Intuitionistic Fuzzy β^{**}G irresolute Mappings with Separation Axioms

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Abstract

The aim of this paper is to introduce and study the concepts of theoretical applications of intuitionistic fuzzy β^{**}generalized closed sets by defining new spaces namely,intuitionistic fuzzy β^{**} generalized$T_{1/2}$ space andintuitionistic fuzzy β^{**} pre$T_{1/2}$ space. And also we have introducedintuitionistic fuzzy β^{**} generalized irresolute mappings and investigated some of their properties.

Keywords: Intuitionistic fuzzy topology,intuitionistic fuzzy β^{**} generalized closed set, intuitionistic fuzzy β^{**} generalized $T_{1/2}$ space, intuitionistic fuzzy β^{**} pre$T_{1/2}$space andintuitionistic fuzzy β^{**} generalized irresolute mappings.

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1. Introduction

The concept of fuzzy sets was introduced by Zadeh [11] and later Atanassov [1] introduced intuitionistic fuzzy sets using the notion of fuzzy sets. Coker [2] introduced intuitionistic fuzzy topological spaces using the notion of intuitionistic fuzzy sets.Saranya and Jayanthi introduced intuitionistic fuzzy β generalized closed sets in 2016. Sudha and Jayanthi [6] introduced intuitionistic fuzzy β^{**} generalized closed sets. In this paper we overtly enunciate the notion of intuitionistic fuzzy β^{**} generalized $T_{1/2}$ space,intuitionistic fuzzy β^{**}pre $T_{1/2}$ space,intuitionistic fuzzy β^{**} generalized irresolute mappings and investigated some of their properties.

2. Preliminaries

Definition 2.1: [1]An **intuitionistic fuzzy set** (IFS) A 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. An intuitionistic fuzzy set A in X is simply denoted by $A = \langle x, \mu_A, \nu_A \rangle$ instead of denoting $A = \{\langle x, \mu_A(x), \nu_A(x) \rangle : x \in X\}$.

Definition 2.2: [1]Let A and B be two 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 $A \supseteq B$,

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

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

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

The intuitionistic fuzzy sets $0_\sim = \langle x, 0, 1 \rangle$ and $1_\sim = \langle x, 1, 0 \rangle$ are respectively the empty set and the whole set of X.

Definition 2.3: [2] An **intuitionistic fuzzy topology** (IFT) 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 the **intuitionistic fuzzy topological space** (IFTS) and any IFS in τ is known as an **intuitionistic fuzzy open set** (IFOS) in X. The complement A^c of an IFOS A in an IFTS (X, τ) is called an intuitionistic fuzzy closed set (IFCS) in X.

Definition 2.4: [8]Two IFSs A and B are said to be q-coincident ($A_q B$) if and only if there exists an element $x \in X$ such that $\mu_A(x) > \nu_B(x)$ or $\nu_A(x) < \mu_B(x)$.

Definition 2.5: [3] An **intuitionistic fuzzy point** (IFP), written as $p_{(\alpha, \beta)}$ is defined to be an IFS of X given by

$$p_{(\alpha, \beta)}(x) = \begin{cases} (\alpha, \beta) & \text{if } x = p, \\ (0,1) & \text{otherwise.} \end{cases}$$

An IFP $p_{(\alpha, \beta)}$ is said to belong to a set A if $\alpha \le \mu_A$ and $\beta \ge \nu_A$.

Definition 2.6: [6]An IFS A of an IFTS (X, τ) is said to be an **intuitionistic fuzzy β^{**} generalized closed set** (IFβ^{**}GCS) if $cl(int(cl(A))) \cap int(cl(int(A))) \subseteq U$ whenever $A \subseteq U$ and U is an IFOS in (X, τ).

The complement A^c of an IFβ^{**}GCS A in an IFTS (X, τ) is called an **intuitionistic fuzzy β^{**} generalized open set** (IFβ^{**}GOS) in X.

The family of all IFβ^{**}GOSs of an IFTS (X, τ) is denoted by IFβ^{**}GO(X).

Result 2.7: [6] Every IFCS, IFRCS, IFSCS, IFPCS, IFβCS, IFαCS, IFGCS is an IFβ^{**}GCS but the converses may not true in general.

Definition 2.8: [9]An IFTS (X, τ) is said to be an ***intuitionistic fuzzy$T_{1/2}$ space***if every IFGCS is an IFCS in (X, τ).

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

Definition 2.10:[7]A mapping f : (X, τ) → (Y, σ) is called an **intuitionistic fuzzy β^{**} generalized continuous (**IFβ^{**}G continuous) **mapping** if $f^{-1}(V)$ is an IFβ^{**}GCS in (X, τ) for every IFCS V of (Y, σ).

Definition 2.11:[5] A mapping f : (X, τ) → (Y, σ) is called an **intuitionistic fuzzy generalized irresolute** (IF irresolute) **mapping** if $f^{-1}(V)$ is an IFGCS in (X, τ) for every IFGCS V of (Y, σ).

3.Theoretical applications of intuitionistic fuzzy β** generalized closed sets

In this section we have investigated some theoretical applications of intuitionistic fuzzy β** generalized closed sets by defining new spaces and obtained many interesting propositions.

Definition 3.1: An IFTS (X, τ) is an ***intuitionistic fuzzy β**pT$_{1/2}$***(IFβ**pT$_{1/2}$) ***space*** if every IFβ**GCS is an IFPCS in X.

Example 3.2: Let X = {a, b} and τ = {$0_\sim$, G_1, G_2, $1_\sim$} be an IFT on X, where G_1 = ⟨x, (0.5_a, 0.3_b), (0.5_a, 0.4_b)⟩, G_2 = ⟨x, (0.5_a, 0.4_b), (0.5_a, 0.3_b)⟩.

Then,

IFPC(X) ={$0_\sim$,$1_\sim$, $\mu_a \in [0,1]$, $\mu_b \in [0,1]$, $\nu_a \in [0,1]$, $\nu_b \in [0,1]$/ $0 \leq \mu_a + \nu_a \leq 1$ and $0 \leq \mu_a + \nu_a \leq 1$} and

IFβ**GC(X) ={$0_\sim$,$1_\sim$, $\mu_a \in [0,1]$, $\mu_b \in [0,1]$, $\nu_a \in [0,1]$, $\nu_b \in [0,1]$/ $0 \leq \mu_a + \mu_b \leq 1$, $0 \leq \mu_a + \mu_b \leq 1$}

Therefore the space (X, τ) is an intuitionistic fuzzy β**pT$_{1/2}$ space, as every IFβ**GCS is an IFPCS in this (X, τ).

Definition 3.3: An IFTS (X, τ) is an ***intuitionistic fuzzy β**gT$_{1/2}$***(IFβ**gT$_{1/2}$) ***space*** if every IFβ**GCS is an IFGCS in X.

Example 3.4: In example 3.2, IFGC(X) ={$0_\sim$,$1_\sim$, $\mu_a \in [0,1]$, $\mu_b \in [0,1]$, $\nu_a \in [0,1]$, $\nu_b \in [0,1]$/ $0 \leq \mu_a + \nu_a \leq 1$ and $0 \leq \mu_a + \nu_a \leq 1$}**.** The space (X, τ) is an intuitionistic fuzzy β**gT$_{1/2}$ space, as every IFβ**GCS is an IFGCS in this (X, τ).

Remark 3.5: Not every IFβ**pT$_{1/2}$ space is an IFT$_{1/2}$ space. This can be seen easily from the following example.

Example 3.6: In example 3.2, (X, τ) is an IFβ**pT$_{1/2}$ space, but not an IFT$_{1/2}$ space. Since the IFS A = ⟨x, (0.6_a, 0.7_b), (0.4_a, 0.3_b)⟩ is an IFGCS, but not an IFCS, as cl(A) = $1_\sim \neq$ A.

Proposition 3.7: An IFTS (X, τ) is an IFβ**g$T_{1/2}$ space if and only if IFGO(X) = IFβ**GO(X).

Proof: Necessity: Let A be an IFβ**GOS in (X, τ), then A^c is an IFβ**GCS in (X, τ). By hypothesis, A^c is an IFGCS in (X, τ). Hence A is an IFGOS in (X, τ). Thus IFGO(X) = IFβ**GO(X).

Sufficiency: Let A be an IFβ**GCS in (X, τ). Then A^c is an IFβ**GOS in (X, τ). By hypothesis, A^c is an IFGOS in (X, τ). Therefore A is an IFGCS in (X, τ). Hence (X, τ) is an IFβ**g$T_{1/2}$ space.

Proposition 3.8: Let X be an IFβ**p$T_{1/2}$ space. Then for an IFS A the following conditions are equivalent:

(i) A $\in$ IFβ**GO(X)

(ii) A $\subseteq$int(cl(A))

(iii) There exists an IFOS G such that G $\subseteq$ A$\subseteq$int(cl(A))

Proof: (i) ⇒ (ii) Let A$\in$IFβ**GO(X). This implies A is an IFPOS in X, since X is an IFβ**p$T_{1/2}$ space. Then A^c is an IFPCS in X. Therefore cl(int(A^c)) $\subseteq$ A^c. This implies A $\subseteq$int(cl(A)).

(ii) ⇒ (iii) Let A $\subseteq$int(cl(A)). Hence int(int(A)) $\subseteq$ A $\subseteq$int(cl(A)). Then there exists IFOS G in X such that G $\subseteq$ A$\subseteq$int(cl(A)), where G = int(A).

(iii)⇒ (i) Suppose that there exists IFOS G such that G $\subseteq$ A$\subseteq$int(cl(A)). It is clear that $(int(cl(A)))^c$ $\subseteq$ A^c. This implies cl(int(A^c)) $\subseteq$ A^c .That is A^c is an IFPCS in X. This implies A is an IFPOS in X. Hence A$\in$ IFβ**GO(X).

Proposition 3.9: Let X be an IFβ**g$T_{1/2}$ space. If A is an IFS of X then the following properties are equivalent:

(i) A $\in$ IFβ**GO(X)

(ii) U $\subseteq$int(cl(int(A))) whenever U $\subseteq$ A and U is an IFCS in X.

(iii) There exist IFOSs G and G_1 such that $G_1$$\subseteq$ U$\subseteq$int(cl(G)).

Proof: (i) ⇒ (ii) Let A$\in$ IFβ**GO(X). This implies A is an IFGOS in X, since X is an IFβ**g$T_{1/2}$ space. Then A^c is an IFGCS in X. Therefore cl(A^c) $\subseteq$ V whenever $A^c$$\subseteq$ V and V is an IFOS in X. That is cl(int(cl(A^c))) $\subseteq$ cl(cl(A^c)) $\subseteq$ cl(A^c) $\subseteq$ V. This implies

$V^c \subseteq int(cl(int(A)))$ whenever $V^c \subseteq A$ and V^c is an IFCS in X. Replacing V^c by U, $U \subseteq int(cl(int(A)))$ whenever $U \subseteq A$ and U is an IFCS in X.

(ii) ⇒ (iii) Let $U \subseteq int(cl(int(A)))$ whenever $U \subseteq A$ and U is an IFCS in X. We have $int(U) \subseteq U \subseteq int(cl(int(A)))$. Hence there exist IFOSs G and G_1 in X such that $G_1 \subseteq U \subseteq int(cl(G))$ where $G = int(A)$ and $G_1 = int(U)$.

(iii)⇒ (i) Suppose that there exist IFOSs G and G_1 such that $G_1 \subseteq U \subseteq int(cl(G))$. Then it is clear that $(int(cl(G)))^c \subseteq U^c$. That is $(int(cl(int(A))))^c \subseteq U^c$. This implies $cl(int(cl(A^c))) \subseteq U^c$, $A^c \subseteq U^c$ and U^c is an IFOS in X. This implies $cl(A^c) \subseteq U^c$. That is A^c is an IFGCS in X. This implies A is an IFGOS in X. Hence $A \in$ IFβ**GO(X).

Proposition 3.10: Let (X, τ) be an IFβ**p$T_{1/2}$ space. Then

(i) Any union of IFβ**GCS is an IFβ**GCS,

(ii) Any intersection of IFβ**GOS is an IFβ**GOS.

Proof: (i) Let $\{A_i\}_{i\in I}$ be a collection of IFβ**GCSs. Since (X, τ) is an IFβ**p$T_{1/2}$ space,every IFβ**GCS is an IFPCS. As any union of IFPCS is an IFPCS, $\bigcup_{i\in I} A_i$ is an IFPCS. Since every IFPCS is an IFβ**GCS, $\bigcup_{i\in I} A_i$ is an IFβ**GCS.

(ii)can be proved easily by taking complement in (i).

Proposition 3.11: An IFTS (X, τ) is an intuitionistic fuzzy β**p$T_{1/2}$ space if and only if IFβ**GO(X) = IFPO(X).

Proof: Necessity: Let A be an IFβ**GOS in (X, τ), then A^c is an IFβ**GCS in (X, τ). By hypothesis, A^c is an IFPCS in (X, τ). Hence A is an IFPOS in X. Thus IFβ**GO(X) = IFPO(X).

Sufficiency: Let A be an IFβ**GCS in (X, τ). Then A^c is an IFβ**GOS in (X, τ). By hypothesis, A^c is an IFPOS in (X, τ) and hence A is an IFPCS (X, τ). Therefore (X, τ) is an intuitionistic fuzzy β**p$T_{1/2}$ space.

Proposition 3.12: For any IFS A in (X, τ) where X is an IFβ**pT$_{1/2}$ space, A ∈ IFβ**GO(X) if and only if for every IFP $p_{(\alpha, \beta)} \in$ A, there exists an IFβ**GOS B in X such that $p_{(\alpha, \beta)} \in B \subseteq$ A.

Proof: Necessity: If A ∈ IFβ**GO(X), then we can take B = A so that $p_{(\alpha, \beta)} \in B \subseteq A$ for every IFP $p_{(\alpha, \beta)} \in$ A.

Sufficiency: Let A be anIFS in (X, τ) and assume that there exists B ∈ IFβ**GO(X) such that $p_{(\alpha, \beta)} \in B \subseteq A$. Since X is an IFβ**pT$_{1/2}$ space, B is an IFPOS [6]. Then A = $\bigcup_{p_{(\alpha,\beta)}\in A} \{p_{(\alpha,\beta)}\}$ $\subseteq \bigcup_{p_{(\alpha,\beta)}\in A} B \subseteq A$. Therefore A = $\bigcup_{p_{(\alpha,\beta)}\in A} B$, which is an IFPOS. Hence A is an IFβ**GOS in X.

4. Intuitionistic fuzzy β** generalized irresolute mappings

In this section we have introduced intuitionistic fuzzy β** generalized irresolute mappings and studied some of their properties.

Definition 4.1:A mapping f : (X, τ) → (Y, σ) is an **intuitionistic fuzzy β** generalized** (IFβ**G) **irresolutemapping**if $f^{-1}(V)$ is an IFβ**GCS in (X, τ) for every IFβ**GCS V of (Y, σ).

Example 4.2: Let X = {a, b} and Y = {u, v}. Then τ = {0~, G$_1$, G$_2$, 1~} and σ = {0~, G$_3$, 1~} are IFTs on X and Y respectively, where G$_1$ = ⟨ x, (0.5_a, 0.4_b), (0.5_a, 0.6_b) ⟩, G$_2$ = ⟨ x, (0.8_a, 0.6_b), (0.2_a, 0.4_b) ⟩ and G$_3$ = ⟨ y, (0.3_u, 0.4_v), (0.5_u, 0.6_v) ⟩. Define a mapping f : (X, τ) → (Y, σ) by f(a) = u and f(b) = v. Then f is an IFβ**G irresolute mapping.

Proposition 4.3: Let f : (X, τ) → (Y, σ) be an IFβ**G irresolute mapping, then f is an IFβ**G continuous mapping but not conversely.

Proof: Let V be any IFCS in Y. Then V is an IFβ**GCS and by hypothesis $f^{-1}(V)$ is an IFβ**GCS in X. Hence f is an IFβ**G continuous mapping.

Example 4.4: Let X = {a, b} and Y = {u, v} and G$_1$ = ⟨ x, (0.6_a, 0.8_b), (0.2_a, 0.1_b) ⟩, G$_2$ = ⟨ x, (0.3_a, 0.3_b), (0.2_a, 0.2_b) ⟩ and G$_3$ = ⟨ y, (0.5_u, 0.6_v), (0.5_u, 0.4_v) ⟩. Then τ = {0~, G$_1$, G$_2$, 1~} and

$\sigma = \{0_\sim, G_3, 1_\sim\}$ 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 IFβ**G continuous mapping but not an IFβ**G irresolute mapping, since the IFS $A = \langle y, (0.5_u, 0.3_v), (0.2_u, 0.1_v) \rangle$ is an IFβ**GCS in Y and its inverse $f^{-1}(A)$ is not an IFβ**GCS in X, as $f^{-1}(A) = \langle x, (0.5_a, 0.3_b), (0.2_a, 0.1_b) \rangle \subseteq G_1$, but $int(cl(int(f^{-1}(A)))) \cap cl(int(cl(f^{-1}(A)))) = 1_\sim \not\subseteq G_1$.

Proposition 4.5: A mapping $f : (X, \tau) \to (Y, \sigma)$ is an IFβ**G irresolute mapping if and only if the inverse image of each IFβ**GOS in Y is an IFβ**GOS in X.

Proof :straightforward.

Proposition 4.6: The composition of two IFβ**G irresolute mappingsis an IFβ**G irresolute mapping.

Proof : Let $f : (X, \tau) \to (Y, \sigma)$ and $g : (Y, \sigma) \to (Z, \delta)$ be any two IFβ**G irresolute mappings. Let V be an IFβ**GCS in Z. Then $g^{-1}(V)$ is an IFβ**GCS in Y, by hypothesis. Since f is an IFβ**G irresolute mapping, $f^{-1}(g^{-1}(V))$ is an IFβ**GCS in X. Hence g o f is an IFβ**G irresolute mapping.

Proposition 4.7: Let $f : (X, \tau) \to (Y, \sigma)$ be an IFβ**G irresolute mapping and $g : (Y, \sigma) \to (Z, \delta)$ is an IFβ**G continuous mapping, then $g \circ f : (X, \tau) \to (Z, \delta)$ is an IFβ**G continuous mapping.

Proof: Let V be an IFCS in Z. Then $g^{-1}(V)$ is an IFβ**GCS in Y. Since f is an IFβ**G irresolute mapping, $f^{-1}(g^{-1}(V))$ is an IFβ**GCS in X. Hence g o f is an IFβ**G continuous mapping.

Proposition 4.8: Let $f : (X, \tau) \to (Y, \sigma)$ be a mapping from an IFTS X into an IFTS Y. Then the following conditions are equivalent if X and Y are IFβ**p$T_{1/2}$ spaces:

(i) f is an IFβ**G irresolute mapping

(ii) $f^{-1}(B)$ is an IFβ**GOS in X for each IFβ**GOS B in Y

(iii) $f^{-1}(pint(B)) \subseteq pint(f^{-1}(B))$ for each IFS B of Y

(iv) $pcl((f^{-1}(B)) \subseteq f^{-1}((pcl(B))$ for each IFS B of Y.

Proof: (i) $\Leftrightarrow$ (ii)is obvious, since $f^{-1}(A^c) = (f^{-1}(A))^c$.

(ii) $\Rightarrow$ (iii) Let B be any IFS in Y and pint(B) $\subseteq$ B. Also f^{-1}(pint(B)) $\subseteq$ f^{-1}(B). Since pint(B) is an IFPOS in Y, it is an IFβ**GOS in Y. Therefore f^{-1}(pint(B)) is an IFβ**GOS in X, by hypothesis. Since X is an IFβ**p$T_{1/2}$ space, f^{-1}(pint(B)) is an IFPOS in X. Hence f^{-1}(pint(B)) = pint(f^{-1}(pint(B))) $\subseteq$ pint(f^{-1}(B)).

(iii)$\Rightarrow$ (iv) is obvious by taking complement in (iii).

(iv)$\Rightarrow$ (i) Let B be an IFβ**GCS in Y. Since Y is an IFβ**p$T_{1/2}$ space, B is an IFPCS in Y and pcl(B)=B. Hence f^{-1}(B) = f^{-1}(pcl(B)) $\supseteq$pcl(f^{-1}(B)), by hypothesis. But f^{-1}(B) $\subseteq$pcl(f^{-1}(B)). Therefore pcl(f^{-1}(B)) = f^{-1}(B). This implies f^{-1}(B) is an IFPCS and hence it is an IFβ**GCS in X.Thus f is an IFβ**G irresolute mapping.

Proposition 4.9: Let f : (X, τ) → (Y, σ) be an IFβ**G irresolute mapping. Then f^{-1}(B) $\subseteq$pint(f^{-1}(int(cl(B))) for every IFβ**GOS B in Y, if X and Y are IFβ**p$T_{1/2}$ spaces.

Proof: Let B be an IFβ**GOS in Y. Then by hypothesis, f^{-1}(B) is an IFβ**GOS in X. Since X is an IFβ**p$T_{1/2}$ space, f^{-1}(B) is an IFPOS in X. Therefore pint(f^{-1}(B)) = f^{-1}(B). Since Y is an IFβ**p$T_{1/2}$ space , B is an IFPOS in Y and B$\subseteq$int(cl(B)). Now f^{-1}(B) = pint(f^{-1}(B)) $\subseteq$ pint(f^{-1}(int(cl(B))).

Proposition 4.10: If f : (X, τ) → (Y, σ) is an IFβ**G irresolute mapping and g : (Y, σ) → (Z, δ) is an IF contra continuous mapping, then g o f : (X, τ) → (Z, δ) is an IF contra β**G continuous mapping.

Proof: Let V be an IFOS in Z. Then g^{-1}(V) is an IFCS in Y, since g is an IF contra continuous mapping. As every IFCS is an IFβ**GCS, g^{-1}(V) is an IFβ**GCS in Y. Since f is an IFβ**G irresolute mapping, f^{-1}(g^{-1}(V)) is an IFβ**GCS in X. Therefore g o f is an IF contra β**G continuous mapping.

Proposition 4.11 : Let f : (X, τ) → (Y, σ) is an IFβ**G irresolute mapping and g : (Y, σ) → (Z, δ) is an IFβ**G continuous mapping, then g o f : (X, τ) → (Z, δ) is an IF almost β**G continuous mapping.

Proof : Let V be an IFRCS in Z. Since every IFRCS is an IFCS, V is an IFCS in Z. Therefore $g^{-1}(V)$ is an IFβ**GCS in Y, by hypothesis. Since f is an IFβ**G irresolute mapping, $f^{-1}(g^{-1}(V))$ is an IFβ**GCS in X. Hence g o f is an IF almost β**G continuous mapping.

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