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Intuitionistic Fuzzy Completely Generalized Semi Continuous Mappings

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Abstract: In this paper the notion of intuitionistic fuzzy completely generalized semi continuous mapping is introduced. The properties of intuitionistic fuzzy completely generalized semi continuous mapping are investigated with suitable examples.

Key words and phrases: Intuitionistic fuzzy topology, intuitionistic fuzzy generalized semi closed set, intuitionistic fuzzy completely generalized semi continuous mappings.

1. INTRODUCTION

The concept of intuitionistic fuzzy sets was introduced by Atanassov[1] in 1986. Then Coker [3] introduced intuitionistic fuzzy topological spaces using the notion of intuitionistic fuzzy sets. In this paper we introduce intuitionistic fuzzy completely generalized semi continuous mappings and studied some of their properties with suitable examples. Also we provide some characterizations of intuitionistic fuzzy completely generalized semi continuous mappings.

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 IFSs of the form $A = \{\langle x, \mu_A(x), \nu_A(x) \rangle / x\in X \}$ 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:[2] An intuitionistic 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) $G_1 \cap G_2 \in \tau$ for any $G_1, G_2 \in \tau$
(iii) $\cup G_i \in \tau$ for any 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 in short) in X. The complement A^c of an IFOS A in IFTS (X, τ) is called an intuitionistic fuzzy closed set (IFCS in short) in X.

Definition 2.4:[2] 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 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 $A \subseteq K \}$.

Definition 2.5:[5] 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 $A = int(cl(A))$.

(iv) *intuitionistic fuzzy semi closed set* (IFSCS in short) if $int(cl(A)) \subseteq A$,

(v) *intuitionistic fuzzy α-closed set* (IFαCS in short) if $cl(int(cl(A)) \subseteq A$,

(vi) 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 2.6:[6] An IFS A in an IFTS (X, τ) is an intuitionistic fuzzy generalized closed set (IFGCS in short) if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is an IFOS in X.

Definition 2.7:[6] 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). An IFS A is said to be an intuitionistic fuzzy generalized semi open set in X if the complement A^c is an IFGSCS in X.
The family of all IFGSCSs of an IFTS (X, τ) is denoted by IFGSC(X).

Definition 2.8:[4] 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 2.9:[8] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be intuitionistic fuzzy α-continuous (IFα continuous in short) if $f^{-1}(B) \in$ IFαO(X) for every B in Y.

Definition 2.10:[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 generalized continuous (IFG continuous in short) if $f^{-1}(B) \in$ IFGCS(X) for every IFCS B in Y.

(ii) intuitionistic fuzzy generalized semi continuous (IFGS continuous in short) if $f^{-1}(B) \in$ IFGSCS(X) for every IFCS B in Y[13].

(iii) intuitionistic fuzzy alpha generalized continuous (IFαG continuous in short) if $f^{-1}(B) \in$ IFαGC(X) for every IFCS B in Y.

(iv) intuitionistic fuzzy almost continuous (IFA continuous in short) if $f^{-1}(B) \in$ IFC(X) for every IFRCS B in Y.

(v) *intuitionistic fuzzy almost generalized continuous* (IFAG continuous in short) if $f^{-1}(B) \in$ IFC(X) for every IFGCS B in Y.

Definition 2.10: [8] An IFTS (X, τ) is said to be an intuitionistic fuzzy ${}_dT_{1/2}$ (in short $IF_dT_{1/2}$) space if every IFGSCS in X is an IFOS in X.

3. Intuitionistic fuzzy completely generalized semi continuous mappings

In this section we introduce intuitionistic fuzzy completely generalized semi continuous mapping and studied some of its properties.

Definition 3.1: A mapping f: (X, τ) $\rightarrow$ (Y,σ) is called an *intuitionistic fuzzy completely generalized semi continuous* (IFCGS continuous in short) if $f^{-1}(B)$ is an IFRCS in (X, τ) for every IFGSCS B of (Y, σ).

Theorem 3.2: Every IFCGS continuous mapping is an IF continuous mapping but not conversely.

Proof: Let f: (X, τ) $\rightarrow$ (Y, σ) be an IFCGS continuous mapping and let B be an IFCS in Y. This implies B is an IFGSCS in Y. Since f is an IFCGS continuous mapping, $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFCS in X. That is $f^{-1}(B)$ is an IFCS in X for every IFCS B in Y. Hence f is an IF continuous mapping.

Example 3.3: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.7) $\rangle$, $T_2 = \langle$ x, (0.1, 0.2), (0.7, 0.8) $\rangle$ and $T_3 = \langle$ y, (0.1, 0.2), (0.7, 0.8) $\rangle$. Then $\tau = \{0_\sim, T_1, T_2, 1_\sim\}$ and $\sigma = \{0_\sim, T_3, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. Then f is an IF continuous mapping but not an IFCGS continuous mapping since B = $\langle$ y, (0.7, 0.8), (0.1, 0.2) $\rangle$ is an IFGSCS in Y but $f^{-1}(B) = \langle$ x, (0.7, 0.8), (0.1, 0.2) $\rangle$ is not an IFRCS in X.

Theorem 3.4: Every IFCGS continuous mapping is an IFG continuous mapping but not conversely.

Proof: Let f: (X, τ) $\rightarrow$ (Y, σ) be an IFCGS continuous mapping and let B be an IFCS in Y. This implies B is an IFGSCS in Y. Since f is an IFCGS continuous mapping, $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFGCS in X. That is $f^{-1}(B)$ is an IFGCS in X for every IFCS B in Y. Hence f is an IFG continuous mapping.

Example 3.5: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.6) $\rangle$, $T_2 = \langle$ x, (0.3, 0.2), (0.6, 0.8) $\rangle$ and $T_3 = \langle$ y, (0.3, 0.2), (0.6, 0.8) $\rangle$. Then $\tau = \{0_\sim, T_1, T_2, 1_\sim\}$ and $\sigma = \{0_\sim, T_3, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. Then f is an IFG continuous mapping but not an IFCGS continuous mapping since B = $\langle$ y, (0.6, 0.8), (0.3, 0.2) $\rangle$ is an IFGSCS in Y but $f^{-1}(B) = \langle$ x, (0.6, 0.8), (0.3, 0.2) $\rangle$ is not an IFRCS in X.

Theorem 3.6: Every IFCGS continuous mapping is an IFS continuous mapping but not conversely.

Proof: Let f: (X, τ) $\rightarrow$ (Y, σ) be an IFCGS continuous mapping and let B be an IFCS in Y. This implies B is an IFGSCS in Y. Since f is an IFCGS continuous mapping, $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFSCS in X. That is $f^{-1}(B)$ is an IFSCS in X for every IFCS B in Y. Hence f is an IFS continuous mapping.

Example 3.7: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.6) $\rangle$, $T_2 = \langle$ x, (0.2, 0.1), (0.6, 0.8) $\rangle$ and $T_3 = \langle$ y, (0.2, 0.1), (0.6, 0.8) $\rangle$. Then $\tau = \{0_\sim, T_1, T_2, 1_\sim\}$ and $\sigma = \{0_\sim, T_3, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) $\rightarrow$ (Y, σ) by f(a) = u and f(b) = v. Then f is an IFS continuous mapping but not an IFCGS continuous mapping since B = $\langle$ y, (0.6, 0.8), (0.2, 0.1) $\rangle$ is an IFGSCS in Y but $f^{-1}(B) = \langle$ x, (0.6, 0.8), (0.2, 0.1) $\rangle$ is not an IFRCS in X.

Theorem 3.8: Every IFCGS continuous mapping is an IFGS continuous mapping but not conversely.

Proof: Let f: $(X, \tau) \rightarrow (Y, \sigma)$ be an IFCGS continuous mapping. Let B be an IFCS in Y. This implies B is an IFGSCS in Y. Since f is an IFCGS continuous mapping, $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFGSCS in X. That is $f^{-1}(B)$ is an IFGSCS in X for every IFCS B in Y. Hence f is an IFGS continuous mapping.

Example 3.9: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.6) $\rangle$, $T_2 = \langle$ x, (0.1, 0.2), (0.6, 0.8) $\rangle$ and $T_3 = \langle$ y, (0.1, 0.2), (0.6, 0.8) $\rangle$. Then $\tau = \{0_\sim, T_1, T_2, 1_\sim\}$ and $\sigma = \{0_\sim, T_3, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: $(X, \tau) \rightarrow (Y, \sigma)$ by f(a) = u and f(b) = v. Then f is an IFGS continuous mapping but not an IFCGS continuous mapping since B = $\langle$ y, (0.6, 0.8), (0.1, 0.2) $\rangle$ is an IFGSCS in Y but $f^{-1}(B) = \langle$ x, (0.6, 0.8), (0.1, 0.2) $\rangle$ is not an IFRCS in X.

Theorem 3.10: Every IFCGS continuous mapping is an IFα continuous mapping but not conversely.

Proof: Let f: $(X, \tau) \rightarrow (Y, \sigma)$ be an IFCGS continuous mapping and let B be an IFCS in Y. This implies B is an IFGSCS in Y. Since f is an IFCGS continuous mapping, $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFαCS in X. That is $f^{-1}(B)$ is an IFαCS in X for every IFCS B in Y. Hence f is an IFα continuous mapping.

Example 3.11: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.6) $\rangle$, $T_2 = \langle$ x, (0.1, 0.1), (0.6, 0.9) $\rangle$ and $T_3 = \langle$ y, (0.1, 0.1), (0.6, 0.9) $\rangle$. Then $\tau = \{0_\sim, T_1, T_2, 1_\sim\}$ and $\sigma = \{0_\sim, T_3, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: $(X, \tau) \rightarrow (Y, \sigma)$ by f(a) = u and f(b) = v. Then f is an IFα continuous mapping but not an IFCGS continuous mapping since B = $\langle$ y, (0.6, 0.9), (0.1, 0.1) $\rangle$ is an IFGSCS in Y but $f^{-1}(B) = \langle$ x, (0.6, 0.9), (0.1, 0.1) $\rangle$ is not an IFRCS in X.

Theorem 3.12: Every IFCGS continuous mapping is an IFαG continuous mapping but not conversely.

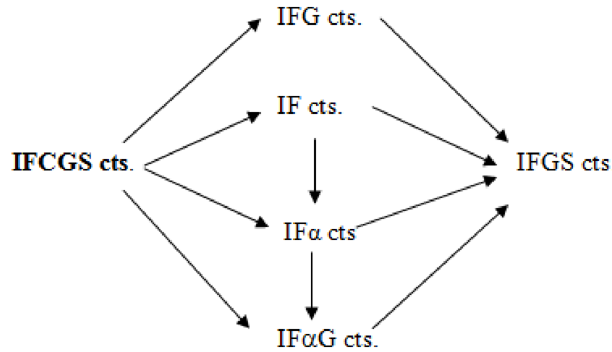
Proof: Let f: $(X, \tau) \rightarrow (Y, \sigma)$ be an IFCGS continuous mapping. Let B be an IFCS in Y. This implies B is an IFGSCS in Y. Since f is an IFCGS continuous mapping, $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFαGCS in X. That is $f^{-1}(B)$ is an IFαGCS in X for every IFCS B in Y. Hence f is an IFαG continuous mapping.

Example 3.13: Let X = {a, b}, Y = {u, v} and $T_1 = \langle$ x, (0.4, 0.2), (0.6, 0.6) $\rangle$, $T_2 = \langle$ x, (0.1, 0.1), (0.6, 0.8) $\rangle$ and $T_3 = \langle$ y, (0.1, 0.1), (0.6, 0.8) $\rangle$. Then $\tau = \{0_\sim, T_1, T_2, 1_\sim\}$ and $\sigma = \{0_\sim, T_3, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: $(X, \tau) \rightarrow (Y, \sigma)$ by f(a) = u and f(b) = v. Then f is an IFαG continuous mapping but not an IFCGS continuous mapping since B = $\langle$ y, (0.6, 0.8), (0.1, 0.1) $\rangle$ is an IFGSCS in Y but $f^{-1}(B) = \langle$ x, (0.6, 0.8), (0.1, 0.1) $\rangle$ is not an IFRCS in X.

Theorem 3.14: If a mapping f: X $\rightarrow$ Y is IFCGS continuous then the inverse image of each IFGSOS in Y is an IFROS in X.

Proof: Let A be an IFGSOS in Y. This implies A^c is IFGSCS in Y. Since f is IFCGS continuous, $f^{-1}(A^c)$ is IFRCS in X. Since $f^{-1}(A^c) = (f^{-1}(A))^c$, $f^{-1}(A)$ is an IFROS in X.

Remark 3.15: Every IFCGS continuous mapping is an IFA continuous mapping but not conversely. The relations between various types of intuitionistic fuzzy continuity are given in the following diagram. In this diagram 'cts.' means continuous.



The reverse implications are not true in general.

Theorem 3.16: Let f : $(X, \tau) \rightarrow (Y, \sigma)$ be an IFαG continuous mapping and g : $(Y, \sigma) \rightarrow (Z, \delta)$ is IFCGS continuous, then g o f : $(X, \tau) \rightarrow (Z, \delta)$ is an IFαG continuous mapping.

Proof: Let A be an IFCS in Z. This implies A is an IFGSCS in Z. Since g is IFCGS continuous mapping, $g^{-1}(A)$ is an IFRCS in Y. That is $g^{-1}(A)$ is an IFCS in Y. Since f is an IFαG continuous mapping, $f^{-1}(g^{-1}(A))$ is an IFαGCS in X. Hence g o f is an IFαG continuous mapping.

Theorem 3.17: Let f : $(X, \tau) \rightarrow (Y, \sigma)$ be an IFA continuous mapping and g : $(Y, \sigma) \rightarrow (Z, \delta)$ is IFCGS continuous mapping, then g o f : $(X, \tau) \rightarrow (Z, \delta)$ is an IF continuous mapping.

Proof: Let A be an IFCS in Z. This implies A is an IFGSCS in Z. Since g is IFCGS continuous mapping mapping, $g^{-1}(A)$ is an IFRCS in Y. Since f is an IFA continuous mapping, $f^{-1}(g^{-1}(A))$ is an IFCS in X. Hence g o f is an IF continuous mapping.

Theorem 3.18: Let f: $(X, \tau) \rightarrow (Y, \sigma)$ be a mapping from an IFTS X into an IFTS Y. Then the following conditions are equivalent if X is an $IF_dT_{1/2}$ space.

(i) f is an IFCGS continuous mapping
(ii) If B is an IFGSCS in Y then $f^{-1}(B)$ is an IFRCS in X
(iii) $cl(int(f^{-1}(B))) \subseteq f^{-1}(B)$ for every IFGSCS B in Y.

Proof: (i) $\Rightarrow$ (ii): is obviously true.

(ii) $\Rightarrow$ (iii): Let B be any IFGSCS in Y. Then by hypothesis $f^{-1}(B)$ is an IFRCS in X. This implies $f^{-1}(B)$ is an IFαCS in X. Hence $cl(int(cl(f^{-1}(B)))) \subseteq f^{-1}(B)$. This implies $cl(int(f^{-1}(B))) \subseteq f^{-1}(B)$.

(iii) $\Rightarrow$ (i): Let B be an IFGSOS in Y. Then its complement B^c is an IFGSCS in Y. By hypothesis $cl(int(f^{-1}(B^c))) \subseteq f^{-1}(B^c)$. Since X is an $IF_dT_{1/2}$ space, $f^{-1}(B^c)$ is open in X. That is $f^{-1}(B^c) = int(f^{-1}(B^c))$. Hence $f^{-1}(B^c) \subseteq int(f^{-1}(B^c))$. Clearly $f^{-1}(B^c) \subseteq cl(int(f^{-1}(B^c)))$. Hence $f^{-1}(B^c) = cl(int(f^{-1}(B^c))$. Therefore $f^{-1}(B^c)$ is an IFRCS in X. Therefore $f^{-1}(B)$ is an IFROS in X. Hence f is an IFCGS continuous mapping.

Theorem 3.19: Let f: $(X, \tau) \to (Y, \sigma)$ be a mapping. Then the following conditions are equivalent if X is an $IF_dT_{1/2}$ space.

(i) f is an IFCSG continuous mapping.

(ii) $f^{-1}(A) \subseteq int(cl(f^{-1}(A)))$ for every IFGSOS A in Y.

Proof: (i) ⇒ (ii): Let A be an IFGSOS in Y. By hypothesis, $f^{-1}(A)$ is an IFROS in X. Hence $f^{-1}(A)$ is an IFSOS in X. This implies $f^{-1}(A) \subseteq int(cl(f^{-1}(A)))$.

(ii) ⇒ (i): Let B be an IFGSCS in Y. Then its complement B^c is an IFGSOS in Y. By hypothesis $f^{-1}(B^c) \subseteq int(cl(f^{-1}(B^c)))$. Since X is an $IF_dT_{1/2}$ space, $f^{-1}(B^c)$ is closed in X. That is $cl(f^{-1}(B^c)) = f^{-1}(B^c)$. Hence $cl(f^{-1}(B^c)) \subseteq f^{-1}(B^c)$. Clearly $int(cl(f^{-1}(B^c))) \subseteq f^{-1}(B^c)$. Hence $f^{-1}(B^c) = int(cl(f^{-1}(B^c)))$. Therefore $f^{-1}(B^c)$ is an IFROS in X. Therefore $f^{-1}(B)$ is an IFRCS in X. Hence f is an IFCGS continuous mapping.

Theorem 3.20: Let f : $(X, \tau) \to (Y, \sigma)$ be an IFAG continuous mapping and g : $(Y, \sigma) \to (Z, \delta)$ is IFCGS continuous, then g o f : $(X, \tau) \to (Z, \delta)$ is an IFG continuous mapping.

Proof: Let A be an IFCS in Z. This implies A is an IFGSCS in Z. Since g is IFCGS continuous mapping, $g^{-1}(A)$ is an IFRCS in Y. Since f is an IFAG continuous mapping, $f^{-1}(g^{-1}(A))$ is an IFGCS in X. Hence g o f is an IFG continuous mapping.

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