Intuitionistic Fuzzy β Generalized Homeomorphisms

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Abstract: *In this paper we introduce the new class of homeomorphisms called intuitionistic fuzzy β generalized homeomorphisms. We also introduce M – β generalized homeomorphisms in intuitionistic fuzzy topological spaces and investigate some of the properties. We provide the relation between intuitionistic fuzzy β generalized homeomorphisms and intuitionistic fuzzy M – β generalized homeomorphisms. Also we prove that the set of all M-generalized semi-pre homeomorphisms forms a group under the operation of composition of maps.*

Keywords: *Intuitionistic fuzzy topology, intuitionistic fuzzy $\beta_g T_{1/2}$ space, intuitionistic fuzzy β generalized homeomorphisms and intuitionistic fuzzy M - β generalized homeomorphisms.*

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I. INTRODUCTION

Atanassov [1] introduced the idea of intuitionistic fuzzy sets. Coker [2] introduced intuitionistic fuzzy topological spaces using the notion of intuitionistic fuzzy sets. The notion of homeomorphisms plays a vital role in intuitionistic fuzzy topology as well as in topology. Here we introduce the new class of homeomorphisms called β generalized homeomorphisms in intuitionistic fuzzy topological spaces. We also introduce the M - β generalized homeomorphisms in intuitionistic fuzzy topological spaces and investigate some of their properties. We provide the relation between intuitionistic fuzzy β generalized homeomorphisms and intuitionistic fuzzy M - β generalized homeomorphisms. Also we prove that the set of all M - β generalized homeomorphisms forms a group under the operation of composition of maps.

II. 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 $\mu_A : X \to [0,1]$ 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 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 ***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]: An IFS A in an IFTS (X, τ) is said to be an ***intuitionistic fuzzy β generalized closed set*** (IFβGCS for short) if βcl(A) ⊆ U whenever A ⊆ U and U is an IFβOS in (X, τ).

The complement A^c of an IFβGCS A in an IFTS (X, τ) is called an ***intuitionistic fuzzy β generalized open set*** (IFβGOS for short) **[4]** in X.

Definition 2.5 [5]: If every IFβGCS in (X, τ) is an IFβCS in (X, τ), then the space can be called as an ***intuitionistic fuzzy β generalized*** $T_{1/2}$ (IF$\beta_g T_{1/2}$ in short) ***space***.

Definition 2.6 [5]: An IFTS (X, τ) is an ***intuitionistic fuzzy β generalized a*** $T_{1/2}$ (IF$\beta_{ga} T_{1/2}$ in short) ***space*** if every IFβGCS is an IFCS in X.

Definition 2.7 [6]: A mapping f: (X, τ) → (Y, σ) is called an ***intuitionistic fuzzy β generalized continuous*** (IFβG continuous for short) **mapping** if f^{-1} (V) is an IFβGCS in (X, τ) for every IFCS V of (Y, σ).

Definition 2.8 [7]: A mapping f: (X, τ) → (Y, σ) is called an ***intuitionistic fuzzy β generalized irresolute*** (IFβG irresolute) ***mapping*** if f^{-1}(V) is an IFβGCS in (X, τ) for every IFβGCS V of (Y, σ).

Definition 2.9 [8]: A mapping f: (X, τ) → (Y, σ) is called an ***intuitionistic fuzzy β generalized closed mapping*** (IFβGCM for short) if f (V) is an IFβGCS in Y for every IFCS V of X.

Definition 2.10 [8]: A mapping f: X→ Y is said to be an ***intuitionistic fuzzy β generalized open mapping*** (IFβGOM for short) if f(A) is an IFβGOS in Y for each IFOS A in X.

Definition 2.11 [8] : A mapping f: (X, τ) → (Y, σ) is said to be an ***intuitionistic fuzzy M - β generalized closed mapping*** (IFMβGCM for short) if f(A) is an IFβGCS in Y for every IFβGCS A in X.

Definition 2.12 [2]: Let X and Y be two nonempty IFSs and f: X → Y be a function. If A = {⟨x, (μ_A (x), ν_A (x) / x ∈ X⟩} is an IFS in X, then the ***image*** of A under f, denoted by f(A), is the IFS in Y defined by

$$f(A) = \{\langle y, f(\mu_A)(y), f_-(\nu_A)(y) \,/\, y \in Y\rangle\}$$

where $f_-(\nu_A) = 1 - f(1-\nu_A)$.

Definition 2.13 [2]: Let X and Y be two nonempty sets and f: X → Y be a function. If B = {⟨y, (μ_B (y), ν_B (y) / y ∈ Y⟩} is an IFS in Y, then the ***preimage*** of B under f is denoted and defined by

$$f^{-1}(B) = \{\langle x, f^{-1}(\mu_B)(x), f^{-1}(\nu_B)(x) \,/\, x \in X\rangle\}$$

where $f^{-1}(\mu_B)(x) = \mu_B(f(x))$ for every x ∈ X.

III. Intuitionistic Fuzzy β Generalized Homeomorphisms

In this section we introduce intuitionistic fuzzy β generalized homeomorphisms and investigate some properties.

Definition 3.1: Let f: (X, τ) → (Y, σ) be a bijective mapping. Then f is said to be an ***intuitionistic fuzzy β generalized homeomorphism*** (IFβGHM for short) if f is both an IFβG continuous mapping and an IFβGOM.

Example 3.2: Let X = {a, b}, Y = {u, v} and G_1 = ⟨x, (0.5_a, 0.4_b), (0.5_a, 0.6_b)⟩, G_2 = ⟨y, (0.6_u, 0.7_v), (0.4_u, 0.3_v)⟩. Then τ = {0~, G_1, 1~} and σ = {0~, G_2, 1~} are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v.

Then, IFβC(X) = {0~, 1~, μ_a ∈ [0,1], μ_b ∈ [0,1], ν_a ∈ [0,1], ν_b ∈ [0,1] / $0 \le \mu_a+\nu_a \le 1$ and $0 \le \mu_b+\nu_b \le 1$},

IFβO(X) = {0~, 1~, μ_a ∈ [0,1], μ_b ∈ [0,1], ν_a ∈ [0,1], ν_b ∈ [0,1] / $0 \le \mu_a+\nu_a \le 1$ and $0 \le \mu_b+\nu_b \le 1$},

IFβC(Y) = {0~, 1~, μ_u ∈ [0, 1], μ_v ∈ [0,1], ν_u ∈ [0,1], ν_v ∈ [0,1] / either $\mu_u < 0.6$ or $\mu_v < 0.7$ or both, $0 \le \mu_u+\nu_u \le 1$ and $0 \le \mu_v+\nu_v \le 1$},

IFβO(Y) = {0~, 1~, μ_u ∈ [0,1], μ_v ∈ [0,1], ν_u ∈ [0,1], ν_v ∈ [0,1] / either $\mu_u > 0.4$ or $\mu_v > 0.3$ or both, $0 \le \mu_u+\nu_u \le 1$ and $0 \le \mu_v+\nu_v \le 1$}.

Then f is both an IFβG continuous mapping and an IFβGOM. Therefore f is an IFβGHM.

Theorem 3.3: Let f: (X, τ) → (Y, σ) be an IFβGHM, then f is an IF homeomorphism if X and Y are IF$\beta_{ga} T_{1/2}$ space.

Proof: Let B be an IFCS in Y. Then f^{-1}(B) is an IFβGCS in X, by hypothesis. Since X is an IF$\beta_{ga} T_{1/2}$ space, f^{-1}(B) is an IFCS in X. Hence f is an IF continuous mapping. By hypothesis f^{-1}: (Y, σ) → (X, τ) is an IFβG continuous mapping. Let A be an IFCS in X. Then $(f^{-1})^{-1}$ (A) = f(A) is an IFβGCS in Y, by hypothesis. Since Y is an IF$\beta_{ga} T_{1/2}$ space, f(A) is an IFCS in Y. Hence f^{-1} is an IF continuous mapping. Therefore the mapping f is an IF homeomorphism.

Theorem 3.4: Let f: (X, τ) → (Y, σ) be a bijective mapping. If f is an IFβG continuous mapping, then the following are equivalent:

(i) f is an IFβGOM
(ii) f is an IFβGHM
(iii) f is an IFβGCM

Proof: Straight forward.
Remark 3.5: The composition of two IFβGHMs need not be an IFβGHM in general.

Example 3.6: Let X = {a, b}, Y = {c, d} and Z = {e, f}. Let $G_1 = \langle x, (0.7_a, 0.8_b), (0.3_a, 0.2_b)\rangle$, $G_2 = \langle x, (0.6_a, 0.7_b), (0.4_a, 0.3_b)\rangle$, $G_3 = \langle y, (0.6_c, 0.4_d), (0.4_c, 0.3_d)\rangle$, $G_4 = \langle z, (0.4_e, 0.2_f), (0.6_e, 0.8_f)\rangle$. Then $\tau = \{0_\sim, G_1, G_2, 1_\sim\}$ and $\sigma = \{0_\sim, G_3, 1_\sim\}$ and $\eta = \{0_\sim, G_4, 1_\sim\}$ are IFTs on X, Y and Z respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = c and f(b) = d and g: (Y, σ) → (Z, η) by g(c) = e and g(d) = f.

Then, $IF\beta C(X) = \{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0,1], \nu_a \in [0,1], \nu_b \in [0,1]$ / either $\mu_a < 0.6$ or $\mu_b < 0.7$ or both, $0 \le \mu_a+\nu_a \le 1$ and $0 \le \mu_b+\nu_b \le 1\}$,

$IF\beta O(X) = \{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0,1], \nu_a \in [0,1], \nu_b \in [0,1]$ / either $\mu_a > 0.4$ or $\mu_b > 0.3$ or both, $0 \le \mu_a+\nu_a \le 1$ and $0 \le \mu_b+\nu_b \le 1\}$,

$IF\beta C(Y) = \{0_\sim, 1_\sim, \mu_c \in [0, 1], \mu_d \in [0,1], \nu_c \in [0,1], \nu_d \in [0,1]$ / either $\mu_c < 0.6$ or $\mu_d < 0.4$ or both, $0 \le \mu_c+\nu_c \le 1$ and $0 \le \mu_d+\nu_d \le 1\}$,

$IF\beta O(Y) = \{0_\sim, 1_\sim, \mu_c \in [0,1], \mu_d \in [0,1], \nu_c \in 0,1], \nu_d \in [0,1]$ / either $\mu_c > 0.4$ or $\mu_d > 0$ .3 or both, $0 \le \mu_c+\nu_c \le 1$ and $0 \le \mu_d+\nu_d \le 1\}$,

$IF\beta C(Z) = \{0_\sim, 1_\sim, \mu_e \in [0, 1], \mu_f \in [0,1], \nu_e \in [0,1], \nu_f \in [0,1]$ / $0 \le \mu_e+\nu_e \le 1$ and $0 \le \mu_f+\nu_f \le 1\}$,

$IF\beta O(Z) = \{0_\sim, 1_\sim, \mu_e \in [0,1], \mu_f \in [0,1], \nu_e \in [0,1], \nu_f \in [0,1]$ / either $\mu_e > 0.6$ or $\mu_f > 0$ .8 or both, $0 \le \mu_e+\nu_e \le 1$ and $0 \le \mu_f+\nu_f \le 1\}$.

Then f and g are IFβGHMs but g ∘ f : (X, τ) → (Z, η) is not an IFβGHM, since g ∘ f is not an IFβG continuous mapping, since $G_4^c = \langle z, (0.6_e, 0.8_f), (0.4_e, 0.2_f)\rangle$ is an IFCS in Z but $(g \circ f)^{-1}(G_4^c) = \langle x, (0.6_a, 0.8_b), (0.4_a, 0.2_b)\rangle$ is not an IFβGCS in X, since $(g \circ f)^{-1}(G_4^c) \subseteq G_2$ but $\beta cl((g \circ f)^{-1}(G_4^c)) = 1_\sim \not\subseteq G_2$.

Definition 3.7: Let f: (X, τ) → (Y, σ) be a bijective mapping. Then f is said to be an ***intuitionistic fuzzy M - β generalized homeomorphism*** (IFMβGHM for short) if f is both an IFβG irresolute mapping and an IFMβGOM.

The family of all IFβGHMs in X is denoted by IFMβGHM(X).

Theorem 3.8: Every IFMβGHM is an IFβGHM but not conversely.

Proof: Let f: (X, τ) → (Y, σ) be an IFMβGHM. Let A ⊆ Y be an IFCS. Then A is an IFβGCS in Y. By hypothesis, $f^{-1}(A)$ is an IFβGCS in X. Hence f is an IFβG continuous mapping. Let B ⊆ X be an IFOS. Then B is an IFβGOS in X. By hypothesis, f(B) is an IFβGOS in Y. Hence f is an IFβGOM. Thus f is an IFβGHM.

Example 3.9: Let X = {a, b}, Y = {u, v} and $G_1 = \langle x, (0.5_a, 0.6_b), (0.5_a, 0.4_b)\rangle$, $G_2 = \langle y, (0.5_u, 0.3_v), (0.5_u, 0.7_v)\rangle$. Then $\tau = \{0_\sim, G_1, 1_\sim\}$ and $\sigma = \{0_\sim, G_2, 1_\sim\}$ are IFTs on X and Y respectively. Define a mapping f: (X, τ) → (Y, σ) by f(a) = u and f(b) = v.

Then, $IF\beta C(X) = \{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0,1], \nu_a \in [0,1], \nu_b \in [0,1]$ / either $\mu_a < 0.5$ or $\mu_b < 0.6$ or both, $0 \le \mu_a+\nu_a \le 1$ and $0 \le \mu_b+\nu_b \le 1\}$,

$IF\beta O(X) = \{0_\sim, 1_\sim, \mu_a \in [0,1], \mu_b \in [0,1], \nu_a \in [0,1], \nu_b \in [0,1]$ / either $\mu_a > 0.5$ or $\mu_b > 0.4$ or both, $0 \le \mu_a+\nu_a \le 1$ and $0 \le \mu_b+\nu_b \le 1\}$,

$IF\beta C(Y) = \{0_\sim, 1_\sim, \mu_u \in [0, 1], \mu_v \in [0,1], \nu_u \in [0,1], \nu_v \in [0,1]$ / $0 \le \mu_u+\nu_u \le 1$ and $0 \le \mu_v+\nu_v \le 1\}$,

$IF\beta O(Y) = \{0_\sim, 1_\sim, \mu_u \in [0, 1], \mu_v \in [0,1], \nu_u \in [0,1], \nu_v \in [0,1]$ / $0 \le \mu_u+\nu_u \le 1$ and $0 \le \mu_v+\nu_v \le 1\}$.

Then f is an IFβGHM but not an IFMβGHM, since $A = \langle y, (0.5_u, 0.6_v), (0.5_u, 0.4_v)\rangle$ is an IFβGCS in Y but $f^{-1}(A)$ is not an IFβGCS in X, since $f^{-1}(A) \subseteq G_1$ but $\beta cl(f^{-1}(A)) = 1_\sim \not\subseteq G_1$.

Theorem 3.10: The composition of two IFMβGHMs is an IFMβGHM.

Proof: Let f: (X, τ) → (Y, σ) and g: (Y, σ) → (Z, δ) be any two IFMβGHMs. Let A ⊆ Z be an IFβGCS in Y. By hypothesis, $g^{-1}(A)$ is an IfβGCs in Y. Again by hypothesis, $f^{-1}(g^{-1}(A))$ is an IFβGCS in X. Therefore g ∘ f is an IFβG irresolute mapping. Now let B ⊆ X be an IFβGOS. Then by hypothesis, f(B) is an IFβGOS in Y and also g(f(B)) is an IFβGOS in Z. This implies g ∘ f is an IFMβGOM. Hence g∘ f is an IFMβGHM.

Theorem 3.11: Let f: (X, τ) → (Y, σ) be a bijective mapping. If f is an IFβG irresolute mapping, then the following are equivalent:

(i) f is an IFMβGOM
(ii) f is an IFMβGHM
(iii) f is an IFMβGCM

Proof: Straight forward.

Theorem 3.12: The set of all IFMβGHMs in an IFTS (X, τ) is a group under the composition maps.

Proof: Define a binary operation * : IFMβGHM(X) x IFMβGHM(X) → IFMβGHM(X) by f *g = g∘ f for every for every f, g ∈ IFMβGHM(X) and o is the usual operation of composition of maps. Since g ∈ IFMβGHM(X) and f ∈ IFMβGHM(X), by Theorem 3.10, g ∘ f ∈ IFMβGHM(X). We know that the composition of maps is associative. The identity map I: (X, τ) → (X, τ) belonging to IFMβGHM(X) is the identity element. If f ∈ IFMβGHM(X), then f^{-1} ∈ IFMβGHM(X). Therefore f ∘ f^{-1} = f^{-1} ∘ f = I and so the inverse exists for each element of IFMβGHM(X). Hence (IFMβGHM(X), o) is a group under the composition of maps.

Theorem 3.13: If f: (X, τ) → (Y, σ) is an IFMβGHM, then βgcl(f^{-1}(B)) ⊆ f^{-1}(βcl(B)) for every IFS B in (Y, σ).

Proof: Let B ⊆ Y. Then βcl(B) is an IFβGCS in Y. Since f is an IFβG irresolute mapping, f^{-1}(βcl(B)) is an IFβGCS in X. This implies βgcl(f^{-1}(βcl(B))) = f^{-1}(βcl(B)) . Now βgcl(f^{-1}(B)) ⊆ βgcl(f^{-1}(βcl(B))) = f^{-1}(βcl(B)).

Theorem 3.14: If f: (X, τ) → (Y, σ) is an IFMβGHM, where (X, τ) and (Y, σ) are $IF\beta_gT_{1/2}$ spaces, then βcl(f^{-1}(B)) = f^{-1}(βcl(B)) for every IFS B in (Y, σ).

Proof: Since f is an IFMβGHM, f is an IFβG irresolute mapping. Since βcl(f(B)) is an IFβGCS in Y, f^{-1}(βcl(f(B))) is an IFβGCS in X. Since X is an $IF\beta_gT_{1/2}$ space, f^{-1}(βcl(f(B))) is an IFβCS in X. Now, f^{-1}(B) ⊆ f^{-1}(βcl(B)) ⊆ βcl(f^{-1}(βcl(B))). We have βcl(f^{-1}(B)) ⊆ βcl(f^{-1}(βcl(B))) = f^{-1}(βcl(B)). This implies βcl(f^{-1}(B)) ⊆ f^{-1}(βcl(B)) ------ (1). Again since f is an IFMβGHM, f^{-1} is IFβG irresolute mapping. Since βcl(f^{-1}(B)) is an IFβGCS in X, $(f^{-1})^{-1}$(βcl(f^{-1}(B))) = f(βcl(f^{-1}(B))), is an IFβGCS in Y. Now B ⊆ $(f^{-1})^{-1}$(f^{-1}(B)) ⊆ $(f^{-1})^{-1}$(βcl(f^{-1}(B))). Therefore βcl(B) ⊆ βcl(f(βcl(f^{-1}(B)))) = f(βcl(f^{-1}(B))), since Y is an $IF\beta_gT_{1/2}$ space. Hence f^{-1}(βcl(B)) ⊆ f^{-1}(f(βcl(f^{-1}(B)) ⊆ βcl(f^{-1}(B)). That is f^{-1}(βcl(B)) ⊆ βcl(f^{-1}(B)) ---------- (2). Thus from (1) and (2) we get βcl(f^{-1}(B)) = f^{-1}(βcl(B)) and hence the proof.

Theorem 3.15: Let f: X→Y be an IFMβGHM. Then f induces an isomorphism from the group IFMβGHM(X) onto the group IFMβGHM(Y).

Proof: Using f, we define a map φ_f : h(X) → h(Y) by φ_f(h) = f ∘ h ∘ f^{-1} for every h ∈ IFMβGHM(X). Then φ_f is a bijection. Also for all h_1, h_2 ∈ IFMβGHM(X), φ_f(h_1 ∘ h_2) = f ∘ (h_1 ∘ h_2) ∘ f^{-1} = (f ∘ h_1 ∘ f^{-1}) ∘ (f ∘ h_2 ∘ f^{-1}) = φ_f(h_1) ∘ φ_f(h_2). This implies φ_f is a homeomorphism and so φ_f is an isomorphism induced by f.

Corollary 3.16: If f: (X, τ) → (Y, σ) is an IFMβGHM, where (X, τ) and (Y, σ) are $IF\beta_gT_{1/2}$ spaces, then βcl(f(B)) = f(βcl(B)) for every IFS B in X.

Proof: Since f is an IFMβGHM, f^{-1} is also an IFMβGHM. Therefore by Theorem 3.14 βcl($(f^{-1})^{-1}$(B)) = $(f^{-1})^{-1}$(βcl(B)) for every B ⊆ X. That is βcl(f(B)) = f(βcl(B)) for every IFS B in X.

Corollary 3.17: If f: (X, τ) → (Y, σ) is an IFMβGHM, where (X, τ) and (Y, σ) are $IF\beta_gT_{1/2}$ spaces, then βint(f(B)) = f(βint(B)) for every IFS B in X.

Proof: For any IFS B ⊆ X, βint(B) = βcl(B^c))^c. By Corollary 3.16 , f(βint(B)) = f(βcl(B^c))^c = (f(βcl(B^c)))^c = βcl(f(B^c)))^c = βint(f(B^c))^c = βint(f(B^c)^c) = βint(f(B)).

Corollary 3.18: If f: (X, τ) → (Y, σ) is an IFMβGHM, where (X, τ) and (Y, σ) are $IF\beta_gT_{1/2}$ spaces, then βint(f^{-1}(B)) = f^{-1}(βint(B)) for every IFS B in Y.

Proof: Since f is an IFMβGHM, f^{-1} is also an IFMβGHM, the proof directly follows from corollary 3.17.

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