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REGULAR WEAKLY GENERALIZED CONTINUOUS MAPPINGS IN INTUITIONISTIC FUZZY TOPOLOGICAL SPACES

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ABSTRACT

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

Keywords: *Intuitionistic fuzzy topology, intuitionistic fuzzy regular weakly generalized closed set, intuitionistic fuzzy regular weakly generalized open set, intuitionistic fuzzy regular weakly generalized continuous mappings, intuitionistic fuzzy $_{rw}T_{1/2}$ space and $_{rwg}T_{1/2}$ space.*

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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 we introduce and study the concept of intuitionistic fuzzy regular weakly generalized continuous mappings in intuitionistic fuzzy topological space.

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

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(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 $A = \{\langle x, \mu_A, \nu_A \rangle\}$ 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 $A = \langle x, \mu_A, \nu_A \rangle$ 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
$sint(A) = \cup\{G / G$ is an IFSOS in X and $G \subseteq A\}$,
$scl(A) = \cap\{K / K$ 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] An IFS $A = \langle x, \mu_A, \nu_A \rangle$ in an IFTS (X, τ) is said to be an intuitionistic fuzzy regular weakly generalized closed set (IFRWGCS in short) if $cl(int(A)) \subseteq U$, whenever $A \subseteq U$ and U is an IFROS in X.

Result 2.9: [7] Every IFCS, IFRCS, IFGCS, IFPCS, IFαCS, IFαGCS is an IFRWGCS but the converses may not be true in general.

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.

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 $scl(A) \subseteq U$ whenever $A \subseteq U$ 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 $\alpha cl(A) \subseteq U$ whenever $A \subseteq U$ 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 $B \in \sigma$.

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

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

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.

Definition 2.21: [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 2.22: [7] An IFTS (X, τ) is said to be an intuitionistic fuzzy ${}_{rw}T_{1/2}$ ($IF_{rw}T_{1/2}$ in short) space if every IFRWGCS in X is an IFCS in X.

Definition 2.23: [7] An IFTS (X, τ) is said to be an intuitionistic fuzzy ${}_{rwg}T_{1/2}$ ($IF_{rwg}T_{1/2}$ in short) space if every IFRWGCS in X is an IFPCS in X.

3. INTUITIONISTIC FUZZY REGULAR WEAKLY GENERALIZED CONTINUOUS MAPPINGS

In this section we have introduced intuitionistic fuzzy regular weakly generalized continuous mapping and studied some of its properties.

Definition 3.1: A mapping f: $(X, \tau) \to (Y,\sigma)$ is called an *intuitionistic fuzzy regular weakly generalized continuous* (IFRWG continuous in short) if $f^{-1}(A)$ is an IFRWGCS in (X, τ) for every IFCS A of (Y,σ).

Example 3.2: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.4, 0.4), (0.6, 0.6) \rangle$, $G_2 = \langle y, (0.8, 0.8), (0.2, 0.2) \rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: $(X, \tau) \to (Y, \sigma)$ by f(a) = u and f(b) = v. Then f is an IFRWG continuous mapping.

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

Proof: Let f: $(X, \tau) \to (Y, \sigma)$ be an IF continuous mapping. Let A be an IFCS in Y. Since f is an IF continuous mapping, $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFRWGCS, $f^{-1}(A)$ is an IFRWGCS in X. Hence f is an IFRWG continuous mapping.

Example 3.4: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.1, 0.2), (0.8, 0.8) \rangle$, $G_2 = \langle y, (0.5, 0.7), (0.5, 0.3) \rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: $(X, \tau) \to (Y, \sigma)$ by f(a) = u and f(b) = v. The IFS $A = \langle y, (0.5, 0.3), (0.5, 0.7) \rangle$ is IFCS in Y. Then $f^{-1}(A)$ is IFRWGCS in X but not an IFCS in X.

Therefore f is an IFRWG continuous mapping but not an IF continuous mapping.

Remark 3.5: The converse of the above theorem is true if X is an $IF_{rw}T_{1/2}$ space.

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

Theorem 3.6: Every IFP continuous mapping is an IFRWG 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 IFRWGCS, $f^{-1}(A)$ is an IFRWGCS in X. Hence f is an IFRWG continuous mapping.

Example 3.7: Let X = {a, b }, Y = {u, v } and G_1 = ⟨ x, (0.1, 0.2), (0.9, 0.8) ⟩, and G_2 = ⟨y, (0.4, 0.4), (0.5, 0.6)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨y, (0.5, 0.6), (0.4, 0.4) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFRWGCS in X but not an IFPCS in X. Therefore f is an IFRWG continuous mapping but not an IFP continuous mapping.

Remark 3.8: The converse of the above theorem is true if X is an $IF_{rwg}T_{1/2}$ space.

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

Theorem 3.9: Every IFα continuous mapping is an IFRWG 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 IFRWGCS, $f^{-1}(A)$ is an IFRWGCS in X. Hence f is an IFRWG continuous mapping.

Example 3.10: Let X = {a, b }, Y = {u, v} and G_1 = ⟨ x, (0.4, 0.2), (0.6, 0.7) ⟩, and G_2 = ⟨ y, (0.7, 0.8), (0.3, 0.1)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨ y, (0.3, 0.1), (0.7, 0.8) ⟩ is an IFCS in Y. Then $f^{-1}(A)$ is an IFRWGCS in X but not an IFαCS in X.

Theorem 3.11: Every IFαG continuous mapping is an IFRWG 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 IFRWGCS, $f^{-1}(A)$ is an IFRWGCS in X. Hence f is an IFRWG continuous mapping.

Example 3.12: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.5, 0.6), (0.5, 0.4) ⟩, and G_2 = ⟨ y, (0.6, 0.5), (0.4, 0.5) ⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨y, (0.4, 0.5), (0.6, 0.5) ⟩ is IFCS in Y. Then $f^{-1}(A)$ is IFRWGCS in X but not IFαGCS in X.

Theorem 3.13: Every IFR continuous mapping is an IFRWG 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 IFRWGCS, $f^{-1}(A)$ is an IFRWGCS in X. Hence f is an IFRWG continuous mapping.

Example 3.14: Let X = {a, b}, Y = {u, v} and G_1 = ⟨ x, (0.7, 0.7), (0.3, 0.2)⟩, and G_2 = ⟨y, (0.8, 0.8), (0.2, 0.2)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨y, (0.2, 0.2), (0.8, 0.8) ⟩ is an IFCS in Y. Then $f^{-1}(A)$ is IFRWGCS in X but not IFRCS in X.

Proposition 3.15: IFRWG continuous mapping and IFS continuous mapping are independent to each other.

Example 3.16: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.8, 0.8), (0.2, 0.2) ⟩, G_2 = ⟨y, (0.2, 0.2), (0.8, 0.7)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨y, (0.8, 0.7), (0.2, 0.2)⟩ is an IFCS in Y. Then $f^{-1}(A)$ is an IFRWGCS in X but not an IFSC in X.

Example 3.17: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.5, 0.2), (0.5, 0.6) ⟩, G_2 = ⟨y, (0.5, 0.6), (0.5, 0.2),⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨y, (0.5, 0.2), (0.5, 0.6) ⟩ is an IFCS in Y. Then $f^{-1}(A)$ is an IFSC in X but not an IFRWGCS in X.

Proposition 3.18: IFRWG continuous mapping and IFGS continuous mapping are independent to each other.

Example 3.19: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.7, 0.9), (0.3, 0.1)⟩, G_2 = ⟨y, (0.4, 0.3), (0.6, 0.7),⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨y, (0.6, 0.7), (0.4, 0.3) ⟩ is an IFCS in Y. Then $f^{-1}(A)$ is an IFRWGCS in X but not an IFGSC in X.

Example 3.20: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.5, 0.4), (0.5, 0.6)⟩, G_2 = ⟨y, (0.5, 0.6), (0.5, 0.4),⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, 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. The IFS A = ⟨ y, (0.5, 0.4), (0.5, 0.6) ⟩ is an IFCS in Y. Then $f^{-1}(A)$ is IFGSC in X but not an IFRWGCS in X.

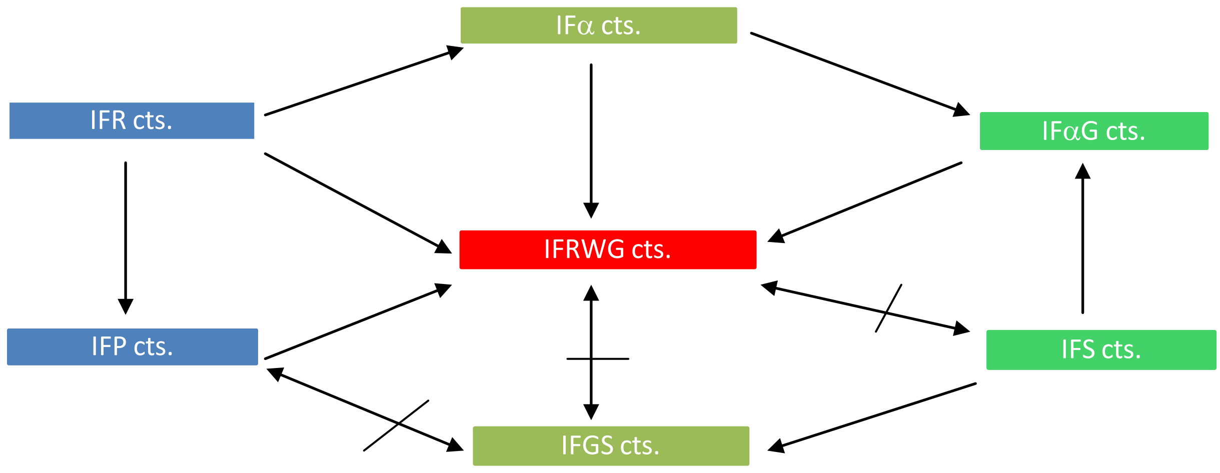

Fig.1

Fig.1: The relations between various types of intuitionistic fuzzy continuity. In this diagram 'cts.' means continuous, "A ⟶ B" means A implies B but not conversely and "A ⟷ B" means A and B are independent of each other.

Theorem 3.21: If the mapping f: X → Y is an IFRWG continuous then the inverse image of each IFOS in Y is an IFRWGOS in X.

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

Theorem 3.22: Let f : (X, τ) → (Y, σ) be an IFRWG continuous mapping and g: (Y, σ) → (Z, δ) is IF continuous, then g o f : (X, τ) → (Z, δ) is an IFRWG continuous.

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

4. CONCLUSION

In this paper we have introduced intuitionistic fuzzy regular weakly generalized continuous mappings and studied some of its basic properties. Also we have studied the relationship between intuitionistic fuzzy regular weakly generalized continuous mappings and some of the intuitionistic fuzzy continuous mappings already exists.

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