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On Some New Continuous Mappings in Intuitionistic Fuzzy Topological Spaces

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Abstract: In this paper we introduce intuitionistic fuzzy almost semipre generalized continuous mappings, intuitionistic fuzzy completely semipre generalized continuous mappings,intuitionistic fuzzy almost semipre generalized closed mappings and intuitionistic fuzzy almost semipre generalized open mappings. Some of their properties are studied.

Keywords: Intuitionistic fuzzy topology, intuitionistic fuzzy point, intuitionistic fuzzy almost semipre generalized continuous mappings, intuitionistic fuzzy completely semipre generalized continuous mappings, intuitionistic fuzzy almost semipre generalized closed mappings and intuitionistic fuzzy almost semipre generalized open mappings.

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1. INTRODUCTION

After the introduction of fuzzy sets by Zadeh [15], there have been a number of generalizations of this fundamental concept. Later on, fuzzy topology was introduced by Chang [2] in 1967. The notion of intuitionistic fuzzy sets introduced by Atanassov [1] is one among them. Using the notion of intuitionistic fuzzy sets, Coker [3] introduced the notion of intuitionistic fuzzy topological spaces. Intuitionistic fuzzy semi-pre continuous mappings in intuitionistic fuzzy topological spaces are introduced by Young Bae Jun and SeokZun Song [14]. In this paper we introduce intuitionistic fuzzy almost semi-pre generalized continuous mappings, intuitionistic fuzzy completely semipre generalized continuous mappings, intuitionistic fuzzy almost semipre generalized closed mappings and intuitionistic fuzzy almost semipre generalized open mappings. We investigate some of its properties.

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 $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$ where the functions $\mu_A: X \to [0,1]$ and $\nu_A : X \to [0,1]$ 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

(i) $A \subseteq B$ if and only if $\mu_A(x) \leq \mu_B(x)$ and $\nu_A(x) \geq \nu_B(x)$ for all $x \in X$,
(ii) $A = B$ if and only if $A \subseteq B$ and $B \subseteq A$,
(iii) $A^c = \{ \langle x, \nu_A(x), \mu_A(x)\rangle / x \in X \}$,
(iv) $A \cap B = \{ \langle x, \mu_A(x) \wedge \mu_B(x), \nu_A(x) \vee \nu_B(x)\rangle / x \in X \}$,
(v) $A \cup B = \{ \langle x, \mu_A(x) \vee \mu_B(x), \nu_A(x) \wedge \nu_B(x)\rangle / x \in X \}$.

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 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 an IFTS (X, τ) is called an intuitionistic fuzzy closed set (IFCS in 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

(i) $int(A) = \cup\{ G / G$ is an IFOS in X and $G \subseteq A \}$,
(ii) $cl(A) = \cap\{ K / K$ is an IFCS in X and $A \subseteq K \}$,
(iii) $cl(A^c) = (int(A))^c$,
(iv) $int(A^c) = (cl(A))^c$.

Definition 2.5: [4] An IFS A of an IFTS (X, τ) is an

(i) intuitionistic fuzzy semiclosed set (IFSCS in short) if $int(cl(A)) \subseteq A$,
(ii) intuitionistic fuzzy semiopen set (IFSOS in short) if $A \subseteq cl(int(A))$.

Definition 2.6: [4] An IFS A of an IFTS (X, τ) is an

(i) intuitionistic fuzzy preclosed set (IFPCS in short) if $cl(int(A)) \subseteq A$,
(ii) intuitionistic fuzzy preopen set (IFPOS in short) if $A \subseteq int(cl(A))$.

Note that every IFOS in (X, τ) is an IFPOS in X.

Definition 2.7: [4] An IFS A of an IFTS (X, τ) is an

(i) intuitionistic fuzzy α-closed set (IFαCS in short) if $cl(int(cl(A))) \subseteq A$,
(ii) intuitionistic fuzzy α-open set (IFαOS in short) if $A \subseteq int(cl(int(A)))$,

(iii) intuitionistic fuzzy regular closed set (IFRCS in short) if A = cl(int(A)),
(iv) intuitionistic fuzzy regular open set (IFROS in short) if A = int(cl(A)),
(v) intuitionistic fuzzy β-closed set (IFβCS in short) if int(cl(int(A))) ⊆ A,
(vi) intuitionistic fuzzy β-open set (IFβOS in short) if A ⊆ cl(int(cl(A))).

Definition 2.8: [14] An IFS A of an IFTS (X, τ) is an
(i) intuitionistic fuzzy semipre closed set (IFSPCS for short) if there exists an IFPCS B such that int(B) ⊆ A ⊆ B,
(ii) intuitionistic fuzzy semipre open set (IFSPOS for short) if there exists an IFPOS B such that B ⊆ A ⊆ cl(B).

Definition 2.9: [11] An IFS A is an IFTS (X, τ) is said to be an intuitionistic fuzzysemipre generalized closed set (IFSPGCS) if spcl(A) ⊆ U whenever A ⊆ U and U is an IFSOS in (X, τ). An IFS A of an IFTS (X, τ) is called an intuitionistic fuzzy semipre generalized open set (IFSPGOS in short) if A^c is an IFSPGCS in (X, τ).

Every IFCS, IFSCS, IFαCS, IFRCS, IFPCS, IFSPCS, IFβCS is an IFSPGCS but the converses are not true in general.

Definition 2.10: [9] The complement A^c of an IFSPGCS A in an IFTS (X, τ) is called an intuitionistic fuzzy semipre generalized open set (IFSPGOS for short) in X.

The family of all IFSPGOSs of an IFTS (X, τ) is denoted by IFSPGO(X). Every IFOS, IFSOS, IFαOS, IFROS, IFPOS, IFSPOS, IFβOS is an IFSPGOS but the converses are not true in general.

Definition 2.11: [7] Let α, β ∈ [0, 1] and α+ β ≤ 1. An intuitionistic fuzzy point (IFP for short)$p_{(\alpha,\beta)}$ of X is an IFS of X defined by

$$p_{(\alpha,\beta)}(y) = \begin{cases} (\alpha,\beta) if y = p \\ (0,1) \quad if y \neq p \end{cases}$$

Definition 2.12: [7] Let $p_{(\alpha,\beta)}$ be an IFP of an IFTS (X, τ). An IFS A of X is called an intuitionistic fuzzy neighborhood (IFN for short) of $p_{(\alpha,\beta)}$ if there exists an IFOS B in X such that $p_{(\alpha,\beta)} \in B \subseteq A$.

Definition 2.13: [8] Let an IFS A of an IFTS (X, τ). Then
(i) αint(A) = ∪{ K / K is an IFαOS in X and K ⊆A}.
(ii) αcl(A) = ∩{ K / K is an IFαCS in X and A ⊆K }.

Definition 2.14: [14] Let A be an IFS in an IFTS (X, τ). Then
(i) sint(A) = ∪{ G / G is an IFSOS in X and G ⊆A },
(ii) scl(A) = ∩{ K / K is an IFSCS in X and A ⊆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 2.15: [4] Let A be an IFS in an IFTS (X, τ). Then
(i) spint (A) = ∪{G / G is an IFSPOS in X and G ⊆A }.
(ii) spcl (A) = ∩{ K / K is an IFSPCS in X and A ⊆K }.

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

Definition 2.16: [13] Let A be an IFS in an IFTS (X, τ). Then semipre generalized interior of A (spgint(A) for short) and semipre generalized closure of A (spgcl(A) for short) are defined by
(i) spgint (A) = ∪{ G / G is an IFSPGOS in X and G ⊆A }.
(ii) spgcl(A) = ∩{K / K is an IFSPGCS in X and A⊆K}.

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

Definition 2.17: [9] If every IFSPGCS in (X, τ) is an IFSPCS in (X, τ), then the space can be called as an intuitionistic fuzzy semipre $T_{1/2}$ ($IFSPT_{1/2}$ for short) space.

Definition 2.18: [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 ∈ σ.

Definition 2.19: [4] 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 $f^{-1}(B) \in IF\alpha O(X)$ for every B ∈ σ,
(iii) intuitionistic fuzzy pre continuous(IFP continuous in short) if $f^{-1}(B) \in IFPO(X)$ for every B ∈ σ,
(iv) intuitionistic fuzzy β- continuous(IFβ continuous in short) if $f^{-1}(B) \in IF\beta O(X)$ for every B ∈ σ.

Result 2.20:
(i) Every IF continuous mapping is an IFα-continuous mapping and every IFα-continuous mapping is an IFS continuous mapping as well as intuitionistic fuzzy pre continuous mapping. [4]
(ii) Every IF continuous mapping is an IFSG continuous mapping. [5]

Definition 2.21: [14] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an intuitionistic fuzzy semipre continuous (IFSP continuous for short) mapping if $f^{-1}(B) \in IFSPO(X)$ for every B ∈ σ .
Every IFS continuous mapping and IFP continuous mappings are IFSP continuous mapping but the converses may not be true in general.

Definition 2.22: [12]A mapping f : (X, τ) → (Y, σ) is called an intuitionistic fuzzy semipre generalized continuous (IFSPG continuous for short) mappings if $f^{-1}(V)$ is an IFSPGCS in (X, τ) for every IFCS V of (Y, σ).

Definition 2.23: [7] A map f : (X, τ) → (Y, σ) is called an intuitionistic fuzzy closed mapping (IFCM for short) if f(A) is an IFCS in Y for each IFCS A in X.

Definition 2.24: [7] A map f : (X, τ) → (Y, σ) is called an
(i) intuitionistic fuzzy semiopen mapping (IFSOM for short) if f(A) is an IFSOS in Y for each IFOS A in X.
(ii) intuitionistic fuzzy α-open mapping (IFαOM for short) if f(A) is an IFαOS in Y for each IFOS A in X.
(iii) intuitionistic fuzzy preopen mapping (IFPOM for short) if f(A) is an IFPOS in Y for each IFOS A in X.

Definition 2.25: [10]A mapping f : (X, τ) → (Y, σ) is called an intuitionistic fuzzy semipre generalized closed mapping

(IFSPGCM for short) if f(A) is an IFSPGCS in Y for each IFCS A in X.

Definition 2.26: [10] A mapping f : (X, τ) → (Y, σ) is said to be an intuitionistic fuzzy M-semipre generalized closed mapping (IFMSPGCM for short) if f(A) is an IFSPGCS in Y for every IFSPGCS A in X.

Definition 2.27: [6] An IFS A is said to be intuitionistic fuzzy dense (IFD for short) in another IFS B in an IFT (X, τ), if cl(A) = B.

3. INTUITIONISTIC FUZZY ALMOST SEMIPRE GENERALIZED CONTINUOUS MAPPINGS

In this section we have introduced intuitionistic fuzzy almost semipregeneralized continuous mapping and investigated some of its properties.

Definition 3.1: A mapping f : X → Y is said to be an intuitionistic fuzzy almostsemipre generalized continuous mapping (IFaSPG continuous mapping for short) if $f^{-1}(A)$ is an IFSPGCS in X for every IFRCS A in Y.

For the sake of simplicity, we shall use the notation A= ⟨x, (μ, μ), (ν, ν)⟩ instead of A= ⟨x,(a/μ_a, b/μ_b), (a/ν_a, b/ν_b)⟩ in all the examples used in this paper. Similarly we shall use the notation B= ⟨x, (μ, μ), (ν, ν)⟩ instead of B= ⟨x,(u/μ_u, v/μ_v), (u/ν_u, v/ν_v)⟩ in the following examples.

Example 3.2: Let X = {a, b}, Y = {u, v} and G_1= ⟨x, (0.5, 0.4), (0.5, 0.6)⟩,G_2 = ⟨y, (0.2, 0.3), (0.8, 0.7)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFaSPG continuous mapping.

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

Proof: Letf : (X, τ) → (Y, σ) be an IF continuous mapping. Let V be an IFRCS in Y. Since every IFRCS is an IFCS, V is an IFCS in Y. Then $f^{-1}(V)$ is an IFCS in X, by hypothesis. Since every IFCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.4: Let X = {a, b}, Y = {u, v} and G_1= ⟨x, (0.5, 0.4), (0.5, 0.6)⟩, G_2 = ⟨y, (0.2, 0.3), (0.8, 0.7)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFaSPG continuous mapping but not an IF continuous mapping.

Theorem 3.5: Every IFS continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFS continuous mapping. Let V be an IFRCS in Y. Since every IFRCS is an IFCS, V is an IFCS in Y. Then $f^{-1}(V)$ is an IFSCS in X. Since every IFSCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.6: Let X = {a, b}, Y = {u, v} and G_1= ⟨x, (0.5, 0.4), (0.5, 0.6)⟩, G_2 = ⟨y, (0.2, 0.3), (0.8, 0.7)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFaSPG continuous mapping but not an IFS continuous mapping.

Theorem 3.7: EveryIFP continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFP continuous mapping. Let V be an IFRCS in Y. Since every IFRCS is an IFCS, V is an IFCS in Y. Then $f^{-1}(V)$ is an IFPCS in X. Since every IFPCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.8: Let X = {a, b}, Y = {u, v}, G_1 = ⟨x, (0.5, 0.6), (0.5, 0.4)⟩ andG_2 = ⟨y, (0.5, 0.3), (0.5, 0.7)⟩. Then τ = {$0_\sim$, G, $1_\sim$}andσ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFaSPG continuous mapping but not an IFP continuous mapping.

Theorem 3.9: Every IFβ continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFβ continuous mapping. Let V be an IFRCS in Y. Since every IFRCS is an IFCS, V is an IFCS in Y. Then $f^{-1}(V)$ is an IFβCS in X. Since every IFβCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.10: Let X = {a, b}, Y = {u, v}, G_1 = ⟨x, (0.7, 0.8), (0.3, 0.2)⟩, G_2 = ⟨x, (0.2, 0.1), (0.8, 0.9)⟩, G_3 = ⟨x, (0.5, 0.6), (0.5, 0.4)⟩, G_4 = ⟨x, (0.6, 0.7), (0.4, 0.3)⟩, and G_5 = ⟨y, (0.1, 0.4), (0.9, 0.6)⟩. Then τ = {$0_\sim$, G_1, G_2, G_3, G_4, $1_\sim$}andσ = {$0_\sim$, G_5, $1_\sim$} are IFT on X and Y respectively. Define a mappingf : (X, τ) → (Y, σ) by f(a) = u and f(b) = v. Then f is an IFaSPG continuous mapping but not an IFβ continuous mapping.

Theorem 3.11: Every IFSP continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFSP continuous mapping. Let V be an IFRCS in Y. Since every IFRCS is an IFCS, V is an IFCS in Y. Then $f^{-1}(V)$ is an IFSPCS in X. Since every IFSPCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.12: Let X = {a, b}, Y = {u, v}, G_1 = ⟨x, (0.7, 0.8), (0.3, 0.2)⟩, G_2 = ⟨x, (0.2, 0.1), (0.8, 0.9)⟩, G_3 = ⟨x, (0.5, 0.6), (0.5, 0.4)⟩, G_4 = ⟨x, (0.6, 0.7), (0.4, 0.3)⟩, and G_5 = ⟨y, (0.1, 0.4), (0.9, 0.6)⟩. Then τ = {$0_\sim$, G_1, G_2, G_3, G_4, $1_\sim$}andσ = {$0_\sim$, G_5, $1_\sim$} are IFT 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 IFaSPG continuous mapping but not an IFSP continuous mapping.

Theorem 3.13: Every IFα continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFα continuous mapping. Let V be an IFRCS in Y. Since every IFRCS is an IFCS, V is an IFCS in Y. Then $f^{-1}(V)$ is an IFαCS in X. Since every IFαCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.14: Let X = {a, b}, Y = {u, v} and G_1= ⟨x, (0.5, 0.4), (0.5, 0.6)⟩, G_2 = ⟨y, (0.2, 0.3), (0.8, 0.7)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFaSPG continuous mapping but not an IFαcontinuous mapping.

Theorem 3.15: Let $f : (X, \tau) \to (Y, \sigma)$ be a mapping where $f^{-1}(V)$ is an IFRCS in X for every IFCS in Y. Then f is an IFaSPG continuous mapping but not conversely.

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

Example 3.16: Let $X = \{a, b\}$, $Y = \{u, v\}$, $G_1 = \langle x, (0.5, 0.6), (0.5, 0.4)\rangle$ and $G_2 = \langle y, (0.5, 0.3), (0.5, 0.7)\rangle$. Then $\tau = \{0_\sim, G, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFaSPG continuous mapping but not a mapping as defined in Theorem 3.15.

Theorem 3.17: Every IFSPG continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Assume that $f : X \to Y$ be an IFSPG continuous mapping. Let A be an IFRCS in Y. Then A is an IFCS in Y. By hypothesis $f^{-1}(A)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 3.18: Let $X = \{a, b\}$, $Y = \{u, v\}$, $G_1 = \langle x, (0.7, 0.8), (0.3, 0.2)\rangle$, $G_2 = \langle x,(0.6, 0.7), (0.4, 0.3)\rangle$, $G_3 = \langle y, (0.4, 0.2), (0.6, 0.8)\rangle$ and $G_4 = \langle y, (0.4, 0.2), (0.4, 0.8)\rangle$. Then $\tau = \{0_\sim, G_1, G_2, 1_\sim\}$ and $\sigma = \{0_\sim, G_3, G_4, 1_\sim\}$ are IFT 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 IFaSPG continuous mapping but not an IFSPG continuous mapping.

Theorem 3.19: Let $f : X \to Y$ be a mapping. Then the following are equivalent:

(i) f is an IFaSPG continuous mapping,

(ii) $f^{-1}(A)$ is an IFSPGOS in X for every IFROS A in Y.

Proof: (i) $\Rightarrow$ (ii) Let A be an IFROS in Y. Then A^c is an IFRCS in Y. By hypothesis, $f^{-1}(A^c)$ is an IFSPGCS in X. That is $f^{-1}(A)^c$ is an IFSPGCS in X. Therefore $f^{-1}(A)$ is an IFSPGOS in X.

(ii) $\Rightarrow$ (i) Let A be an IFRCS in Y. Then A^c is an IFROS in Y. By hypothesis, $f^{-1}(A^c)$ is an IFSPGOS in X. That is $f^{-1}(A)^c$ is an IFSPGOS in X. Therefore $f^{-1}(A)$ is an IFSPGCS in X. Then f is an IFaSPG continuous mapping.

Theorem3.20: Let $p_{(\alpha, \beta)}$ be an IFP in X. A mapping $f : X \to Y$ is an IFaSPGcontinuous mapping if for every IFOS A in Y with $f(p_{(\alpha, \beta)}) \in A$, there exists an IFOS B in X with $p_{(\alpha, \beta)} \in B$ such that $f^{-1}(A)$ is IFD in B.

Proof: Let A be an IFROS in Y. Then A is an IFOS in Y. Let $f(p_{(\alpha, \beta)}) \in A$, then there exists an IFOS B in X such that $p_{(\alpha, \beta)} \in B$ and $cl(f^{-1}(A)) = B$. Since B is an IFOS, $cl(f^{-1}(A))$ is also an IFOS in X. Therefore $int(cl(f^{-1}(A))) = cl(f^{-1}(A))$. Now $f^{-1}(A) \subseteq cl(f^{-1}(A)) = int(cl(f^{-1}(A))) \subseteq cl(int(cl(f^{-1}(A))))$. This implies $f^{-1}(A)$ is an IFβOS in X and hence an IFSPGOS in X. Thus f is an IFaSPG continuous mapping.

Theorem 3.21: Let $f : X \to Y$ be a mapping where X is an $IFSPT_{1/2}$ space. Then the following are equivalent:

(i) f is an IFaSPG continuous mapping,

(ii) $spcl(f^{-1}(A)) \subseteq f^{-1}(cl(A))$ for every IFSPOS in Y,

(iii) $spcl(f^{-1}(A)) \subseteq f^{-1}(cl(A))$ for every IFSOS A in Y,

(iv) $f^{-1}(A) \subseteq spint(f^{-1}(int(cl(A))))$ for every IFPOS A in Y.

Proof: (i) $\Rightarrow$ (ii) let A be an IFSPOS in Y. Then by Definition 2.8, there exists an IFPOS B such that $B \subseteq A \subseteq cl(B)$ and $B \subseteq int(cl(B))$. Now $cl(int(cl(A))) \supseteq cl(int(cl(B))) \supseteq cl(B) \supseteq A$. Hence $A \subseteq cl(int(cl(A)))$. Therefore $cl(A) \subseteq cl(int(cl(A)))$. But $cl(int(cl(A))) \subseteq cl(A)$. Hence $cl(int(cl(A))) = cl(A)$. This implies cl(A) is an IFRCS in (X, τ). By hypothesis $f^{-1}(cl(A))$ is an IFSPGCS in X and hence $f^{-1}(cl(A))$ is an IFSPCS in X, since X is an $IFSPT_{1/2}$ space. This implies $spcl(f^{-1}(cl(A))) = f^{1}(cl(A))$. Now $spcl(f^{-1}(A)) \subseteq spcl(f^{-1}(cl(A))) = f^{-1}(cl(A))$. Thus $spcl(f^{-1}(A)) \subseteq f^{-1}(cl(A))$.

(ii) $\Rightarrow$ (iii) Since every IFSOS is an IFSPOS, proof is similar as in (i) $\Rightarrow$ (ii).

(iii) $\Rightarrow$ (i) Let A be an IFRCS in Y. Then $A = cl(int(A))$. Therefore A is an IFSOS in Y. By hypothesis, $spcl(f^{-1}(A)) \subseteq f^{-1}(cl(A)) = f^{-1}(A) \subseteq spcl(f^{-1}(A))$. Hence $f^{-1}(A)$ is an IFSPCS and hence is an IFSPGCS in X. Thus f is an IFaSPG continuous mapping.

(i) $\Rightarrow$ (iv) Let A be an IFPOS in Y. Then $A \subseteq int(cl(A))$. Since $int(cl(A))$ is an IFROSin Y, by hypothesis, $f^{-1}(int(cl(A)))$ is an IFSPGOS in X. Since X is an $IFSPT_{1/2}$ space, $f^{-1}(int(cl(A)))$ is an IFSPOS in X. Therefore $f^{-1}(A) \subseteq f^{-1}(int(cl(A))) = spint(f^{-1}(int(cl(A))))$.

(iv) $\Rightarrow$ (i) Let A be an IFROS in Y. Then A is an IFPOS in X. By hypothesis, $f^{-1}(A) \subseteq spint(f^{-1}(int(cl(A)))) = spint(f^{-1}(A)) \subseteq f^{-1}(A)$. This implies $f^{-1}(A)$ is an IFSPOS in X and hence is an IFSPGOS in X. Therefore f is an IFaSPG continuous mapping.

Theorem 3.22: Let $f : X \to Y$ be a mapping. If f is an IFaSPG continuous mapping, then $spgcl(f^{-1}(A)) \subseteq f^{-1}(cl(A))$ for every IFSPOS A in Y.

Proof: Let A be an IFSPOS in Y. Then cl(A) is an IFRCS in Y. By hypothesis $f^{-1}(cl(A))$ is an IFSPGCS in X. Then $spgcl(f^{-1}(cl(A))) = f^{-1}(cl(A))$. Now $spgcl(f^{-1}(A)) \subseteq spgcl(f^{-1}(cl(A))) = f^{-1}(cl(A))$. That is $spgcl(f^{-1}(A) \subseteq f^{-1}(cl(A))$.

Corollary 3.23: Let $f : X \to Y$ be a mapping. If f is an IFaSPGcontinuous mapping, then $spgcl(f^{-1}(A)) \subseteq f^{-1}(cl(A))$ for every IFSOS A in Y.

Proof: Since every IFSOS is an IFSPOS, the proof is obvious from the Theorem 3.22.

Corollary 3.24: Let $f : X \to Y$ be a mapping. If f is an IFaSPG continuous mapping, then $spgcl(f^{-1}(A)) \subseteq f^{-1}(cl(A))$ for every IFPOS A in Y.

Proof: Since every IFPOS is an IFSPOS, the proof is obvious from the Theorem 3.22.

Theorem 3.25: Let $f : X \to Y$ be a mapping. If f is an IFaSPG continuous mapping, then $spgcl(f^{-1}(cl(A))) \subseteq f^{-1}(cl(spint(A)))$ for every IFSPOS A in Y.

Proof: Let A be an IFSPOS in Y. Then cl(A) is an IFRCS in Y and $spint(A) = A$. By hypothesis, $f^{-1}(cl(A))$ is an IFSPGCS in X. Then $spgcl(f^{-1}(cl(A))) = f^{-1}(cl(A)) \subseteq f^{-1}(cl(spint(A)))$.

Corollary 3.26: Let $f : X \to Y$ be a mapping. If f is an IFaSPG continuous mapping, then $spgcl(f^{-1}(cl(A))) \subseteq f^{-1}(cl(spint(A)))$ for every IFSOS A in Y.

Proof: Since every IFSOS is an IFSPOS, the proof is obvious from the Theorem 3.25.

Corollary 3.27: Let $f : X \to Y$ be a mapping. If f is an IFaSPG continuous mapping, then $spgcl(f^{-1}(cl(A))) \subseteq f^{-1}(cl(spint(A)))$ for every IFPOS A in Y.

Proof: Since every IFPOS is an IFSPOS, the proof is obvious from the Theorem 3.25.

Theorem 3.28: Let $f : X \rightarrow Y$ be a mapping. If $f^{-1}(spint(B)) \subseteq spint(f^{-1}(B))$ for every IFS B in Y, then f is an IFaSPG continuous mapping.

Proof: Let $B \subseteq Y$ be an IFROS. By hypothesis, $f^{-1}(spint(B)) \subseteq spint(f^{-1}(B))$. Since B is an IFROS, it is an IFSPOS in Y. Therefore $spint(B) = B$. Hence $f^{-1}(B) = f^{-1}(spint(B)) \subseteq spint(f^{-1}(B)) \subseteq f^{-1}(B)$. This implies $f^{-1}(B)$ is an IFSPOS and hence an IFSPGOS in X. Thus f is an IFaSPG continuous mapping.

Remark 3.29: The converse of the above theorem is true if $B \subseteq Y$ is an IFROS and X is an $IFSPT_{1/2}$ space.

Proof: Let f be an IFaSPG continuous mapping. Let B be an IFROSin Y. Then $f^{-1}(B)$ is an IFSPGOS in X. Since X is an $IFSPT_{1/2}$ space, $f^{-1}(B)$ is an IFSPOS in X. Therefore $f^{-1}(spint(B)) \subseteq f^{-1}(B) = spint(f^{-1}(B))$. That is $f^{-1}(spint(B)) \subseteq spint(f^{-1}(B))$.

Theorem 3.30: Let $f : X \rightarrow Y$ be a mapping. If $spcl(f^{-1}(B)) \subseteq f^{-1}(spcl(B))$ for every IFS B in Y, then f is an IFaSPG continuous mapping.

Proof: Let $B \subseteq Y$ be an IFRCS. By hypothesis, $spcl(f^{-1}(B)) \subseteq f^{-1}(spcl(B))$. Since B is an IFRCS, it is an IFSPCS in Y. Therefore $spcl(B) = B$. Hence $f^{-1}(B) = f^{-1}(spcl(B)) \supseteq spcl(f^{-1}(B)) \supseteq f^{-1}(B)$. This implies $f^{-1}(B)$ is an IFSPCS and hence an IFSPGCS in X. Thus f is an IFaSPG continuous mapping.

Remark 3.31: The converse of the above theorem is true if $B \subseteq Y$ is an IFRCS and X is an $IFSPT_{1/2}$ space.

Proof: Let f be an IFaSPG continuous mapping. Let B be an IFRCS in Y. Then $f^{-1}(B)$ is an IFSPGCS in X. Since X is an $IFSPT_{1/2}$ space, $f^{-1}(B)$ is an IFSPCS in X. Therefore $spcl(f^{-1}(B)) = f^{-1}(B)) \subseteq f^{-1}(spcl(B))$.

Theorem 3.32: The following are equivalent for a mapping $f : X \rightarrow Y$ where X is an $IFSPT_{1/2}$ space:

(i) f is an IFaSPG continuous mapping,

(ii) $spcl(f^{-1}(A)) \subseteq f^{-1}(\alpha cl(A))$ for every IFSPOS A in Y,

(iii) $spcl(f^{-1}(A)) \subseteq f^{-1}(\alpha cl(A))$ for every IFSOS A in Y,

(iv) $f^{-1}(A) \subseteq spint(f^{-1}(scl(A)))$ for every IFPOS A in Y.

Proof: (i) $\Rightarrow$ (ii) Let A be an IFSPOS in Y. Then cl(A) is an IFRCS in Y. Hence by hypothesis $f^{-1}(cl(A))$ is an IFSPGCS in X and hence is an IFSPCS in X, since X is an $IFSPT_{1/2}$ space. This implies $spcl(f^{-1}(cl(A))) = f^{-1}(cl(A))$. Now $spcl(f^{-1}(A)) \subseteq spcl(f^{-1}(cl(A))) = f^{-1}(cl(A))$. Since cl(A) is an IFRCS, $cl(int(cl(A))) = cl(A)$. Now$spcl(f^{-1}(A)) \subseteq f^{-1}(cl(A)) = f^{-1}(cl(int(cl(A)))) \subseteq f^{1}(A \cup cl(int(cl(A)))) = f^{-1}(\alpha cl(A))$. Hence $spcl(f^{-1}(A)) \subseteq f^{-1}(\alpha cl(A))$.

(ii) $\Rightarrow$ (iii) Let A be an IFSOS in Y. Since every IFSOS is an IFSPOS, the proof is obvious.

(iii) $\Rightarrow$ (i) Let A be an IFRCS in Y. Then $A = cl(int(A))$. Therefore A is an IFSOS in Y. By hypothesis, $spcl(f^{-1}(A)) \subseteq f^{-1}(\alpha cl(A)) \subseteq f^{-1}(cl(A)) = f^{-1}(A) \subseteq spcl(f^{-1}(A))$. That is $spcl(f^{-1}(A)) = f^{-1}(A)$. Hence$f^{-1}(A)$ is an IFSPCS and hence is an IFSPGCSin X. Thus f is an IFaSPG continuous mapping.

(i) $\Rightarrow$ (iv) Let A be an IFPOS in Y. Then $A \subseteq int(cl(A))$. Since int(cl(A)) is an IFROS in Y, by hypothesis, $f^{-1}(int(cl(A)))$ is an IFSPGOS in X. Since X is an $IFSPT_{1/2}$ space, $f^{-1}(int(cl(A)))$ is an IFSPOS in X. Therefore $f^{-1}(A) \subseteq f^{-1}(int(cl(A))) = spint(f^{-1}(int(cl(A)))) \subseteq spint(f^{-1}(A \cup int(cl(A)))) = spint(f^{-1}(scl(A)))$. That is $f^{-1}(A) \subseteq spint(f^{-1}(scl(A)))$.

(iv) $\Rightarrow$ (i) Let A be an IFROS in Y. Then A is an IFPOS in Y. Hence by hypothesis, $f^{-1}(A) \subseteq spint(f^{-1}(scl(A)))$. This implies $f^{-1}(A) \subseteq spint(f^{-1}(A \cup int(cl(A)))) = spint(f^{-1}(A \cup A)) = spint(f^{-1}(A)) \subseteq f^{-1}(A)$. Therefore $f^{-1}(A)$ is an IFSPOS in X and hence it is an IFSPGOS in X. Thus f is an IFaSPG continuous mapping.

Theorem 3.33: Let $f : X \rightarrow Y$ be a mapping where X is an $IFSPT_{1/2}$ space. If f is an IFaSPG continuous mapping, then $int(cl(int(f^{-1}(B)))) \subseteq f^{-1}(spcl(B))$ for every$B \in IFRC(Y)$.

Proof: Let $B \subseteq Y$ be an IFRCS. By hypothesis, $f^{-1}(B)$ is an IFSPGCS in X. Since Xis an $IFSPT_{1/2}$ space, $f^{-1}(B)$ is an IFSPCS in X. Therefore $spcl(f^{-1}(B)) = f^{-1}(B)$. Now $int(cl(int(f^{-1}(B)))) \subseteq f^{-1}(B) \cup int(cl(int(f^{-1}(B)))) \subseteq spcl(f^{-1}(B)) = f^{-1}(B) = f^{-1}(spcl(B))$. Hence $int(cl(int(f^{-1}(B)))) \subseteq f^{-1}(spcl(B))$.

Theorem 3.34: Let $f : X \rightarrow Y$ be a mapping where X is an $IFSPT_{1/2}$ space. If f is an IFaSPG continuous mapping, then $f^{-1}(spint(B)) \subseteq cl(int(cl(f^{-1}(B))))$ for every$B \in IFRO(Y)$.

Proof: This theorem can be easily proved by taking complement in Theorem 3.33.

4. INTUITIONISTIC FUZZY COMPLETELYSEMIPRE GENERALIZED CONTINUOUS MAPPINGS

In this section we have introduced intuitionistic fuzzy completely semipregeneralized continuous mappings and studied some of their properties.

Definition 4.1: A mapping $f : X \rightarrow Y$ is said to be an intuitionistic fuzzy completelysemipre generalized continuous mapping (IFcSPG continuous mapping for short) iff^{-1}(V) is an IFRCS in X for every IFSPGCS V in Y.

Theorem 4.2: Every IFcSPG continuous mapping is an IFSPG continuous mapping but not conversely.

Proof: Let$f : (X, \tau) \rightarrow (Y, \sigma)$ be an IFcSPG continuous mapping. Let V be an IFCS in Y. Hence V is an IFSPGCS in Y. Then $f^{-1}(V)$ is an IFRCS in X. Since every IFRCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFSPG continuous mapping.

Example 4.3: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.5, 0.4), (0.5, 0.6)\rangle$, $G_2 = \langle y,(0.6, 0.7), (0.4, 0.2)\rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFSPG continuous mapping but not an IFcSPG continuous mapping.

Theorem 4.4: Every IFcSPG continuous mapping is an IFaSPG continuous mapping but not conversely.

Proof: Let$f : (X, \tau) \rightarrow (Y, \sigma)$ be an IFcSPG continuous mapping. Let V be an IFRCS in Y. Hence V is an IFSPGCS in Y. Then $f^{-1}(V)$ is an IFRCS in X. Since every IFRCS is an IFSPGCS, $f^{-1}(V)$ is an IFSPGCS in X. Hence f is an IFaSPG continuous mapping.

Example 4.5: Let X = {a, b}, Y = {u, v}, G_1 = ⟨x, (0.7, 0.8), (0.3, 0.2)⟩, G_2 = ⟨x,(0.6, 0.7), (0.4, 0.3)⟩ and G_3 = ⟨y, (0.5, 0.4), (0.5, 0.6)⟩. Then τ = {$0_\sim$, G_1, G_2, $1_\sim$} and σ = {$0_\sim$, G_3, $1_\sim$} are IFT 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 IFaSPG continuous mapping but not an IFcSPGcontinuous mapping.

Theorem 4.6: Every IFcSPG continuous mapping is an IF continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFcSPG continuous mapping. Let V be an IFCS in Y. Hence V is an IFSPGCS in Y. Then f^{-1}(V) is an IFRCS in X and hence an IFCS in X. Hence f is an IF continuous mapping.

Example 4.7: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.6, 0.7), (0.4, 0.2)⟩, G_2 = ⟨y,(0.6, 0.7), (0.4, 0.2)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IF continuous mapping but not an IFcSPG continuous mapping.

Theorem 4.8: Every IFcSPG continuous mapping is an IFS continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFcSPG continuous mapping. Let V be an IFCS in Y. Since every IFCS is an IFSPGCS, V is an IFSPGCS in Y. Then f^{-1}(V) is an IFRCS in X. Since every IFRCS is an IFSCS, f^{-1}(V) is an IFSCS in X. Hence f is an IFS continuous mapping.

Example 4.9: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.6, 0.7), (0.4, 0.2)⟩, G_2 = ⟨y,(0.6, 0.7), (0.4, 0.2)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFS continuous mapping but not an IFcSPG continuous mapping.

Theorem 4.10: Every IFcSPG continuous mapping is an IFP continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFcSPG continuous mapping. Let V be an IFCS in Y. Hence V is an IFSPGCS in Y. Then f^{-1}(V) is an IFRCS in X, by hypothesis. Since every IFRCS is an IFPCS, f^{-1}(V) is an IFPCS in X. Hence f is an IFP continuous mapping.

Example 4.11: Let X = {a, b}, Y = {u, v}, G_1 = ⟨x, (0.7, 0.8), (0.3, 0.2)⟩, , G_2 = ⟨x,(0.6, 0.7), (0.4, 0.3)⟩ and G_3 = ⟨y, (0.5, 0.4), (0.5, 0.6)⟩. Then τ = {$0_\sim$, G_1, G_2, $1_\sim$} and σ = {$0_\sim$, G_3, $1_\sim$} are IFT 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 IFP continuous mapping but not an IFcSPG continuous mapping.

Theorem 4.12: Every IFcSPG continuous mapping is an IFSP continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFcSPG continuous mapping. Let V be an IFCS in Y. Hence V is an IFSPGCS in Y. Then f^{-1}(V) is an IFRCS in X, by hypothesis. Since every IFRCS is an IFSPCS, f^{-1}(V) is an IFSPCS in X. Hence f is an IFSP continuous mapping.

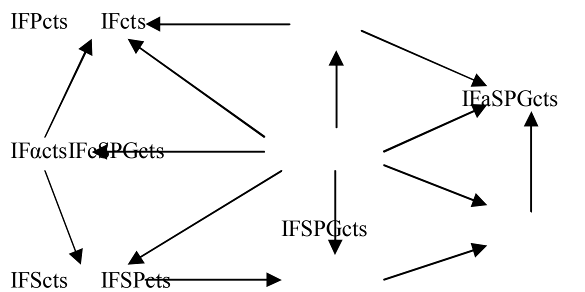
Example 4.13: Let X = {a, b}, Y = {u, v}, G_1 = ⟨x, (0.7, 0.8), (0.3, 0.2)⟩, G_2 = ⟨x,(0.6, 0.7), (0.4, 0.3)⟩ and G_3 = ⟨y, (0.5, 0.4), (0.5, 0.6)⟩. Then τ = {$0_\sim$, G_1, G_2, $1_\sim$} and σ = {$0_\sim$, G_3, $1_\sim$} are IFT on X and Y respectively. Define a mapping f : (X, τ) → (Y, σ) by f(a) = u and f(b) = v. Then f is an IFSP continuous mapping but not an IFcSPGcontinuous mapping.

Theorem 4.14: Every IFcSPG continuous mapping is an IFα continuous mapping but not conversely.

Proof: Letf : (X, τ) → (Y, σ) be an IFcSPG continuous mapping. Let V be an IFCS in Y. Hence V is an IFSPGCS in Y. Then f^{-1}(V) is an IFRCS in X, by hypothesis. Since every IFRCS is an IFαCS, f^{-1}(V) is an IFαCS in X. Hence f is an IFα continuous mapping.

Example 4.15: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.6, 0.7), (0.4, 0.2)⟩, G_2 = ⟨y, (0.6, 0.7), (0.4, 0.2)⟩. Then τ = {$0_\sim$, G_1, $1_\sim$} and σ = {$0_\sim$, G_2, $1_\sim$} are IFT 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 IFα continuous mapping but not an IFcSPG continuous mapping.

The relation between various types of intuitionistic fuzzy continuity is given in the following diagram. In this diagram cts means continuous mapping.



In the above diagram none of them is reversible.

Theorem 4.16: If f : X → Y is an IFcSPG continuous mapping where X is an IFSP$T_{1/2}$ space, then spcl(f^{-1}(A)) ⊆ f^{-1}(cl(A)) for every IFSPOS A ⊆ Y.

Proof: Let A be an IFSPOS in Y. Then cl(A) is an IFRCS in Y. Hence cl(A) is an IFSPGCS in Y. By hypothesis, f^{-1}(cl(A)) is an IFRCS in X and thus an IFSPCS in X. Therefore spcl(f^{-1}(A)) ⊆spcl(f^{-1}(cl(A))) = f^{-1}(cl(A)).

Corollary 4.17: If f : X → Y is an IFcSPG continuous mapping where X is an IFSP$T_{1/2}$ space, then spcl(f^{-1}(A)) ⊆ f^{-1}(cl(A)) for every IFSOS A ⊆ Y.

Proof: Since every IFSOS is an IFSPOS, the proof is obvious from the Theorem 4.16.

Theorem4.18: A mapping f : X → Y is an IFcSPG continuous mapping if and only if f^{-1}(V) is an IFROS in X for every IFSPGOS V in Y.

Proof: Straightforward.

Theorem 4.19: If a mapping f : X → Y is an IFcSPG continuous mapping, then for every IFP $p_{(\alpha, \beta)}$ ∈ X and for every IFN A of f($p_{(\alpha, \beta)}$), there exists an IFROS B ⊆ X such that $p_{(\alpha, \beta)}$ ∈ B ⊆f^{-1}(A).

Proof: Let $p_{(\alpha, \beta)}$ ∈ X and let A be an IFN of f($p_{(\alpha, \beta)}$). Then there exists an IFOS C in Y such that f($p_{(\alpha, \beta)}$) ∈ C ⊆ A. Since every IFOS is an IFGSPOS, C is an IFSPGOS in Y. Hence by hypothesis, $f^{-1}(C)$ is an IFROS in X and $p_{(\alpha, \beta)} \in f^{-1}(C)$. Now let $f^{-1}(C) = B$. Therefore $p_{(\alpha, \beta)} \in B = f^{-1}(C) \subseteq f^{-1}(A)$.

Theorem 4.20: If a mapping $f : X \to Y$ is an IFcSPG continuous mapping, then for every IFP $p_{(\alpha, \beta)} \in X$ and for every IFN A of $f(p_{(\alpha, \beta)})$, there exists an IFROS $B \subseteq X$ such that $p_{(\alpha, \beta)} \in B$ and $f(B) \subseteq A$.

Proof: Let $p_{(\alpha, \beta)} \in X$ and let A be an IFN of $f(p_{(\alpha, \beta)})$. Then there exists an IFOS C in Y such that $f(p_{(\alpha, \beta)}) \in C \subseteq A$. Since every IFOS is an IFSPGOS, C is an IFSPGOS in Y. Hence by hypothesis, $f^{-1}(C)$ is an IFROS in X and $p_{(\alpha, \beta)} \in f^{-1}(C)$. Now let $f^{-1}(C) = B$. Therefore $p_{(\alpha, \beta)} \in B \subseteq f^{-1}(A)$. Thus $f(B) \subseteq f(f^{-1}(A)) \subseteq A$. That is $f(B) \subseteq A$.

Theorem 4.21: If a mapping $f : X \to Y$ is an IFcSPG continuous mapping, then $int(cl(f^{-1}(int(B)))) \subseteq f^{-1}(B)$ for every IFS B in Y.

Proof: Let $B \subseteq Y$ be an IFS. Then int(B) is an IFOS in Y and hence an IFSPGOS in Y. By hypothesis, $f^{-1}(int(B))$ is an IFROS in X. Hence $int(cl(f^{-1}(int(B)))) = f^{-1}(int(B)) \subseteq f^{-1}(B)$.

Theorem 4.22: If an injective mapping $f : X \to Y$ is an IFcSPG continuous mapping, then the following are equivalent:
(i) for any IFSPGOS A in Y and for any IFP $p_{(\alpha, \beta)} \in X$, if $f(p_{(\alpha, \beta)})_q A$ then $p_{(\alpha, \beta)q} int(f^{-1}(A))$,
(ii) for any IFSPGOS A in Y and for any $p_{(\alpha, \beta)} \in X$, if $f(p_{(\alpha, \beta)})_q A$ then there exists an IFOS B in X such that $p_{(\alpha, \beta)q} B$ and $f(B) \subseteq A$.

Proof: (i) $\Rightarrow$ (ii) Let $A \subseteq Y$ be an IFSPGOS and let $p_{(\alpha, \beta)} \in X$. Let $f(p_{(\alpha, \beta)})_q A$. Then $p_{(\alpha, \beta)q} f^{-1}(A)$. By hypothesis, $p_{(\alpha, \beta)q} int(f^{-1}(A))$, where $int(f^{-1}(A))$ is an IFOS in X. Let $B = int(f^{-1}(A))$. Since $int(f^{-1}(A)) \subseteq f^{-1}(A)$, $B \subseteq f^{-1}(A)$. Then $f(B) \subseteq f(f^{-1}(A)) \subseteq A$.
(ii) $\Rightarrow$ (i) Let $A \subseteq Y$ be an IFSPGOS and let $p_{(\alpha, \beta)} \in X$. Suppose $f(p_{(\alpha, \beta)})_q A$, then by (ii) there exists an IFOS B in X such that $p_{(\alpha, \beta)q} B$ and $f(B) \subseteq A$. Now $B = f^{-1}(f(B)) \subseteq f^{-1}(A)$. That is $B = int(B) \subseteq int(f^{-1}(A))$. Therefore $p_{(\alpha, \beta)q} B$ implies $p_{(\alpha, \beta)q} int(f^{-1}(A))$.

5. INTUITIONISTIC FUZZY ALMOST SEMIPRE GENERALIZED CLOSED MAPPINGS

In this section we have introduced intuitionistic fuzzy almostsemipregeneralized closed mappings and intuitionistic fuzzy almost semipregeneralized open mappings. We have studied some of their properties.

Definition 5.1: A mapping $f : X \to Y$ is called an intuitionistic fuzzy almost semipregeneralized closed mapping (IFaSPGC mapping for short) if f(A) is an IFSPGCS in Y for each IFRCS A in X.

Example 5.2: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.2, 0.3), (0.8, 0.7) \rangle$, $G_2 = \langle y, (0.5, 0.4), (0.5, 0.6) \rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFaSPGC mapping.

Theorem 5.3: Every IFC mapping is an IFaSPGC mapping but not conversely.

Proof: Assume that $f: X \to Y$ is an IFC mapping. Let A be an IFRCS in X. Since every IFRCS is an IFCS, A is an IFCS in X. Then f(A) is an IFCS in Y. Since every IFCS is an IFSPGCS, f(A) is an IFSPGCS in Y. Hence f is an IFaSPGC mapping.

Example 5.4: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.2, 0.3), (0.8, 0.7) \rangle$, $G_2 = \langle y, (0.5, 0.4), (0.5, 0.6) \rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFaSPGC mapping but not an IFC mapping.

Theorem 5.5: Every IFSC mapping is an IFaSPGC mapping but not conversely.

Proof: Assume that $f : X \to Y$ be an IFSC mapping. Let A be an IFRCS in X. Since every IFRCS is an IFCS, A is an IFCS in X. Then f(A) is an IFSCS in Y. Since every IFSCS is an IFSPGCS, f(A) is an IFSPGCS in Y. Hence f is an IFaSPGC mapping.

Example 5.6: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.2, 0.3), (0.8, 0.7) \rangle$, $G_2 = \langle y, (0.5, 0.4), (0.5, 0.6) \rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFaSPGC mapping but not an IFSC mapping.

Theorem 5.7: Every IFαC mapping is an IFaSPGC mapping but not conversely.

Proof: Let $f : X \to Y$ be an IFαC mapping . Let A be an IFRCS in X. Since every IFRCS is an IFCS, A is an IFCS in X. Then f(A) is an IFαCS in Y. Since every IFαCS is an IFSPGCS, f(A) is an IFSPGCS in Y. Hence f is an IFaSPGC mapping.

Example 5.8: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.2, 0.3), (0.8, 0.7) \rangle$, $G_2 = \langle y, (0.5, 0.4), (0.5, 0.6) \rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFaSPGC mapping but not an IFαC mapping.

Theorem 5.9: Every IFPC mapping is an IFaSPGC mapping but not conversely.

Proof: Assume that $f : X \to Y$ be an IFPC mapping. Let A be an IFRCS in X. Since every IFRCS is an IFCS, A is an IFCS in X. Then f(A) is an IFPCS in Y. Since every IFPCS is an IFSPGCS, f(A) is an IFSPGCS in Y. Hence f is an IFaSPGC mapping.

Example 5.10: Let X = {a, b}, Y = {u, v}, $G_1 = \langle x, (0.5, 0.3), (0.5, 0.7) \rangle$ and $G_2 = \langle y, (0.5, 0.6), (0.5, 0.4) \rangle$. Then $\tau = \{0_\sim, G, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFT 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 IFaSPGC mapping but not an IFPC mapping.

Theorem 5.11: Every IFSPGC mapping is an IFaSPGC mapping but not conversely.

Proof: Assume that $f : X \to Y$ be an IFGSPC mapping. Let A be an IFRCS in X. Since every IFRCS is an IFCS, A is an IFCS in X. Then f(A) is an IFSPGCS in Y. Hence f is an IFaSPGC mapping.

Example 5.12: Let X = {a, b}, Y = {u, v}, $G_1 = \langle x, (0.4, 0.2), (0.6, 0.8) \rangle$, $G_2 = \langle x, (0.4, 0.2), (0.4, 0.8) \rangle$, $G_3 = \langle y, (0.7, 0.8), (0.3, 0.2) \rangle$ and $G_4 = \langle y, (0.6, 0.7), (0.4, 0.3) \rangle$. Then $\tau = \{0_\sim, G_1, G_2, 1_\sim\}$ and $\sigma = \{0_\sim, G_3, G_4, 1_\sim\}$ are IFT on Xand y respectively.

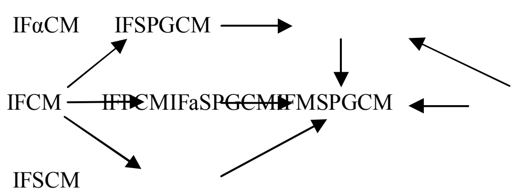
Define a mapping $f : (X, \tau) \to (Y, \sigma)$ by $f(a) = u$ and $f(b) = v$. Then f is an IFaSPGC mapping but not an IFSPGC mapping.

Theorem 5.13: Every IFMSPGC mapping is an IFaSPGC mapping but not conversely.

Proof: Assume that $f : X \to Y$ be an IFMSPGC mapping . Let A be an IFRCS in X. Then A is an IFSPGCS in X. By hypothesis f (A) is an IFSPGCS in Y. Therefore f is an IFaSPGC mapping.

Example 5.14: Let $X = \{a, b\}$, $Y = \{u, v\}$, $G_1 = \langle x, (0.4, 0.2), (0.6, 0.8) \rangle$, $G_2 = \langle x,(0.4, 0.2), (0.4, 0.8) \rangle$, $G_3 = \langle y, (0.7, 0.8), (0.3, 0.2) \rangle$ and $G_4 =\langle y, (0.6, 0.7), (0.4, 0.3)\rangle$. Then $\tau = \{0_\sim, G_1, G_2, 1_\sim\}$ and $\sigma = \{0_\sim, G_3, G_4, 1_\sim\}$ are IFT on Xand y respectively. Define a mapping $f : (X, \tau) \to (Y, \sigma)$ by $f(a) = u$ and $f(b) = v$. Then f is an IFaSPGC mapping but not an IFMSPGC mapping.

The relation between various types of intuitionistic fuzzy closed mappings is given in the following diagram.



The reverse implications are not true in general in the above diagram.

Definition 5.15: A mapping $f : X \to Y$ is called an intuitionistic fuzzy almostsemipre generalized open mapping (IFaSPGO mapping for short) if f(A) is an IFSPGOS in Y for each IFROS A in X.

Theorem 5.16: Let $f : X \to Y$ be a bijective mapping. Then the following statements are equivalent:
(i) f is an IFaSPGO mapping,
(ii) f is an IFaSPGC mapping.
Proof: Straightforward.

Theorem 5.17: Let $p_{(\alpha, \beta)}$ be an IFP in X. A mapping $f : X \to Y$ is an IFaSPGO mapping if for every IFOS A in X with $f^{-1}(p_{(\alpha, \beta)}) \in A$, then there exists an IFOS B in Y with $p_{(\alpha, \beta)} \in B$ such that f(A) is IFD in B.

Proof: Let A be an IFROS in X. Then A is an IFOS in X. Let $f^{-1}(p_{(\alpha, \beta)}) \in A$, then there exists an IFOS B in Y such that $p_{(\alpha, \beta)} \in B$ and $cl(f(A)) = B$. Since B is an IFOS, $cl(f(A)) = B$ is also an IFOS in Y. Therefore $int(cl(f(A))) = cl(f(A))$. Now $f(A) \subseteq cl(f(A)) = int(cl(f(A))) \subseteq cl(int(cl(f(A))))$. This implies f(A) is an IFSPOS in Y and hence an IFSPGOS in Y. Thus f is an IFaSPGO mapping.

Theorem 5.18: Let $f : X \to Y$ be a mapping where Y is an $IFSPT_{1/2}$ space. Then the following statements are equivalent:
(i) f is an IFaSPGC mapping,
(ii) $spcl(f(A)) \subseteq f(cl(A))$ for every IFSPOS A in X,
(iii) $spcl(f(A)) \subseteq f(cl(A))$ for every IFSOS A in X,
(iv) $f(A) \subseteq spint(f(int(cl(A))))$ for every IFPOS A in X.

Proof: (i) $\Rightarrow$ (ii) Let A be an IFSPOS in X. Then cl(A) is an IFRCS in X. By hypothesis, f(cl(A)) is an IFSPGCS in Y and hence is an IFSPCS in Y, since Y is an $IFSPT_{1/2}$ space. This implies $spcl(f(cl(A))) = f(cl(A))$. Now $spcl(f(A)) \subseteq spcl(f(cl(A))) = f(cl(A))$. Thus $spcl(f(A)) \subseteq f(cl(A))$.
(ii) $\Rightarrow$ (iii) Since every IFSOS is an IFSPOS, the proof directly follows.
(iii) $\Rightarrow$ (i) Let A be an IFRCS in X. Then $A = cl(int(A))$. Therefore A is an IFSOS in X. By hypothesis, $spcl(f(A)) \subseteq f(cl(A)) = f(A) \subseteq spcl(f(A))$. Hence f(A) is an IFSPCS and hence is an IFSPGCS in Y. Thus f is an IFaSPGC mapping.
(i) $\Rightarrow$ (iv) Let A be an IFPOS in X. Then $A \subseteq int(cl(A))$. Since int(cl(A)) is an IFROS in X, by hypothesis, f(int(cl(A))) is an IFSPGOS in Y. Since Y is an $IFSPT_{1/2}$ space, f(int(cl(A))) is an IFSPOS in Y. Therefore $f(A) \subseteq f(int(cl(A))) \subseteq spint(f(int(cl(A))))$.
(iv) $\Rightarrow$ (i) Let A be an IFROS in X. Then A is an IFPOS in X. By hypothesis, $f(A) \subseteq spint(f(int(cl(A)))) = spint(f(A)) \subseteq f(A)$. This implies f(A) is an IFSPOS in Y and hence is an IFSPGOS in Y. Therefore f is an IFaSPGC mapping.

Theorem 5.19: Let $f : X \to Y$ be a mapping. If f is an IFaSPGC mapping, then $spgcl(f(A)) \subseteq f(cl(A))$ for every IFSPOS A in X.

Proof: Let A be an IFSPOS in X. Then cl(A) is an IFRCS in X. By hypothesis f(cl(A)) is an IFSPGCS in Y. Then $spgcl(f(cl(A))) = f(cl(A))$. Now $spgcl(f(A)) \subseteq spgcl(f(cl(A))) = f(cl(A))$. That is $spgcl(f(A)) \subseteq f(cl(A))$.

Corollary 5.20: Let $f : X \to Y$ be a mapping. If f is an IFaSPGC mapping, then $spgcl(f(A) \subseteq f(cl(A))$ for every IFSOS A in X.

Proof: Since every IFSOS is an IFSPOS, the proof is obvious from the Theorem 5.19.

Corollary 5.21: Let $f : X \to Y$ be a mapping. If f is an IFaGSPC mapping, then $gspcl(f(A) \subseteq f(cl(A))$ for every IFPOS A in X.

Proof: Since every IFPOS is an IFSPOS, the proof is obvious from the Theorem 5.19.

Theorem 5.22: Let $f : X \to Y$ be a mapping. If f is an IFaSPGC mapping, then $spgcl(f(A)) \subseteq f(cl(spint(A)))$ for every IFSPOS A in X.

Proof: Let A be an IFSPOS in X. Then cl(A) is an IFRCS in X. By hypothesis, f(cl(A)) is an IFSPGCS in Y. Then $spgcl(f(A)) \subseteq spgcl(f(cl(A))) = f(cl(A)) \subseteq f(cl(spint(A)))$, since $spint(A) = A$.

Corollary 5.23: Let $f : X \to Y$ be a mapping. If f is an IFaSPGC mapping, then $spgcl(f(A)) \subseteq f(cl(spint(A)))$ for every IFSOS A in X.

Proof: Since every IFSOS is an IFSPOS, the proof is obvious from the Theorem 5.22.

Corollary 5.24: Let $f: X \to Y$ be a mapping. If f is an IFaSPGC mapping, then $spgcl(f(A)) \subseteq f(cl(spint(A)))$ for every IFPOS A in X.

Proof: Since every IFPOS is an IFSPOS, the proof is obvious from the Theorem 5.22.

Theorem 5.25: Let $f : X \to Y$ be a mapping. If $f(spint(B)) \subseteq spint(f(B))$ for every IFS B in X, then f is an IFaSPGO mapping.

Proof: Let B $\subseteq$ X be an IFROS. By hypothesis, f(spint(B)) $\subseteq$spint(f(B)). Since B is an IFROS, it is an IFSPOS in X. Therefore spint(B) = B. Hence f(B) = f(spint(B)) $\subseteq$spint(f(B)) $\subseteq$ f(B). This implies f(B) is an IFSPOS and hence an IFSPGOS in Y. Thus f is an IFaSPGO mapping.

Theorem 5.26: Let f : X $\rightarrow$ Y be a mapping. If spcl(f(B)) $\subseteq$ f(spcl(B)) for every IFS B in X, then f is an IFaSPGC mapping.

Proof: Let B $\subseteq$ X be an IFRCS. By hypothesis, spcl(f(B)) $\subseteq$ f(spcl(B)). Since B is an IFRCS, it is an IFSPCS in X. Therefore spcl(B) = B. Hence f(B) = f(spcl(B)) $\supseteq$spcl(f(B)) $\supseteq$ f(B). This implies f(B) is an IFSPCS and hence an IFSPGCS in Y. Thus f is an IFaSPGC mapping.

Theorem 5.27: The following statements are equivalent for a mapping f : X $\rightarrow$ Y, where Y is an IFSP$T_{1/2}$ space:

(i) f is an IFaSPGC mapping,
(ii) spcl(f(A)) $\subseteq$ f(αcl(A)) for every IFSPOS A in X,
(iii) spcl(f(A)) $\subseteq$ f(αcl(A)) for every IFSOS A in X,
(iv) f(A) $\subseteq$spint(f(scl(A))) for every IFPOS A in X.

Proof: (i) $\Rightarrow$ (ii) Let A be an IFSPOS in X. Then cl(A) is an IFRCS in X. By hypothesis f(cl(A)) is an IFSPGCS in Y and hence is an IFSPCS in Y, since Y is an IFSP$T_{1/2}$ space. This implies spcl(f(cl(A))) = f(cl(A)). Now spcl(f(A)) $\subseteq$spcl(f(cl(A))) = f(cl(A)). Since cl(A) is an IFRCS, cl(int(cl(A))) = cl(A). Therefore spcl(f(A)) $\subseteq$ f(cl(A)) = f(cl(int(cl(A)))) $\subseteq$ f(A $\cup$ cl(int(cl(A)))) = f(αcl(A)). Hence spcl(f(A)) $\subseteq$ f(αcl(A)).
(ii) $\Rightarrow$ (iii) Since every IFSOS is an IFSPOS, the proof is obvious.
(iii) $\Rightarrow$ (i) Let A be an IFRCS in X. Then A = cl(int(A)). Therefore A is an IFSOS in X. By hypothesis, spcl(f(A)) $\subseteq$ f(αcl(A)) $\subseteq$ f(cl(A)) = f(A) $\subseteq$spcl(f(A)). That is spcl(f(A)) = f(A). Hence f(A) is an IFSPCS and hence is an IFSPGCS in Y. Thus f is an IFaSPGC mapping.
(i) $\Rightarrow$ (iv) Let A be an IFPOS in X. Then A $\subseteq$int(cl(A)). Since int(cl(A)) is an IFROS in X, by hypothesis, f(int(cl(A))) is an IFSPGOS in Y. Since Y is an IFSP$T_{1/2}$ space, f(int(cl(A))) is an IFSPOS in Y. Therefore f(A) $\subseteq$ f(int(cl(A))) $\subseteq$spint(f(int(cl(A)))) $\subseteq$spint(f(A $\cup$int(cl(A)))) = spint(f(scl(A))). That is f(A) $\subseteq$spint(f(scl(A))).
(iv) $\Rightarrow$ (i) Let A be an IFROS in X. Then A is an IFPOS in X. By hypothesis, f(A) $\subseteq$spint(f(scl(A))). This implies f(A) $\subseteq$spint(f(A $\cup$int(cl(A)))) $\subseteq$spint(f(A $\cup$ A)) = spint(f(A)) $\subseteq$ f(A). Therefore f(A) is an IFSPOS in Y and hence an IFSPGOS in Y. Thus f is an IFaSPGC mapping.

Theorem 5.28: Let f : X $\rightarrow$ Y be a mapping where Y is an IFSP$T_{1/2}$ space. If f is an IFaSPGC mapping, then int(cl(int(f(B)))) $\subseteq$ f(spcl(B)) for every IFRCS B in X.

Proof: Let B $\subseteq$ X be an IFRCS. By hypothesis, f(B) is an IFSPGCS in Y. Since Y is an IFSP$T_{1/2}$ space, f(B) is an IFSPCS in Y. Therefore spcl(f(B)) = f(B). Now int(cl(int(f(B)))) $\subseteq$ f(B) = f(spcl(B)), since B = spcl(B). Hence int(cl(int(f(B)))) $\subseteq$ f(spcl(B)).

Theorem 5.29: Let f : X $\rightarrow$ Y be a mapping where Y is an IFSP$T_{1/2}$ space. If f is an IFaSPGC mapping, then f(spint(B)) $\subseteq$ cl(int(cl(f(B)))) for every IFROS B in X.

Proof: This theorem can be easily proved by taking complement in Theorem 5.28.

Theorem 5.30: Let f : X $\rightarrow$ Y be a bijective mapping. Then the following statements are equivalent:

(i) f is an IFaSPGO mapping,
(ii) f is an IFaSPGC mapping,
(iii) f^{-1} is an IFaSPG continuous mapping.

Proof: (i) $\Leftrightarrow$ (ii) is obvious from the Theorem 5.16.
(ii) $\Rightarrow$ (iii) Let A $\subseteq$ X be an IFRCS. Then by hypothesis, f(A) is an IFSPGCS in Y. That is $(f^{-1})^{-1}(A)$ is an IFSPGCS in Y. This implies f^{-1} is an IFaSPG continuous mapping.
(iii) $\Rightarrow$ (ii) Let A $\subseteq$ X be an IFRCS. Then by hypothesis $(f^{-1})^{-1}(A)$ is an IFSPGCSin Y. That is f(A) is an IFSPGCS in Y. Hence f is an IFaSPGC mapping.

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