Intuitionistic Fuzzy Quasi γ Generalized Continuous Mappings

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Abstract: In this paper, I am introduce intuitionistic fuzzy quasi γ generalized continuous mappings and investigate some of their properties. I am provide the relation between intuitionistic fuzzy quasi γ generalized continuous mappings and some of the already existing intuitionistic fuzzy continuous mappings.

Keywords: Intuitionistic fuzzy topology, intuitionistic fuzzy continuous mappings, intuitionistic fuzzy quasi γ generalized continuous mappings.

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1. Introduction

Atanassov [1] introduced the idea of intuitionistic fuzzy sets. Coker [2] introduced intuitionistic fuzzy topological spaces using the notion of intuitionistic fuzzy sets. Prema, S and Jayanthi, D[5] introduced intuitionistic fuzzy γ generalized closed sets. In this paper, I am introduce the notion of intuitionistic fuzzy quasi γ generalized continuous mappings in intuitionistic fuzzy topological spaces. I am provide some characterizations of intuitionistic fuzzy quasi γ generalized continuous mappings and establish the relationships with other classes of early defined forms of intuitionistic fuzzy continuous mappings.

2. Preliminaries

Definition 2.1: **[**1**]** An intuitionistic fuzzy set (IFS for short) A is an object having the form

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

where the functions $\mu_A : X \longrightarrow [0,1]$ and $\nu_A : X \longrightarrow [0,1]$ 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: [5] An IFS A in an IFTS (X, τ) is said to be an intuitionistic fuzzy γ generalized closed set (IFγGCS) if $\gamma cl(A) \subseteq U$ whenever $A \subseteq U$ and U is an IFγOS in (X, τ).

The complement A^c of an IFγGCS A in an IFTS (X, τ) is called an intuitionistic fuzzy γ generalized open set (IFγGOS) in X.

Definition 2.5: [6] A mapping $f: (X, \tau) \to (Y, \sigma)$ is called an intuitionistic fuzzy γ generalized α continuous (IFγG continuous) mapping if $f^{-1}(V)$ is an IFγGCS in (X, τ) for every IFCS V of (Y, σ).

Definition 2.6: [5] An IFTS (X, τ) is an intuitionistic fuzzy γ_γ $T_{1/2}$ (IFγ_γ $T_{1/2}$) space if every IFγGCS is an IFγCS in X.

Definition 2.7: [6] A mapping $f: X \to Y$ is called an intuitionistic fuzzy γ generalized irresolute mapping if $f^{-1}(A)$ is an IFγGCS in X for each IFγGCS A in Y.

Definition 2.8: [7] A mapping $f: X \to Y$ is called an intuitionistic fuzzy almost γ generalized continuous mapping if $f^{-1}(A)$ is an IFγGCS in X for each IFRCS A in Y.

Corollary 2.9: [3] Let A, A_i ($i \in J$) be intuitionistic fuzzy sets in X and B, B_j ($j \in K$) be intuitionistic fuzzy sets in Y and f: X → Y be a mapping. Then

a) $A_1 \subseteq A_2 \Rightarrow f(A_1) \subseteq f(A_2)$

b) $B_1 \subseteq B_2 \Rightarrow f^{-1}(B_1) \subseteq f^{-1}(B_2)$

c) $A \subseteq f^{-1}(f(A))$ [If f is injective, then $A = f^{-1}(f(A))$]

d) $f(f^{-1}(B)) \subseteq B$ [If f is surjective, then $B = f(f^{-1}(B))$]

e) $f^{-1}(\cup B_j) = \cup f^{-1}(B_j)$

f) $f^{-1}(\cap B_j) = \cap f^{-1}(B_j)$

g) $f^{-1}(0_\sim) = 0_\sim$

h) $f^{-1}(1_\sim) = 1_\sim$

i) $f^{-1}(B^c) = (f^{-1}(B))^c$

Definition 2.10: [4] Let (X, τ) be an IFTS and $A= \langle x, \mu_A, \nu_A \rangle$ be an IFS in X. Then the intuitionistic fuzzy γ interior and intuitionistic fuzzy γ closure are defined by

$$\gamma int(A) = \cup\{ G / G \text{ is an IF}\gamma\text{OS in X and } G \subseteq A \},$$

$$\gamma cl(A) = \cap\{K / K \text{ is an IF}\gamma\text{CS in X and } A \subseteq K\}.$$

Note that for any IFS A in (X, τ), we have $\gamma cl(A^c) = (\gamma int(A))^c$ and $\gamma int(A^c) = (\gamma cl(A))^c$.

Definition 2.12: [3] Let f be a mapping from an IFTS (X, τ) into an IFTS (Y, σ). Then f is said to be an

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

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

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

Definition 2.13: [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 γ continuous mapping if $f^{-1}(B) \in$ IFPO(X) for every $B \in \sigma$.

3. Intuitionistic Fuzzy Quasi γ Generalized Continuous Mappings

In this section we introduce intuitionistic fuzzy quasi γ generalized continuous mappings and study some of their properties.

Definition 3.1: A mapping f: (X, τ) → (Y, σ) is called an intuitionistic fuzzy quasi γ generalized α continuous mapping (IF quasi γG continuous mapping) if $f^{-1}(V)$ is an IFCS in X for every IFγGCS V of Y.

Theorem 3.2: Every IF quasi γG continuous mapping is an IF continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFCS in Y. Since every IFCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Hence f is an IF continuous mapping.

Example 3.3: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.5_a, 0.6_b), (0.5_a, 0.4_b)\rangle$, $G_2 = \langle x, (0.4_a, 0.3_b), (0.6_a, 0.7_b)\rangle$, $G_3 = \langle y, (0.5_u, 0.6_v), (0.5_u, 0.4_v)\rangle$ and $G_4 = \langle y, (0.4_u, 0.3_v), (0.6_u, 0.7_v)\rangle$. Then $\tau = \{0_\sim, G_1, G_2\ 1_\sim\}$ and $\sigma = \{0_\sim, G_3, G_4, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v.

IFγO(X)= $\{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0,1], \nu_a \in [0,1], \nu_b \in [0,1]/$ either $\nu_a < 0.4$ or $\nu_b < 0.3$, $\nu_a \geq 0.5$ whenever $\nu_b < 0.6$, $0.4 \leq \nu_a \leq 0.5$ whenever $\nu_b \leq 0.4$, $\mu_a \geq 0.5$, $\mu_b \geq 0.6$, $0.5 \leq \nu_a < 0.6$ whenever $\nu_b \geq 0.6$, $\mu_a \geq 0.4$, $\mu_b \geq 0.3$ and $\nu_a \geq 0.6$ whenever $\nu_b \geq 0.4$, $0 \leq \mu_a + \nu_a \leq 1$ and $0 \leq \mu_b + \nu_b \leq 1\}$.

IFγC(X) = $\{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0, 1], \nu_a \in [0,1], \nu_b \in [0,1]/$ either $\mu_a < 0.4$ or $\mu_b < 0.3$, $\mu_a \geq 0.5$ whenever $\mu_b < 0.6$, $0.4 \leq \mu_a \leq 0.5$ whenever $\mu_b \leq 0.4$, $\nu_a \geq 0.5$, $\nu_b \geq 0.6$, $0.5 \leq \mu_a < 0.6$ whenever $\mu_b \geq 0.6$, $\nu_a \geq 0.4$, $\nu_b \geq 0.3$ and $\mu_a \geq 0.6$ whenever $\mu_b \geq 0.4$, $0 \leq \mu_a + \nu_a \leq 1$ and $0 \leq \mu_b + \nu_b \leq 1\}$.

IFγO(Y)= $\{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0,1], \nu_a \in [0,1], \nu_b \in [0,1]/$ either $\nu_a < 0.4$ or $\nu_b < 0.3$, $\nu_a \geq 0.5$ whenever $\nu_b < 0.6$, $0.4 \leq \nu_a \leq 0.5$ whenever $\nu_b \leq 0.4$, $\mu_a \geq 0.5$, $\mu_b \geq 0.6$, $0.5 \leq \nu_a < 0.6$ whenever $\nu_b \geq 0.6$, $\mu_a \geq 0.4$, $\mu_b \geq 0.3$ and $\nu_a \geq 0.6$ whenever $\nu_b \geq 0.4$, $0 \leq \mu_a + \nu_a \leq 1$ and $0 \leq \mu_b + \nu_b \leq 1\}$.

IFγC(Y) = $\{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0, 1], \nu_a \in [0,1], \nu_b \in [0,1]/$ either $\mu_a < 0.4$ or $\mu_b < 0.3$, $\mu_a \geq 0.5$ whenever $\mu_b < 0.6$, $0.4 \leq \mu_a \leq 0.5$ whenever $\mu_b \leq 0.4$, $\nu_a \geq 0.5$, $\nu_b \geq 0.6$, $0.5 \leq \mu_a < 0.6$ whenever $\mu_b \geq 0.6$, $\nu_a \geq 0.4$, $\nu_b \geq 0.3$ and $\mu_a \geq 0.6$ whenever $\mu_b \geq 0.4$, $0 \leq \mu_a + \nu_a \leq 1$ and $0 \leq \mu_b + \nu_b \leq 1\}$.

Here f is an IF continuous mapping but not an IF quasi γG continuous mapping. Since $G_3 = \langle y, (0.5_u, 0.6_v), (0.5_u, 0.4_v)\rangle$ is an IFγGCS in Y but $f^{-1}(G_3)$ is not an IFCS in X.

Theorem 3.4: Every IF quasi γG continuous mapping is an IF semi continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFCS in Y. Since every IFCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFSCS, $f^{-1}(A)$ is an IFSCS in X. Hence f is an IF semi continuous mapping.

Example 3.5: In Example 3.3, f is an IF semi continuous mapping but not an IF quasi γG continuous mapping.

Theorem 3.6: Every IF quasi γG continuous mapping is an IF pre continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFCS in Y. Since every IFCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFPCS, $f^{-1}(A)$ is an IFPCS in X. Hence f is an IF pre continuous mapping.

Example 3.7: In Example 3.3, f is an IF pre continuous mapping but not an IF quasi γG continuous mapping.

Theorem 3.8: Every IF quasi γG continuous mapping is an IFα continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFCS in Y. Since every IFCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFαCS, $f^{-1}(A)$ is an IFαCS in X. Hence f is an IFα continuous mapping.

Example 3.9: In Example 3.3, f is an IFα continuous mapping but not an IF quasi γG continuous mapping.

Theorem 3.10: Every IF quasi γG continuous mapping is an IFγ continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFCS in Y. Since every IFCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFγCS, $f^{-1}(A)$ is an IFγCS in X. Hence f is an IFγ continuous mapping.

Example 3.11: In Example 3.3, f is an IFγ continuous mapping but not an IF quasi γG continuous mapping.

Theorem 3.12: Every IF quasi γG continuous mapping is an IFγG continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFCS in Y. Since every IFCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFγGCS, $f^{-1}(A)$ is an IFγGCS in X. Hence f is an IFγG continuous mapping.

Example 3.13: In Example 3.3, f is an IFγG continuous mapping but not an IF quasi γG continuous mapping.

Theorem 3.14: Every IF quasi γG continuous mapping is an IFaγG continuous mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFRCS in Y. Since every IFRCS is an IFγGCS in Y, A is an IFγGCS in Y. Then by hypothesis $f^{-1}(A)$ is an IFCS in X. Since every IFCS is an IFγGCS, $f^{-1}(A)$ is an IFγGCS in X. Hence f is an IFaγG continuous mapping.

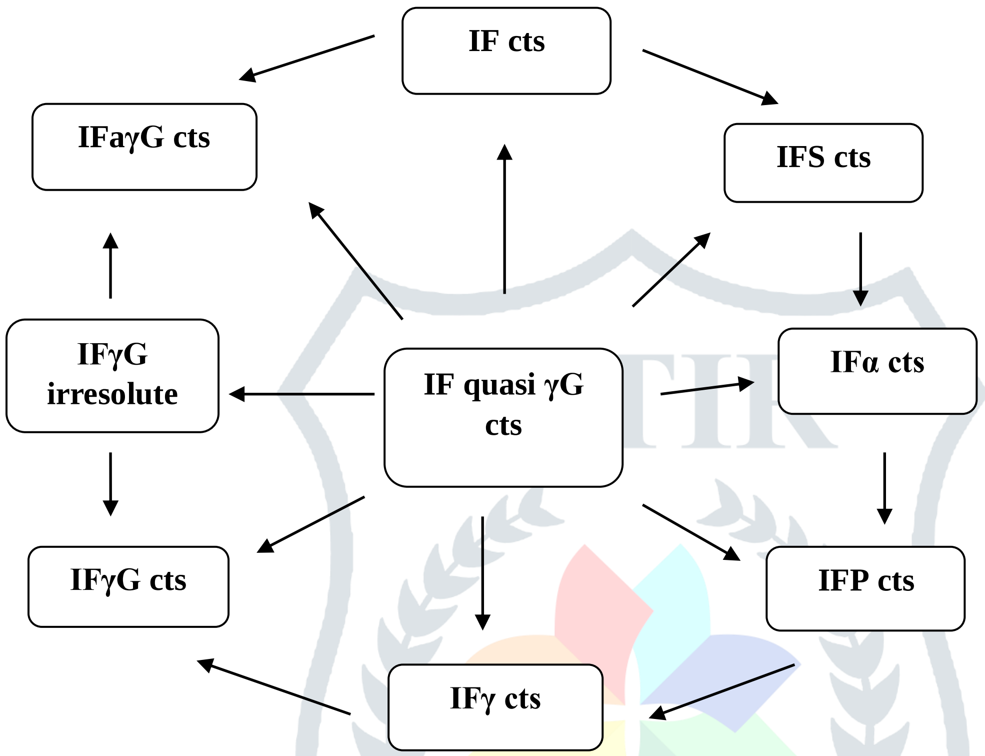
Example 3.15: In Example 3.3, f is an IFaγG continuous mapping but not an IF quasi γG continuous mapping.

Theorem 3.16: Every IF quasi γG continuous mapping is an IFγG irresolute mapping but not conversely in general.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping. Let A be an IFγGCS in Y. Then $f^{-1}(A)$ is an IFCS in X by hypothesis. Since every IFCS is an IFγGCS, $f^{-1}(A)$ is an IFγGCS in X. Hence f is an IFγG irresolute mapping.

Example 3.17: In Example 3.3, f is an IFγG irresolute mapping but not an IF quasi γG continuous mapping.

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



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

Theorem 3.18: Let f: (X, τ) → (Y, σ). be an mapping. Then the following statements are equivalent:

(i) f is an IF quasi γG continuous mapping.

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

Proof: Proof is obvious as $f^{-1}(A^c) = (f^{-1}(A))^c$

Theorem 3.19: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping then f(cl(A)) ⊆ γcl(f(A)) for every IFS A in X.

Proof: Let A be an IFS in X. Then γcl(f (A)) is an IFγGCS in Y. Since f is an IF quasi γG continuous mapping, f^{-1}(γcl(f(A))) is an IFCS in X. Clearly A ⊆ f^{-1}(f(A)) ⊆ f^{-1}(γcl(f(A))). Therefore cl(A) ⊆ cl(f^{-1}(γcl(f(A)))) = f^{-1}(γcl(f(A))). Hence f(cl(A)) ⊆ f(f^{-1}(γcl(f(A)))) ⊆ γcl(f (A)).

Theorem: 3.20: If (Y, σ) is an IFγ_γ $T_{1/2}$ space, then a mapping f : (X, τ) → (Y, σ) is an IF quasi γG continuous mapping if and only if f^{-1}(γint(B)) ⊆ int(f^{-1}(B)) for every IFS B of Y.

Proof: Let f be an IF quasi γG continuous mapping. Let B ⊆ Y be an IFS. Then we have γint(B) ⊆ B and f^{-1}(γint(B)) ⊆ f^{-1}(B). Since γint(B) is an IFγOS, it is an IFγGOS. Then by hypothesis f^{-1}(γint(B)) is an IFOS in X. Therefore f^{-1}(γint(B)) = int(f^{-1}(γint(B))) ⊆ int(f^{-1}(B)).

Conversely assume that B is an IFγGOS in Y. Since Y is an IFγ_γ $T_{1/2}$ space, B is an IFγOS in Y and then $f^{-1}(B) = f^{-1}(\gamma int(B)) \subseteq int(f^{-1}(B)) \subseteq f^{-1}(B)$. Therefore $f^{-1}(B)$ is an IFOS in X. Hence f is an IF quasi γG continuous mapping.

Theorem 3.21: Let Y be an IFγ_γ $T_{1/2}$ space. If an bijective mapping f: (X, τ) → (Y, σ) is an IF quasi γG continuous mapping, then $\gamma int(f(B)) \subseteq f(int(B))$, for every IFS B of X.

Proof: Let B be an IFS of X. Then γint(f(B)) is an IFγOS in Y and hence is an IFγGOS in Y. By hypothesis $f^{-1}(\gamma int(f(B)))$ is an IFOS in X. Hence $f^{-1}(\gamma int(f(B))) \subseteq int(f^{-1}(\beta int(f(B)))) \subseteq int(f^{-1}(f(B))) = int(B)$. Now $\gamma int(f(B)) = f(f^{-1}(\gamma int(f(B)))) \subseteq f(int(B))$.

Theorem 3.22: The composition of two IF quasi γG continuous mapping is an IF quasi γG continuous mapping.

Proof: Let f: (X, τ) → (Y, σ) be an IF quasi γG continuous mapping and g : (Y, σ) → (Z, δ) an IF quasi γG continuous mapping. Let A be an IFγGCS in Z. By hypothesis, $g^{-1}(A)$ is an IFCS in Y and hence is an IFγGCS in Y. Now $f^{-1}(g^{-1}(A)) = (g \circ f)^{-1}(A)$ is an IFCS in X, by hypothesis. Hence g o f is an IF quasi γG continuous mapping.

Theorem 3.23: Let f: (X, τ) → (Y, σ) and g : (Y, σ) → (Z, δ) be any two mappings. Then the following statements hold

(i) If f: (X, τ) → (Y, σ) is an IF continuous mapping and g : (Y, σ) → (Z, δ) is an IF quasi γG continuous mapping. Then g o f : (X, τ) → (Z, δ) is an IF quasi γG continuous mapping.

(ii) If f: (X, τ) → (Y, σ) is an IF quasi γG continuous mapping and g : (Y, σ) → (Z, δ) is an IF continuous mapping .Then g o f : (X, τ) → (Z, δ) is an IF continuous mapping.

(iii) If f: (X, τ) → (Y, σ) is an IF quasi γG continuous mapping and g : (Y, σ) → (Z, δ) is an IF γG continuous mapping. Then g o f : (X, τ) → (Z, δ) is an IF continuous mapping.

Proof: (i) Let A be an IFγGCS in Z. By hypothesis, $g^{-1}(A)$ is an IFCS in Y. Since f is an IF continuous mapping, $f^{-1}(g^{-1}(A)) = (gof)^{-1}(A)$ is an IFCS in X. Hence gof is an IF quasi γG continuous mapping.

(ii) Let A be an IFCS in Z. By hypothesis, $g^{-1}(A)$ is an IFCS in Y. Since every IFCS is an IFγGCS, $g^{-1}(A)$ is an IFγGCS in Y. Then $f^{-1}(g^{-1}(A)) = (gof)^{-1}(A)$ is an IFCS in X, by hypothesis. Hence gof is an IF continuous mapping.

(iii) Let A be an IFCS in Z. By hypothesis, $g^{-1}(A)$ is an IFγGCS in Y. Since f is an IF quasi γG continuous mapping, $f^{-1}(g^{-1}(A)) = (gof)^{-1}(A)$ is an IFCS in X. Hence gof is an IF continuous mapping.

Theorem 3.24: If g : (Y, σ) → (Z, δ) is an IF γG irresolute mapping and f: (X, τ) → (Y, σ) is an IF quasi γG continuous mapping, then g o f : (X, τ) → (Z, δ) is an IF quasi γG continuous mapping.

Proof: Let B be an IFγGCS in Z. By hypothesis, $g^{-1}(A)$ is an IFγGCS in Y. Since f is an IF quasi γG continuous mapping, $f^{-1}(g^{-1}(A)) = (g \circ f)^{-1}(A)$ is an IFCS in X. Hence g o f is an IF quasi γG continuous mapping.

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