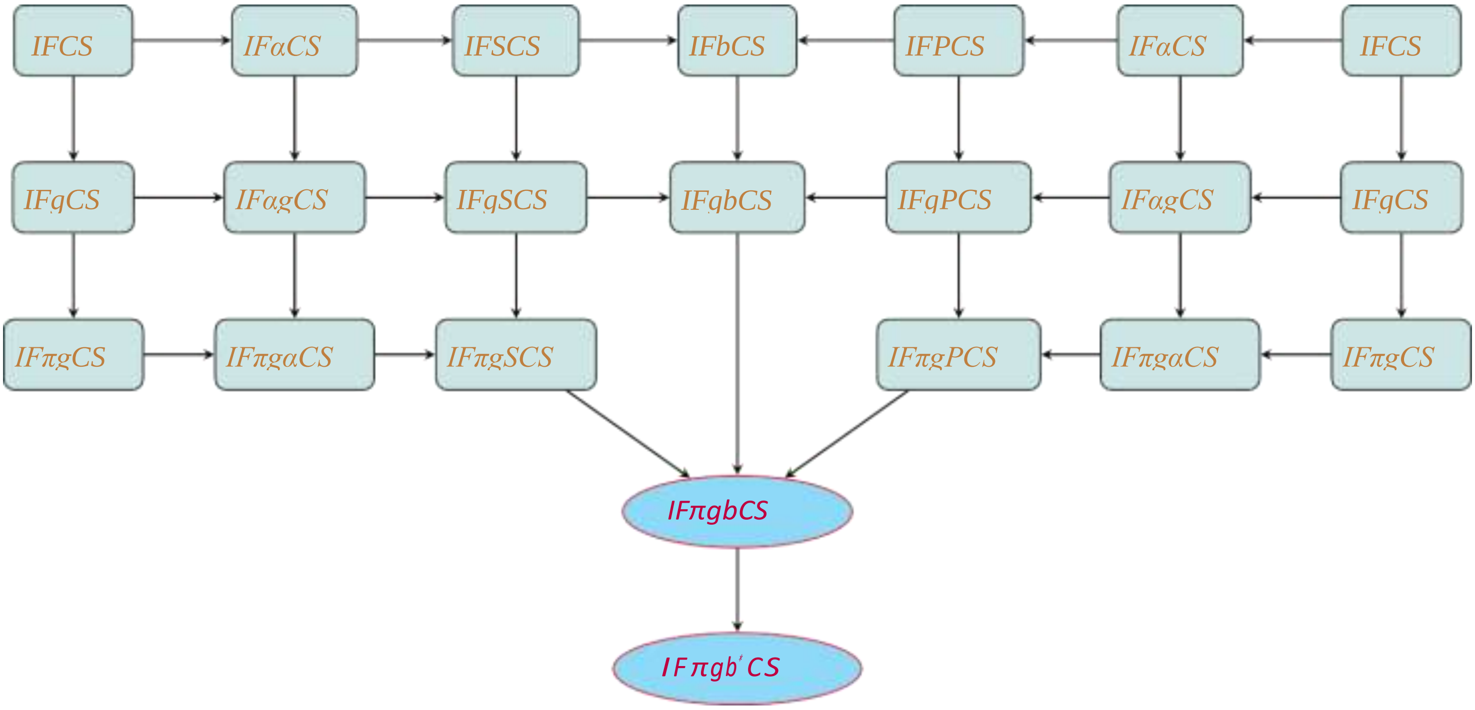

Example 5.6 Let$X=\{a,b\}$,$Y=\{u,v\}$and$U_1=\{<a,0,1>,<b,0.6,0.4>\}$, $U_2=\{<a,0.8,0.2>,<b,0,1>\}$, $U_3=\{<a,0.8,0.2>,<b,0.6,0.4>\}$, $U_4=\{<u,0.4,0.6>,<v,0.4,0.6>\}$, then $\tau=\{0_\sim,1_\sim,U_1,U_2,U_3\}$ and $\sigma=\{0_\sim,1_\sim,U_4\}$ are IFT's on X and Y, respectively. Define a bijection function $f:(X,\tau)\to(Y,\sigma)$ by$f(a)=u$and$f(b)=v$. Then f is an intuitionistic fuzzy πgb^* homeomorphism but not an intuitionistic fuzzy πgb homeomorphism, since f is not an IFπgb-continuous function. Hence f is not an IFπgb homeomorphism.

Conclusion

As an extension of this paper, can be study more properties of intuitionistic fuzzy πgb and πgb*-sets with other intuitionistic fuzzy sets.

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