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ON INTUITIONISTIC FUZZY GENERALIZED PRE CONTINUOUS MAPPINGS

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Abstract

The purpose of this paper is to introduce and study the concepts of intuitionistic fuzzy generalized pre continuous mappings in intuitionistic fuzzy topological space. I investigate some of their properties.

Keywords:

Intuitionistic fuzzy topology; Intuitionistic fuzzy generalized pre closed set; Intuitionistic fuzzy generalized pre continuous mappings.

1. Introduction

After the introduction of fuzzy sets by Zadeh [11] in 1965 and fuzzy topology by chang [2] in 1967, several researches were conducted on the generalizations of the notions of fuzzy sets and fuzzy topology. The concept of intuitionistic fuzzy sets was introduced by Atanassov [1] as a generalization of fuzzy sets. In 1997 Coker [3] introduced the concept of intuitionistic fuzzy topological spaces.

In the present paper, I introduce and study the concepts of intuitionistic fuzzy generalized pre continuous mappings in intuitionistic fuzzy topological space.

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2. 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 functions $\mu_A(x): X \to [0, 1]$ 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 set A, respectively, and $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for each $x \in X$. Denote by IFS(X), the set of all intuitionistic fuzzy sets in X.

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

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

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

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

For the sake of simplicity, we shall use the notation $A = \langle x, \mu_A, \nu_A \rangle$ instead of $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$. Also for the sake of simplicity, we shall use the notation $A = \langle x, (\mu_A, \mu_B), (\nu_A, \nu_B)\rangle$ instead of $A = \langle x, (A/\mu_A, B/\mu_B), (A/\nu_A, B/\nu_B) \rangle$.

The intuitionistic fuzzy sets $0_\sim = \{ \langle x, 0, 1 \rangle / x \in X \}$ 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 a non empty X is a family τ of IFS in X satisfying the following axioms:

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

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

(c) $\cup G_i \in \tau$ for any arbitrary 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 for short) in X.

The complement A^c of an IFOS A in an IFTS (X, τ) is called an intuitionistic fuzzy closed set (IFCS for 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 an intuitionistic fuzzy closure are defined by

$int(A) = \cup \{ G / G$ is an IFOS in X and $G \subseteq A \}$,

$cl(A) = \cap \{ K / K$ is an IFCS in X and $A \subseteq K \}$.

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: [6] An IFS A = { ⟨ x, μ_A, ν_A ⟩ } in an IFTS (X, τ) is said to be an

(i) intuitionistic fuzzy semi open set (IFSOS in short) if $A \subseteq cl(int(A))$,
(ii) intuitionistic fuzzy α-open set (IFαOS in short) if $A \subseteq int(cl(int(A)))$,
(iii) intuitionistic fuzzy regular open set (IFROS in short) if $A = int(cl(A))$.

The family of all IFOS (respectively IFSOS, IFαOS, IFROS) of an IFTS (X, τ) is denoted by IFO(X) (respectively IFSO(X), IFαO(X), IFRO(X)).

Definition 2.6: [6] An IFS A = ⟨ x, μ_A, ν_A ⟩ in an IFTS (X, τ) is said to be an
(i) intuitionistic fuzzy semi closed set (IFSCS in short) if $int(cl(A)) \subseteq A$,
(ii) intuitionistic fuzzy α-closed set (IFαCS in short) if $cl(int(cl(A)) \subseteq A$,
(iii) intuitionistic fuzzy regular closed set (IFRCS in short) if $A = cl(int((A)$.

The family of all IFCS (respectively IFSCS, IFαCS, IFRCS) of an IFTS (X, τ) is denoted by IFC(X) (respectively IFSC(X), IFαC(X), IFRC(X)).

Definition 2.7: [8] Let A be an IFS in an IFTS (X, τ). Then
sint(A) = ∪ { G / G is an IFSOS in X and $G \subseteq A$ },
scl(A) = ∩ { K / K is an IFSCS in X and $A \subseteq K$ }.

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

Definition 2.8: [7] Let (X, τ) be an IFTS and A = ⟨ x, μ_A, ν_A ⟩ be an IFS in X. The pre interior of A is denoted by pint(A) and is defined by the union of all fuzzy pre-open sets of X which are contained in A. The intersection of all fuzzy pre-closed sets containing A is called the pre-closure of A and is denoted by pcl(A).
pint(A) = ∪ { G / G is an IFPOS in X and $G \subseteq A$ },

pcl(A) = ∩ { K / K is an IFPCS in X and $A \subseteq K$ }.

Result 2.9: [7] If A is an IFS in X, then
$pcl(A) = A \cup cl(int(A))$.

Result 2.9: [9] Let A be an IFS in (X, τ), then
(i) $\alpha cl(A) = A \cup cl(int(cl(A)))$,

(ii) $\alpha int(A) = A \cap int(cl(int(A)))$.

Definition 2.10: [10] An IFS A in an IFTS (X, τ) is an
(i) intuitionistic fuzzy generalized closed set (IFGCS in short) if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in X.
(ii) intuitionistic fuzzy regular generalized closed set (IFRGCS in short) if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFROS in X.

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Definition 2.11: [8] An IFS A in an IFTS (X, τ) is said to be an intuitionistic fuzzy generalized semi closed set (IFGSCS in short) if scl(A) ⊆ U whenever A ⊆ U and U is an IFOS in (X, τ).

Result 2.12: [8] Every IFCS, IFSCS, IFGCS, IFRCS, IFαCS is an IFGSCS but the converses may not be true in general.

Definition 2.13: [8] An IFS A is said to be an intuitionistic fuzzy generalized semi open set (IFGSOS in short) in X if the complement A^c is an IFGSCS in X. The family of all IFGSCSs (IFGSOSs) of an IFTS (X, τ) is denoted by IFGSC(X) (IFGSO(X)).

Definition 2.14: [6] An IFS A in an IFTS (X, τ) is said to be an intuitionistic fuzzy alpha generalized closed set (IFαGCS in short) if αcl(A) ⊆ U whenever A ⊆ U and U is an IFOS in (X, τ).

Result 2.15: [6] Every IFCS, IFGCS, IFRCS, IFαCS is an IFαGCS but the converses may not be true in general. Every IFαGCS is IFGSCS but the converse is need not be true.

Definition 2.16: [6] An IFS A is said to be an intuitionistic fuzzy alpha generalized open set (IFαGOS in short) in X if the complement A^c is an IFαGCS in X.

The family of all IFαGCSs (IFαGOSs) of an IFTS (X, τ) is denoted by IFαGC(X) (IFGSO(X)).

Definition 2.17: [6] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be intuitionistic fuzzy continuous (IF continuous in short) if $f^{-1}(B) \in$ IFO(X) for every B ∈ σ.

Definition 2.18: [6] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be

(i) intuitionistic fuzzy semi continuous (IFS continuous in short) if $f^{-1}(B) \in$ IFSO(X) for every B ∈ σ.

(ii) intuitionistic fuzzy α continuous (IFα continuous in short) if $f^{-1}(B) \in$ IFαO(X) for every B ∈ σ.

(iii) intuitionistic fuzzy pre continuous (IFP continuous in short) if $f^{-1}(B) \in$ IFPO(X) for every B ∈ σ.

Definition 2.19: [5]A mapping f: (X, τ) → (Y,σ) is called as intuitionistic fuzzy γ continuous (IFγ continuous in short) if $f^{-1}(B)$ is an IFγOS in (X, τ) for every B ∈ σ.

Definition 2.20:[2] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an intuitionistic fuzzy generalized continuous (IFG continuous in short) if $f^{-1}(B) \in$ IFGCS(X) for every IFCS B in Y.

Result 2.21:[2] Every IF continuous mapping is an IFG continuous mapping.

Definition 2.22: [8] A mapping f: (X, τ) → (Y,σ) is called an *intuitionistic fuzzy generalized semi continuous* (IFGS continuous in short) if $f^{-1}(B)$ is an IFGSCS in (X, τ) for every IFCS B of (Y, σ).

Definition 2.23:[7] An IFTS (X, τ) is said to be an intuitionistic fuzzy ${}_pT_{1/2}$ ($IF_pT_{1/2}$ in short) space if every IFGPCS in X is an IFCS in X.

Definition 2.24:[7] An IFTS (X, τ) is said to be an intuitionistic fuzzy ${}_{gp}T_{1/2}$ ($IF_gT_{1/2}$ in short) space if every IFGPCS in X is an IFPCS in X.

3. Intuitionistic Fuzzy Generalized Pre Continuous Mappings

In this section I introduce intuitionistic fuzzy generalized pre continuous mapping and studied some of its properties.

Definition 3.1: A mapping f: (X, τ) → (Y,σ) is called an *intuitionistic fuzzy generalized pre continuous* (IFGP continuous in short) if $f^{-1}(A)$ is an IFGPCS in (X, τ) for every IFCS A of (Y,σ).

Example 3.2: Let X = {a, b}, Y = {u, v} and T_1 = ⟨ x, (0.3, 0.3), (0.7, 0.6) ⟩, T_2 = ⟨ y, (0.7, 0.6), (0.3, 0.4) ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = { $0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y,σ) by f(a) = u and f(b) = v. Then f is an IFGP continuous mapping.

Theorem 3.3: Every IF continuous mapping is an IFGP continuous mapping but not conversely.

Proof: Let f: (X, τ) → (Y, σ) be an IF continuous mapping. Let A be an IFCS in Y. Since f is IF continuous mapping, $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFGPCS, $f^{-1}(A)$ is an IFGPCS in X. Hence f is an IFGP continuous mapping.

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Example 3.4: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.1, 0.2), (0.8, 0.8) $\rangle$, $T_2 = \langle$ y, (0.5, 0.7), (0.5, 0.3) $\rangle$. Then $\tau = \{0_\sim, T_1, 1_\sim\}$ and $\sigma = \{0_\sim, T_2, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.5, 0.3), (0.5, 0.7) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFGPCS in X but not IFCS in X. Therefore f is an IFGP continuous mapping but not an IF continuous mapping.

Theorem 3.5: Every IFP continuous mapping is an IFGP continuous mapping but not conversely.

Proof: Let f: (X, τ) → (Y, σ) be an IFP continuous mapping. Let A be an IFCS in Y. Then by hypothesis
$f^{-1}(A)$ is an IFPCS in X. Since every IFPCS is an IFGPCS, $f^{-1}(A)$ is an IFGPCS in X. Hence f is an IFGP continuous mapping.

Example 3.6: Let X = { a, b }, Y = { u, v } and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.7) $\rangle$ and $T_2 = \langle$y, (0.4, 0.4), (0.5, 0.6) $\rangle$. Then $\tau = \{0_\sim, T_1, 1_\sim\}$ and $\sigma = \{0_\sim, T_2, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.5, 0.6), (0.4, 0.4) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFGPCS in X but not IFPCS in X. Then f is IFGP continuous mapping but not an IFP continuous mapping.

Theorem 3.7: Every IFα continuous mapping is an IFGP continuous mapping but not conversely.

Proof: Let f: (X, τ) → (Y,σ) be an IFαG continuous mapping. Let A be an IFCS in Y. Then by hypothesis
$f^{-1}(A)$ is an IFαCS in X. Since every IFαCS is an IFGPCS, $f^{-1}(A)$ is an IFGPCS in X. Hence f is an IFGP continuous mapping.

Example 3.8: Let X = { a, b }, Y = { u, v } and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.7) $\rangle$, and $T_2 = \langle$ y, (0.7, 0.8), (0.3, 0.1) $\rangle$. Then $\tau = \{0_\sim, T_1, 1_\sim\}$ and $\sigma = \{0_\sim, T_2, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.3, 0.1), (0.7, 0.8) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFGPCS in X but not IFαCS in X.

Theorem 3.9: Every IFαG continuous mapping is an IFGP continuous mapping but not conversely.

Proof: Let f: (X, τ) → (Y,σ) be an IFαG continuous mapping. Let A be an IFCS in Y. Then by hypothesis

$f^{-1}(A)$ is an IFαGCS in X. Since every IFαGCS is an IFGPCS, $f^{-1}(A)$ is an IFGPCS in X. Hence f is an IFGP continuous mapping.

Example 3.10: Let X = { a, b }, Y = { u, v } and T_1 = ⟨ x, (0.5, 0.6), (0.5, 0.4) ⟩, and T_2 = ⟨ y, (0.6, 0.5), (0.4, 0.5) ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = { $0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.4, 0.5), (0.6, 0.5) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFGPCS in X but not IFαGCS in X.

Theorem 3.11: Every IFR continuous mapping is an IFGP continuous mapping but not conversely.

Proof: Let A be an IFCS in Y. Then $f^{-1}(A)$ is an IFRCS in X. Since every IFRCS is an IFGPCS, $f^{-1}(A)$ is an IFGPCS in X. Hence f is an IFGP continuous mapping.

Example 3.12: Let X = { a, b }, Y = { u, v } and T_1 = ⟨ x, (0.7, 0.7), (0.3, 0.2) ⟩, and T_2 = ⟨ y, (0.8, 0.8), (0.2, 0.2) ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = { $0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.2, 0.2), (0.8, 0.8) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFGPCS in X but not IFRCS in X.

Preposition 3.13: IFGP continuous mapping and IFγ continuous mapping are independent to each other.

Example 3.14: Let X = { a, b }, Y = { u, v } and T_1 = ⟨ x, (0.4, 0.2), (0.6, 0.8) ⟩, T_2 = ⟨ y, (0.4, 0.3), (0.6, 0.7) ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = {$0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v. Then f is an IFGP continuous mapping but not an IFγ continuous mapping since A = ⟨ y, (0.6, 0.7), (0.4, 0.3) ⟩ is an IFCS in Y but $f^{-1}(A)$ = ⟨ x, (0.6, 0.7), (0.4, 0.3) ⟩ not IFγCS in X.

Example 3.15: Let X = { a, b }, Y = { u, v } and T_1 = ⟨ x, (0.4, 0.6), (0.2, 0.2) ⟩, T_2 = ⟨ x, (0.4, 0.2), (0.6, 0.8)⟩ and T_3 = ⟨ y, (0.6, 0.2), (0.4, 0.3) ⟩. Then τ = {$0_\sim$, T_1, T_2, $1_\sim$} and

σ = { $0_\sim$, T_3, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.4, 0.3), (0.6, 0.2) ⟩ is IFCS in Y. Then f^{-1}(A) is IFγCS in X but not IFGPCS in X.

Preposition 3.16: IFGP continuous mapping and IFS continuous mapping are independent to each other.

Example 3.17: Let X = {a, b}, Y = {u, v} and T_1 = ⟨ x, (0.8, 0.8), (0.2, 0.2) ⟩, T_2 = ⟨ y, (0.2, 0.2),(0.8, 0.7) ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = { $0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.8, 0.7), (0.2, 0.2) ⟩ is IFCS in Y. Then f^{-1}(A) is IFGPCS in X but not IFSC in X.

Example 3.18: Let X = {a, b}, Y = {u, v} and T_1 = ⟨ x, (0.5, 0.2), (0.5, 0.6) ⟩, T_2 = ⟨ y, (0.5, 0.6), (0.5, 0.2) ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = { $0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.5, 0.2), (0.5, 0.6) ⟩ is IFCS in Y. Then f^{-1}(A) is IFSC in X but not IFGPCS in X.

Preposition 3.19: IFGP continuous mapping and IFGS continuous mapping are independent to each other.

Example 3.20: Let X = {a, b}, Y = {u, v} and T_1 = ⟨ x, (0.7, 0.9), (0.3, 0.1) ⟩, T_2 = ⟨ y, (0.4, 0.3), (0.6, 0.7), ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = {$0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$(Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.6, 0.7), (0.4, 0.3) ⟩ is IFCS in Y. Then f^{-1}(A) is IFGPCS in X but not IFGSC in X.

Example 3.21: Let X = {a, b}, Y = {u, v} and T_1 = ⟨ x, (0.5, 0.4), (0.5, 0.6) ⟩, T_2 = ⟨ y, (0.5, 0.6), (0.5, 0.4), ⟩. Then τ = {$0_\sim$, T_1, $1_\sim$} and σ = { $0_\sim$, T_2, $1_\sim$} are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. The IFS A = ⟨ y, (0.5, 0.4), (0.5, 0.6) ⟩ is IFCS in Y. Then f^{-1}(A) is IFGSC in X but not IFGPCS in X.

The relations between various types of intuitionistic fuzzy continuity are given in the following diagram. In this diagram ‘cts.’ means continuous.

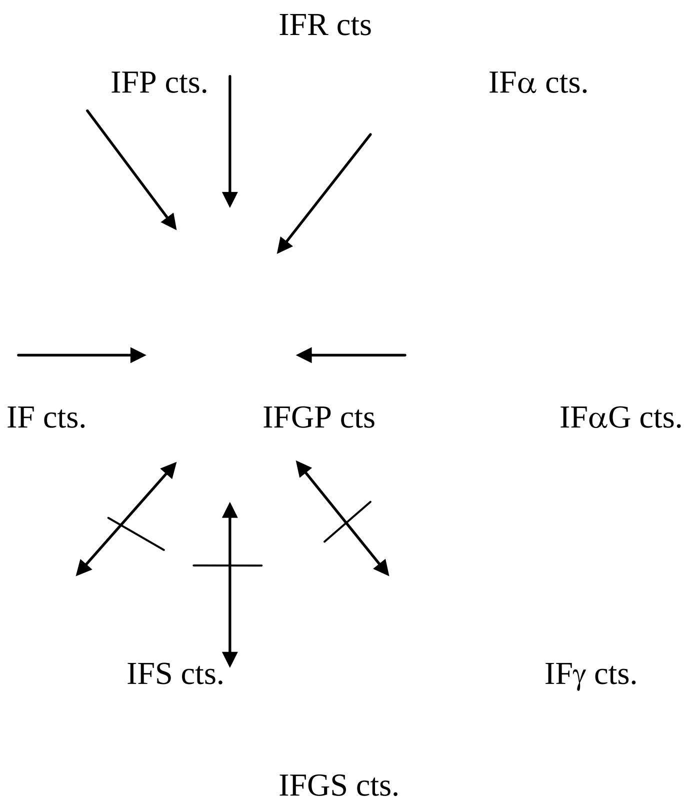

Fig.1 In this diagram by “ A → B” we mean A implies B but not conversely and“A ↮ B” means A and B are independent of each other.

None of them is reversible

Theorem 3.22: If the mapping f: X → Y is an IFGP continuous then the inverse image of each IFOS in Y is an IFGPOS in X.

Proof: Let A be an IFOS in Y. This implies A^c is IFCS in Y. Since f is IFGP continuous, $f^{-1}(A^c)$ is IFGPCS in X. Since $f^{-1}(A^c) = (f^{-1}(A))^c$, $f^{-1}(A)$ is an IFGPOS in X.

Theorem 3.23: Let f: (X, τ) → (Y, σ) be an IFGP continuous mapping, then f is an IF continuous mapping if X is an $IF_pT_{1/2}$ space.

Proof: Let A be an IFCS in Y. Then $f^{-1}(A)$ is an IFGPCS in X, by hypothesis. Since X is an $IF_pT_{1/2}$ space, $f^{-1}(A)$ is an IFCS in X. Hence f is an IF continuous mapping.

Theorem 3.24: Let f: (X, τ) → (Y, σ) be an IFGP continuous function, then f is an IFP continuous mapping if X is an $IF_{gp}T_{1/2}$ space.

Proof: Let A be an IFCS in Y. Then $f^{-1}(A)$ is an IFGPCS in X, by hypothesis. Since X is an $IF_{gp}T_{1/2}$ space, $f^{-1}(A)$ is an IFPCS in X. Hence f is an IFP continuous mapping.

Theorem 3.25: Let f : (X, τ) → (Y, σ) be an IFGP continuous mapping and g : (Y, σ) → (Z, δ) is IF continuous, then g o f : (X, τ) → (Z, δ) is an IFGP continuous.

Proof: Let A be an IFCS in Z. Then $g^{-1}(A)$ is an IFCS in Y, by hypothesis. Since f is an IFGP continuous mapping, $f^{-1}(g^{-1}(A))$ is an IFGPCS in X.Hence g o f is an IFGP continuous mapping.

4. Conclusion

In this paper, a new class of continuous function called intuitionistic fuzzy generalized pre continuous has been defined and their properties are discussed in intuitionistic fuzzy topological space.

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