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INTUITIONISTIC FUZZY CONTRA β GENERALIZED CONTINUOUS MAPPINGS IN INTUITIONISTIC FUZZY TOPOLOGICAL SPACES

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ABSTRACT In this paper we have introduced intuitionistic fuzzy contra β generalized continuous mappings and some of their basic properties are studied.

KEYWORDS : Intuitionistic fuzzy topology, intuitionistic fuzzy β generalized closed set, intuitionistic fuzzy β generalized continuous mappings, intuitionistic fuzzy β a$T_{1/2}$ space and intuitionistic fuzzy β b$T_{1/2}$.

INTRODUCTION

The concept of fuzzy sets was introduced by Zadeh [11] and later Atanassov [1] generalized this idea to intuitionistic fuzzy sets using the notion of fuzzy sets. On the other hand Coker [4] introduced intuitionistic fuzzy topological spaces using the notion of intuitionistic fuzzy sets. Dontchev [5] has introduced contra continuous functions in topological spaces. Erdal Ekici and Etienne [6] have introduced fuzzy contra continuities in fuzzy topological spaces. In this paper, we introduced intuitionistic fuzzy contra β generalized continuous mappings and studied some of their basic properties. We arrived at some characterizations of intuitionistic fuzzy contra β generalized continuous mappings.

2 PRELIMINARIES

Definition 2.1: [1] Let X be a non empty fixed set. An intuitionistic fuzzy set (IFS in short) A in X is an object having the form A = { x, $\mu_A(x)$, $\nu_A(x)$ / x X} where the functions $\mu_A(x)$: X [0, 1] and $\nu_A(x)$: X [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 X to the set A, respectively, and $0 \leq \mu_A(x) + \nu_A(x) \leq 1$ for each x X. Denote the set of all intuitionistic fuzzy sets in X by IFS (X).

Definition 2.2: [1] Let A and B be IFS's of the form
A = { x, $\mu_A(x)$, $\nu_A(x)$ / x X} and
B = { x, $\mu_B(x)$, $\nu_B(x)$ / x X}. Then
(a) A B if and only if $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for all x X,
(b) A = B if and only if A B and B A,
(c) A^c = { x, $\nu_A(x)$, $\mu_A(x)$ / x X},
(d) A B = { x, $\mu_A(x)$ $\mu_B(x)$, $\nu_A(x)$ $\nu_B(x)$ / x X},
(e) A B = { x, $\mu_A(x)$ $\mu_B(x)$, $\nu_A(x)$ $\nu_B(x)$ / x X}.

For the sake of simplicity, we shall use the notation A = x, μ_A, ν_A instead of A = { x, $\mu_A(x)$, $\nu_A(x)$ / x X}. Also for the sake of simplicity, we shall use the notation A = x, (μ_A, μ_B), (ν_A, ν_B) instead of A = x, (A/μ_A, B/μ_B), (A/ν_A, B/ν_B) . The intuitionistic fuzzy sets $0_\sim$ = { x, 0, 1 / x X } and $1_\sim$ = { x, 1, 0 / x X} are respectively the empty set and the whole set of X.

Definition 2.3: [4] 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) $0_\sim$, $1_\sim$ τ
(b) G_1 G_2 τ, for any G_1, G_2 τ
(c) G_i τ for any arbitrary family {G_i / i J} τ.

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: [4 Let (X, τ) be an IFTS and A = x, μ_A, ν_A be an IFS in X. Then the intuitionistic fuzzy interior and an intuitionistic fuzzy closure are defined by
int(A) = { G / G is an IFOS in X and G A},
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:[7] An IFS A = ⟨x, μ_A, ν_A⟩ in an IFTS (X, τ) is said to bea
(i) intuitionistic fuzzy semi closed set (IFSCS for short) if int(cl(A)) ⊆ A,
(ii) intuitionistic fuzzy pre-closed set (IFPCS for short) if cl(int(A)) ⊆ A,
(iii) intuitionistic fuzzy α-closed set (IFαCS for short) if cl(int(cl(A))) ⊆ A,
(iv) intuitionistic fuzzy γ-closed set (IFγCS for short) if cl(int(A)) ∩ int(cl(A)) ⊆ A.

The respective complements of the above IFCSs are called their respective IFOSs.

The family of all IFSCSs, IFPCSs, IFαCSs and IFβCSs (respectively IFSOSs, IFPOSs, IFαOSs and IFγOSs) of an IFTS (X,τ) are respectively denoted by IFSC(X), IFPC(X), IFαC(X) and IFγC(X) (respectively IFSO(X), IFPO(X), IFαO(X) and IFβO(X)).

Definition 2.6 :[8] An IFS A in an IFTS (X, τ) is an intuitionistic fuzzy generalized closed set (IFGCS in short) if cl(A) ⊆ U whenever A ⊆ U and U is an IFOS in X.

Definition 2.6 :[8] An IFS A in an IFTS (X, τ) is an intuitionistic fuzzy generalized closed set (IFGCS in short) if cl(A) ⊆ U whenever A ⊆ U and U is an IFOS in X.

Definition 2.7:[7] 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).

Definition 2.8:[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 2.9:[7] 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 $f^{-1}(B)$ ∈ IFO(X) for every B ∈ σ.

Definition2.10 : [7] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an

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

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

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

(iv) intuitionistic fuzzy γ continuous mapping (IFγ continuous mapping for short) if $f^{-1}(B) \in$ IFγO(X) for every $B \in \sigma$.

Definition 2.11: [10] 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 mapping (IFG continuous mapping for short) if $f^{-1}(B) \in$ IFGC(X) for every IFCS B in Y.

Definition 2.12:[10] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an intuitionistic fuzzy semi-pre continuous mapping (IFSP continuous mapping for short) if $f^{-1}(B) \in$ IFSPO(X) for every $B \in \sigma$.

Result 2.13:[9]Every IF continuous mapping is an IFG continuous mapping.

Definition 2.14 :[8]A mapping f: $(X, \tau) \to (Y, \sigma)$ 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 2.15:[8]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) (IFαGO(X)).

Definition 2.16:[7] 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 $B \in \sigma$.

Definition 2.17:[3] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an intuitionistic fuzzy contra-continuous (IF C continuous in short) mapping if $f^{-1}(B)$ is an IFOS in X for each IFCS B in Y.

Definition 2.18: [3] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an

(i) intuitionistic fuzzy contra continuous mapping (IFC continuous mapping for short) if $f^{-1}(B) \in$ IFO(X) for each IFCS B in Y

(ii) intuitionistic fuzzy contra α-continuous mapping (IFCα-continuous mapping for short) if $f^{-1}(B) \in$ IFαO(X) for each IFCS B in Y

(iii) intuitionistic fuzzy contra pre-continuous mapping (IFCP continuous mapping for short) if $f^{-1}(B) \in$ IFPO(X) for each IFCS B in Y

(iv) intuitionistic fuzzy contra γ-continuous (IFCγ continuous for short) mapping if $f^{-1}(B)$ is an IFγOS in X for each IFCS B in Y.

Result 2.19: [3] Every IF contra-continuous mapping is an IFCα continuous mapping and IFCP continuous mapping.

Definition 2.20: [8] An IFTS (X, τ) is said to be an intuitionistic fuzzy $\beta aT_{1/2}$ (IF $\beta aT_{1/2}$ in short) space if every IF β GCS in X is an IFCS in X.

3. Intuitionistic fuzzy contra β generalized continuous mappings

In this section we have introduced intuitionistic fuzzy contra β generalized continuous mappings. We investigated some of its properties.

Definition 3.1: A mapping : X Y is said to be an intuitionistic fuzzy contra β generalized continuous mapping (IFC β G continuous mapping) if $^{-1}(A)$ is an IF β GOS in X for every IFCS A in Y.

Example 32:
Let X = {a, b}, Y = { u, v } and G_1 = x, (0.1, 0.1), (0.5, 0.6) , G_2 = y, (0.3, 0.1), (0.5, 0.6 . Then τ = { $0_\sim$, G_1, $1_\sim$ } and = { $0_\sim$, G_2, $1_\sim$ } are IFTs on X and Y respectively. Define a mapping f : (X, τ) (Y,) by f(a) = u and f(b) = v. Then f is an IFC β G continuous mapping.

Theorem 3.3: Every IF contra continuous mapping is an IFC β G continuous mapping but not conversely.

Proof: Let f : (X, τ) (Y,) be an IF contra continuous mapping. Let A be an IFCS in Y. By hypothesis, $f^{-1}(A)$ is an IFOS in X. Since every IFOS is an IF β GOS, $f^{-1}(A)$ is an IF β GOS in X. Hence f is an IFC β G continuous mapping.

Example 3.4: Let X = { a, b }, Y = { u, v } and G_1 = x, (0.2, 0.1), (0.5, 0.6) , G_2 = y, (0.3, 0.1), (0.4, 0.3) . Then τ = { $0_\sim$, G_1, $1_\sim$ } and = { $0_\sim$, G_2, $1_\sim$ } are IFTs on X and Y respectively. Define a mapping f : (X, τ) (Y,) by f(a) = u and f(b) = v. Then f is an IFC β G continuous mapping. But f is not an IF contra continuous mapping since G_2^c = y, (0.4, 0.3), (0.3, 0.1) is an IFCS in Y but $f^{-1}(G_2^c)$ = x, (0.4, 0.3), (0.3, 0.1) is not an IFOS in X.

Theorem 3.5: Every IFC continuous mapping is an IFC β G continuous mapping but not conversely.

Proof: Let f : (X, τ) (Y,) be an IFC continuous mapping. Let A be an IFCS in Y. Then by hypothesis, f -1(A) is an IFOS in X. Since every IFOS is an IF β GOS, f -1(A) is an IF β GOS in X. Hence f is an IFC β G continuous mapping.

Example 3.6: Let X = { a, b }, Y = { u, v } and let the IFS G_1 = x, (0.3, 0.1), (0.5, 0.6) , G_2 = x, (0.7, 0.7), (0.1, 0.1) and G_3 = y, (0.4, 0.5), (0.3, 0.3) . Then τ = { $0_\sim$, G_1, G_2, $1_\sim$ } and = { $0_\sim$, G_3, $1_\sim$ } are IFTs on X and Y respectively. Define a mapping f : (X, τ) (Y,) by f(a) = u and f(b) = v. Then f is an IFC β G continuous mapping. But f is not an IFC continuous mapping since G_3^c = y, (0.3, 0.3), (0.4, 0.5) is an IFCS in Y but $f^{-1}(G_3^c)$ = x, (0.3, 0.3), (0.4, 0.5) is not an IFOS in X.

Remark 3.7: IFC continuous mapping and IFC β G continuous mapping are independent of each other.

Example 3.8: Let X = { a, b }, Y = { u, v } and G_1 = x, (0.4, 0), (0.4, 0.8), G_2 = y, (0.3, 0.2), (0.5, 0.1) . Then τ = { $0_\sim$, G_1, $1_\sim$ } and = { $0_\sim$, G_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 IFC continuous mapping. But f is not an IFC β G continuous mapping since G_2^c = y, (0.5, 0.1), (0.3, 0.2) is an IFCS in Y but $f^{-1}(G_2^c)$ = x, (0.5, 0.1), (0.3, 0.2) is not an IF β GOS in X.

Example 3.9: Let X = { a, b }, Y = { u, v } and G_1 = x, (0.4, 0), (0.4, 0.8), G_2 = y, (0.6, 0.7), (0.1, 0.1) . Then τ = { $0_\sim$, G_1, $1_\sim$ } and = { $0_\sim$, G_2, $1_\sim$ } are IFTs on X and Y respectively. Define a mapping f : (X, τ) (Y,) by f(a) = u and f(b) = v. Then f is an IFC β G continuous mapping. But f is not an IFC continuous mapping, since G_2^c = y, (0.1, 0.1), (0.6, 0.7) is an IFCS in Y but $f^{-1}(G_2^c)$ = x, (0.1, 0.1), (0.6, 0.7) is not an IFOS in X.

Remark 3.10: IFCP continuous mapping and IFC β G continuous mapping are independent of each other.

Example 3.11: Let X = { a, b }, Y = { u, v } and G_1 = x, (0, 0.8), (0.4, 0) , G_2 = y, (0, 0.2), (0.7, 0.7) . Then τ = { $0_\sim$, G_1, $1_\sim$ } and = { $0_\sim$, G_2, $1_\sim$ } are IFTs on X and Y respectively. Define a mapping f : (X, τ) (Y,) by f(a) = u and f(b) = v. Then f is an IFCP continuous mapping. But f is not an IFC β G continuous mapping since G_2^c = y, (0.7, 0.7), (0, 0.2) is an IFCS in Y but $f^{-1}(G_2^c)$ = x, (0.7, 0.7), (0, 0.2) is not an IFGOS in X.

Example 3.12: Let X = { a, b }, Y = { u, v } and G_1 = x, (0.2, 0.2), (0.5, 0.6) , G_2 = y, (0.3, 0.2), (0.4, 0.5) . Then τ = { $0_\sim$, G_1, $1_\sim$ } and = { $0_\sim$, G_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 IFC β G continuous mapping. But f is not an IFCP continuous mapping since G_2^c = y, (0.4, 0.5), (0.3, 0.2) is an IFCS in Y but $f^{-1}(G_2^c)$ = x, (0.4, 0.5), (0.3, 0.2) is not an IFPOS in X.

Theorem 3.13: A mapping f : X Y is an IFC β G continuous if and only if the inverse image of each IFOS in Y is an IF β GCS in X.

Proof: Necessity: Let A be an IFOS in Y. This implies Ac is an IFCS in Y. Since f is an IFC β G continuous mapping, $f^{-1}(A^c)$ is an IF β GOS in X. Hence f is an IFC β G continuous mapping.

Theorem 3.14: Let f : (X, τ) (Y, σ) be a mapping and let $f^{-1}(A)$ be an IFROS in X for every IFCS A in Y. Then f is an IFC β G continuous mapping.

Proof: Let A be an IFCS in Y. Then by hypothesis, $f^{-1}(A)$ is an IFROS in X. Since every IFROS is an IF β GOS, $f^{-1}(A)$ is an IF β GOS in X. Hence f is an IFC β G continuous mapping.

Theorem 3.15: Let f : (X, τ) (Y, σ) be an IFC β G continuous mapping, then f is an IF contra continuous mapping if X is an IF β **a**$T_{1/2}$space.

Proof: Let A be an IFCS in Y. Then f -1(A) is an IF β GOS in X, by hypothesis. Since X is an IF β **a**$T_{1/2}$space $f^{-1}(A)$ is an IFOS in X. Hence f is an IF contra continuous mapping.

Theorem 3.16: If f : (X, τ) (Y, σ) is an IFC β G continuous mapping and g : (Y, σ) (Z, η) is an IF contra continuous mapping, then g o f : (X, τ) (Z, η) is an IF β G continuous mapping.

Proof: Let A be an IFCS in Z. Then $g^{-1}(A)$ is an IFOS in Y, by hypothesis. Since f is an IFC β G continuous mapping, $f^{1}(g^{-1}(A))$ is an IF β GCS in X. That is $(g \circ f)^{-1}(A)$ is an IF β GCS in X. Hence g o f is an IF β G continuous mapping.

Theorem 3.17: If f : (X, τ) (Y, σ) is an IF β G continuous mapping g : (Y, σ) (Z, η) is an IF contra continuous mapping, then g o f : (X, τ) (Y, σ) is an IFC β G continuous mapping.

Proof: Let A be an IFCS in Z. Then $g^{-1}(A)$ is an IFOS in Y, by hypothesis. Since f is an IF β G continuous mapping, $f^{1}(g^{-1}(A))$ is an IF β GCS in X. That is $(g \circ f)^{-1}(A)$ is an IF β GCS in X. Hence g o f is an IFC β G continuous mapping.

Theorem 3.18: If f : (X, τ) (Y, σ) is an IFC β G continuous mapping g : (Y, σ) (Z, η) is an IF continuous mapping, then g o f : (X, τ) (Z, η) is an IF β G continuous mapping.

Proof: Let A be an IFCS in Z. Then $g^{-1}(A)$ is an IFCS in Y, by hypothesis. Since f is an IFC β G continuous mapping, $f^{1}(g^{-1}(A))$ is an IF β GCS in X. That is $(g \circ f)^{-1}(A)$ is an IF β GCS in X. Hence g o f is an IFC β G continuous mapping.

Theorem 3.19: Let f : (X, τ) (Y, σ) and g : (Y, σ) (Z,δ) be a mapping. Then the following conditions are equivalent if X is an IF β **a**$T_{1/2}$ space.

(I) g o f is an IFC β G continuous mapping
(ii) $cl(int(cl(g\ f)^{-1}(B))) \subseteq (g\ f)^{-1}(B)$ for every IFOS B in Z.

Proof: (I) (ii): Let B be any IFOS in Z. Then (g f)-1(B) is an IF β GCS in X by hypothesis. Since X is an IF β **a**$T_{1/2}$ space, $(g\ f)^{-1}(B)$ is an IFCS in X. Therefore, $cl((g \circ f)^{-1}(B)) = (g \circ f)^{-1}(B)$. Now $cl(int(cl((g \circ f)^{-1}(B)))) \subseteq cl\ (cl(\ (g \circ f)^{-1}(B)))) = cl((g \circ f)^{-1}(B))$. This implies $cl(int(cl((g \circ f)^{-1}(B)))) \subseteq (g \circ f)^{-1}(B)$.

(ii) (I): Let B be an IFCS in Z. Then its complement B^c is an IFOS in Z. By hypothesis $cl(int(cl((g \circ f)^{-1}(B^c)))) \subseteq (g \circ f)^{-1}(B^c)$. Hence $(g \circ f)^{-1}(B^c)$ is an IFCS in X. Since every IFCS is an IF β GCS $(g \circ f)^{-1}(B^c)$ is an IF β GCS in X. Therefore , (g f) -1(B) is an IF β GOS in X. Hence g o f is an IFC β G continuous mapping.

Theorem 3.20: Let f : (X, τ)→(Y, σ) and g : (Y, σ)→(Z, η) be a mapping. Then the following conditions are equivalent if X is an IF β **a**$T_{1/2}$ space.

(i) g o f is an IFC β G continuous mapping.
(ii) (g o f) -1(B) ⊆ int(cl(int((g o f) -1(B)))) for every IFCS B in Z.

Proof: (I) (ii): Let B be an IFCS in Z. By hypothesis, $(g \circ f)^{-1}(B)$ is an IF β GOS in X. Since X is an IF β **a**$T_{1/2}$ space, $(g \circ f)^{-1}(B)$ is an IFOS in X. Therefore, $(g \circ f)^{-1}(B) = int((g \circ f)^{-1}(B))$. But $int((g \circ f)^{-1}(B)) \subseteq int\ (cl(int((g \circ f)^{-1}(B))))$. This implies $(g \circ f)^{-1}(B)\ \ int(cl(int((g \circ f)^{-1}(B))))$ for every IFCS B in Z.

(ii) (I): Let B be an IFCS in Z. By hypothesis $(g\ f)^{-1}(B) \subseteq int(cl(int((g\ f)^{-1}(B))))$. This implies $(g\ f)^{-1}(B)$ is an IFOS in X and hence $(g\ f)^{-1}(B)$ is an IF β GOS in X. Therefore f is an IFC β G continuous mapping.

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