On Intuitionistic Fuzzy M-Precontinuous Mappings

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ABSTRACT
The aim of this paper is to extend the concept of fuzzy M-pre continuous mappings due to Thakur and Singh [9] in intuitionistic fuzzy topological spaces and obtain some of their characterizations and properties.

Keywords
Intuitionistic fuzzy topology, Intuitionistic fuzzy M- pre continuous mappings.

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1. INTRODUCTION
After the introduction of fuzzy sets by Zadeh [11] in 1965 and fuzzy topology by Chang [4] in 1968, several researches were conducted on the generalizations of the notions of fuzzy sets and fuzzy topology. The concept of intuitionistic fuzzy sets was introduced by Atanassov [1, 2, 3] as a generalization of fuzzy sets. In the last 28 years various concepts of fuzzy mathematics have been extended for intuitionistic fuzzy sets. In 1997 Coker [5] introduced the concept of intuitionistic fuzzy topological spaces as a generalization of fuzzy topological spaces. In the same year Guecay Coker and Hayder [7] extended the concepts of fuzzy preopen sets and fuzzy precontinuity due to Bin Sahana [4] in intuitionistic fuzzy topology.In the present paper we introduce and study the concept of fuzzy M-pre continuous mappings in intuitionistic fuzzy topological spaces.

2. PRELIMANIRIES
Definition *2.1* [1]: Let X is a nonempty fixed set. An intuitionistic fuzzy set A in X is an object having the form

$$A= \{<x,\mu_A(x),\gamma_A(x)> : x\in X \}$$

Where the functions μ_A:X→*I* and γ_A: X→*I* denote the degree of membership (namely $\mu_A(x)$) and the degree of non membership (namely $\gamma_A(x)$) of each element x∈X to the set A, respectively, and $0 \le \mu_A(x)+ \gamma_A(x) \le 1$ for each x∈X.

Definition 2.2 [1]: Let *X* be a nonempty set and the intuitionistic fuzzy sets A and B be in the form $A = \{<x, \mu_A(x), \gamma_A(x)> : x \in X\}$, $B = \{<x, \mu_B(x), \gamma_B(x)> : x \in X\}$ and let $\{A_i: i \in J\}$ be an arbitrary family of intuitionistic fuzzy sets in X. Then:

(a) $A \subseteq B$ if $\forall x\in X\ [\mu_A(x) \le \mu_B(x)$ and $\gamma_A(x) \ge \gamma_B(x)]$;

(b) A = B if $A \subseteq B$ and $B \subseteq A$;

(c) $A^c= \{<x, \gamma_A(x), \mu_A(x)> : x\in X\}$;

(d) $\cap A_i = \{<x, \wedge\mu_{Ai}(x), \vee\gamma_{Ai}(x)> : x\in X\}$;

(e) $\cup A_i = \{<x, \vee\mu_{Ai}(x), \wedge\gamma_{Ai}(x)> : x\in X\}$;

(f) $\tilde{0} = \{<x, 0, 1>: x\in X\}$ and $\tilde{1} = \{<x, 1, 0>: x\in X\}$.

Definition 2.3 [5]: Let *X and Y* be two nonempty sets and $f : X \to Y$ be a function. Then

(a) If $B = \{<y, \mu_B(y), \gamma_B(y)> : y \in Y\}$is an intuitionistic fuzzy set in *Y*, then the pre image of B under *f* denoted by $f^{-1}(B)$, is the IFS in *X* defined by

$$f^{-1}(B) = <x, f^{-1}(\mu_B)(x), f^{1}(\gamma_B)(x)> : x\in X\}$$

(b) If $A = \{<x, \lambda_A(x), \nu_A(x)> : x \in X\}$is an intuitionistic fuzzy set in *X*, then the image of A under *f* denoted by *f*(A) is the intuitionistic fuzzy set in *Y* defined by

$$f(A) = \{<y, f(\lambda_A)(y), f(\nu_A)(y)> : y \in Y\}$$

where, $f(\nu_A) = 1 – f(1- \nu_A)$.

Definition 2.4 [5]: Two intuitionistic fuzzy sets A and B of X said to be q-coincident (AqB for short) if and only if there exits an element x∈X such that $\mu_A(x) > \gamma_B(x)$ or $\gamma_A(x) < \mu_B(x)$.

Lemma 2.1 [5]: For any two intuitionistic fuzzy sets A and B of X, $\rceil$(AqB) ⇔ $A\subset B^c$ [5].

Definition 2.5[5]: An intuitionistic fuzzy topology on a nonempty set X is a family $\Im$ of intuitionistic fuzzy sets in *X* satisfying the following axioms:

(T_1) $\tilde{0}, \tilde{1} \in \Im$.

(T_2) $G_1\cap G_2 \in \Im$ for any $G_1, G_2 \in \Im$.

(T_3) $\cup G_i \in \Im$ for any arbitrary family $\{G_i : i \in J\}\subseteq \Im$.

In this case the pair $(X,\Im)$ is called an intuitionistic fuzzy**D** topological space and each intuitionistic fuzzy set in $\Im$ is known as an intuitionistic fuzzy open set in *X*. The complement A^c of an intuitionistic fuzzy open set is called an intuitionistic fuzzy closed set in *X*.

Definition 2.6 [5]**:** Let $(X, \Im)$ be an intuitionistic fuzzy topological space and *A* be an intuitionistic fuzzy set in *X*. Then the fuzzy interior and fuzzy closure of *A* are defined by:

$\text{cl}(A) = \cap\{K : K$ is an intuitionistic fuzzy closed set in X and $A \subseteq K\}$,

$\text{int}(A) = \cup\{G : G$ is an intuitionistic fuzzy open set in X and $G \subseteq K\}$

Lemma 2.2 [5] : For any intuitionistic fuzzy set *A* in $(X, \Im)$ we have

(a) *A* is an intuitionistic fuzzy closed set in $X \Leftrightarrow \text{cl}(A) = A$,

(b) *A* is an intuitionistic fuzzy open set in $X \Leftrightarrow \text{int}(A) = A$;

(c) $\text{cl}(A^c) = (\text{int}(A))^c$;

(d) $\text{int}(A^c) = (\text{cl}(A))^c$.

Definition 2.7[7]: An intuitionistic fuzzy set A in an intuitionistic fuzzy topological space X is called :

(a)Iintuitionistic fuzzy pre open if $A \subseteq \text{int}(\text{cl}(A))$;

(b) Intuitionistic fuzzy pre closed if its compliment is intuitionistic fuzzy pre open.

Definition 2.8 [7]: Let $(X, \Im)$ be an intuitionistic fuzzy topological space and *A* be an intuitionistic fuzzy set in *X*. Then the interior and closure of *A* are defined by:

$\text{pcl}(A) = \cap\{K : K$ is an intuitionistic fuzzy pre closed set in X and $A \subseteq K\}$,

$\text{pint}(A) = \cup\{G : G$ is an intuitionistic fuzzy pre open set in X and $G \subseteq A\}$.

Definition 2.9[7]: A mapping $f : (X, \Im) \rightarrow (Y, \Gamma)$ is said to be:

(a) Intuitionistic fuzzy continuous if the inverse image of every Intuitionistic fuzzy open set of Y is Intuitionistic fuzzy open in X.

(b) Intuitionistic fuzzy pre continuous if the inverse image of every Intuitionistic fuzzy open set of Y is intuitionistic fuzzy pre open set in X.

Definition 2.10: Let X be a non empty set and $p \in X$ a fixed element in X. If $\alpha \in (0,1]$ and $\beta \in [0,1)$ are two real numbers such that $\alpha + \beta \leq 1$ then, Intuitionistic fuzzy set $p(\alpha, \beta) = \{<x, p_\alpha, 1\text{-}p_{1-\beta} >: x \in X\}$ (where p_α is the fuzzy point in X with support p and value α) is called an Intuitionistic fuzzy point in X (IFP in short) where α denotes the degree of membership o p(α, β) and β denotes the degree of non membership of p(α, β).

3. INTUITIONISTIC FUZZY M-PRE CONTINUOUS MAPPINGS

Definition 3.1: A mapping f from an intuitionistic fuzzy topological space $(X, \Im)$ to an intuitionistic fuzzy topological space (Y,σ) is called intuitionistic fuzzy M-precontinuous if $f^{-1}(U)$ is intuitionistic fuzzy pre open set in X for every intuitionistic fuzzy pre open set U in Y.

Remark 3.1: Every intuitionistic fuzzy M-Precontinuous mapping is intuitionistic fuzzy precontinuous but the converse may not be true.

Example 3.1: Let X= {a, b}, Y= {x, y} and U, V are the intuitionistic fuzzy sets respectively on X and Y defined as follows:

U= {< a, 0.4, 0.6 >, <b, 0.5, 0.5 >},

V = {< a, 0.5, 0.5 >, <b, 0.7, 0.3 >},

Let $\Im = \{\tilde{0}, U, V, \tilde{1}\}$ and $\sigma = \{\tilde{0}, \tilde{1}\}$ be the intuitionistic fuzzy topologies on X and Y respectively. Then the mapping $f: (X, \Im) \rightarrow (Y, \sigma)$ defined by f(a)= x and f(b) = y is intuitionistic fuzzy pre continuous(in fact intuitionistic fuzzy continuous) but not intuitionistic fuzzy M- pre continuous.

Consider the following example:

Example (3.2): Let X = {a, b}, Y = {x, y} and V be an intuitionistic fuzzy set on Y defined as follows:

V = {< x, 0.5, 0.5 >, <y, 0.6, 0.4 >},

Let $\Im = \{\tilde{0}, \tilde{1}\}$ and $\sigma = \{\tilde{0}, V, \tilde{1}\}$ be intuitionistic fuzzy topologies on X and Y respectively. Then the mapping $g: (X, \Im) \rightarrow (Y, \sigma)$ defined by g(a) = x and g(b) = y is intuitionistic fuzzy M-precontinuous but not intuitionistic fuzzy continuous

Remark 3.2. Example 3.1 and Example 3.2 shows that the concepts of Intuitionistic fuzzy M-precontinuous and intuitionistic fuzzy continuous mappings are independent.

Theorem (3.1): The following statements are equivalent for a mapping f: (X, ℑ) →(Y, σ):

- **(a)** f is intuitionistic fuzzy M-precontinuous.
- **(b)** f^{-1}(V) is intuitionistic fuzzy pre closed set in X for every intuitionistic fuzzy pre closed set V in Y.
- **(c)** for every intuitionistic fuzzy point P(α, β) in X and every intuitionistic fuzzy preopen set V in Y such that f(P(α, β)) ∈ V there is an intuitionistic fuzzy pre open set U in X, such that P(α, β) ∈ U and f(U) ⊆ V.
- **(d)** for every intuitionistic fuzzy point P(α, β) in X and every pre neighbourhood V of f (P(α, β)), f^{-1} (V) is a pre neighbourhood of P(α, β).
- **(e)** for every intuitionistic fuzzy point P(α, β) in X and every pre neighbourhood V of f (P(α, β)) there is a preneighbourhood U of P(α, β) such that f(U) ⊆ V.
- **(f)** f(pcl(U)) ⊆ pcl(f(U)) for every intuitionistic fuzzy set U of X.
- **(g)** pcl(f^{-1} (V))⊆ f^{-1} (pcl(V)) for every intuitionistic fuzzy set Vof Y.
- **(h)** f^{-1} (pint(V))⊆pint (f^{-1} (V)) for every intuitionistic fuzzy set V of Y.

PROOF :(a)⇔(b) Obvious.

(a)⇒(c). Let P (α, β) be an intuitionistic fuzzy point of X and V is an intuitionistic fuzzy pre open set in X such that f (P (α, β)) ∈ V . Put U = f^{-1}(V). Then by (a), U is an intuitionistic fuzzy pre open set in X such that P (α, β) ∈ U and f(U) ⊆ V

(c) ⇒(a). Let V is intuitionistic fuzzy pre open set in Y and P (α, β) ∈ f^{-1} (V). Then f(P(α, β)) ∈ V . Now by (c) there is an intuitionistic fuzzy preopen set U in X such that P (α, β) ∈ $U$and f (U) ⊆ V. Then P(α,β) ∈ U ⊆ f^{-1}(V). Hence f^{-1}(V) is intuitionistic fuzzy pre open set in X.

(a) ⇒(d). Let P (α, β) be an intuitionistic fuzzy point in X and V be a pre neighbourhood of f (P(α, β)). Then there is a intuitionistic fuzzy pre open set W of Y such that f (P (α, β)) ∈ W ⊆ V Now f^{-1}(W) is an intuitionistic fuzzy pre open set in X and P (α, β) ∈ f^{-1}(W) ⊆ f^{-1} (V). Thus f^{-1} (V) is a pre neighbiurhood of P (α, β) in X.

(d) ⇒(e). Let P (α, β) be a intuitionistic fuzzy point of X and V be a pre neighbourhood of f (P(α, β)). Then U = f^{-1}(V) is a pre neighbourhood of P (α, β) and f (U) = f (f^{-1}(V)) ⊆ V.

(e) ⇒(c). Let P (α, β) be an intuitionistic fuzzy point of X and V is an intuitionistic fuzzy pre open set in Y such that f (P(α, β)) ∈ V. So there is pre neighbourhood W of P (α, β) in X such that P (α, β) ∈ W and f (W) ⊆ V.Hence there is an intuitionistic fuzzy pre open set U in X such that P (α, β) ∈ U ⊆ W and f (U) ⊆ f(W) ⊆ V.

(b) ⇒(f). Let U be an intuitionistic fuzzy set of X. Since U= f^{-1}(f (U)), we have U ⊆ f^{-1}(pcl(f(U))). Now pcl (f (U)) is an intuitionistic fuzzy pre closed set of Y and hence f^{-1}(pcl (f (U))) is an intuitionistic fuzzy pre closed of X. Therefore pcl (U) ⊆ f^{-1}(pcl(f(U))) and f(pcl(U) ⊆ f^{-1}(pcl(f(U)))) ⊆ pcl(f(U)).

(f) ⇒(b). Let V is an intuitionistic fuzzy pre closed set of Y. then f(pcl(f^{-1}(V))) ⊆ pcl(f(f^{-1}(V))) ⊆ pcl(V) = V.Hence pcl (f^{-1}(V)) ⊆ f^{-1}(V) and so f^{-1}(V) is an intuitionistic fuzzy pre closed set of X.

(f) ⇒(g). Let V be an intuitionistic fuzzy set of Y then f^{-1}(V) is an intuitionistic fuzzy set of X. Therefore by hypothesis f(pcl (f^{-1}(V))) ⊆ pcl (f^{-1}(V)) ⊆ pcl (V). Hence pcl (f^{-1}(V)) ⊆ f^{-1}(pcl (V)).

(g) ⇒(f). Let U be a intuitionistic fuzzy set of X. Then f(U) is an intuitionistic fuzzy set of Y and by (g) , pcl(f^{-1}(f(U))) ⊆ f^{-1}(pcl (f(U))). Hence f(pcl(U)) ⊆ pcl (f(U)).

(a) ⇒(h). Let V be an intuitionistic fuzzy set of Y. Then pint(V) is an intuitionistic fuzzy pre open set of Y and so by (a) f^{-1}(pint (V)) is an intuitionistic fuzzy pre open set of X. Since f^{-1}(pint (V)) ⊆ f^{-1}(V), then f^{-1}(pint(V) ⊆ pint (f^{-1}(V))

(h)⇒(a). Let V be an intuitionistic fuzzy pre open set of Y. Then pint(V) = V and f^{-1}(V) ⊆ pint (f^{-1}(V)). Thus f^{-1}(V) = pint (f^{-1}(V)) and f^{-1}(V) is an intuitionistic fuzzy pre open set in X. Hence f is intuitionistic fuzzy M-precontinuous. ■

Lemma (3.1): A intuitionistic fuzzy set V is intuitionistic fuzzy pre open set of X if and only if there exists a intuitionistic fuzzy open set U such that V⊆U⊆ cl(V)

Proof: Necessity if V is intuitionistic fuzzy pre open set of X Then V⊆int(cl(V)). Put U=int(cl (V)).Then U is intuitionistic fuzzy open and V⊆ U⊆ cl (V).

Sufficiency: Let U be an intuitionistic fuzzy open set such that V $\subseteq$ U$\subseteq$ cl(V) Then V$\subseteq$ int (U) $\subseteq$int (cl (V)). Hence V is intuitionistic fuzzy pre open set of X

Theorem (3.2): Let f: (X, $\Im$) $\rightarrow$(Y, σ) be intuitionistic fuzzy precontinuous and intuitionistic fuzzy open mapping then f is intuitionistic fuzzy M-precontinuous.

Proof: Let V is intuitionistic fuzzy pre open set of Y then by Lemma (3.2) there exists a intuitionistic fuzzy open set U such that V$\subseteq$ U $\subseteq$ cl(V). Therefore f^{-1}(V) $\subseteq$ f^{-1} (U)$\subseteq$ f^{-1} (cl(V)) $\subseteq$ cl(f^{-1} (V) because f is intuitionistic fuzzy open. Since f is intuitionistic fuzzy precontinuous, f^{-1}(U) is intuitionistic fuzzy pre open set of X. Hence f^{-1}(V) $\subseteq$ f^{-1}(U) $\subseteq$ int (cl (f^{-1}(U)) $\subseteq$ int (cl (f^{-1} (V))) and f^{-1} (V) is intuitionistic fuzzy pre open set of X. ■

Theorem (3.3): Let f: (X, $\Im$) $\rightarrow$(Y, σ) and g: (Y, σ) $\rightarrow$(Z,ω) be two mappings. If f and g are intuitionistic fuzzy M-precontinuous then gof is intuitionistic fuzzy M- precontinuous

Proof: Let **V** is an intuitionistic fuzzy pre open set in Z, since g is intuitionistic fuzzy M- precontinuous. g^{-1} (V) is intuitionistic fuzzy pre open in Y. Therefore $(gof)^{-1}$ (V) is intuitionistic fuzzy pre open in X. because f is intuitionistic fuzzy M-precontinuous. Hence gof is intuitionistic fuzzy M-precontinuous■

Theorem (3.4): Let f: (X, $\Im$) $\rightarrow$(Y, σ) and g: (Y, σ) $\rightarrow$(Z,ω) be two mappings. If f is intuitionistic fuzzy M-precontinuous is and g is intuitionistic fuzzy precontinuous then gof is intuitionistic fuzzy M-precontinuous.

Proof: Let **U** be a intuitionistic fuzzy open set of Z. Since g is intuitionistic fuzzy precontinuous so g^{-1}(U) is intuitionistic fuzzy pre open set of Y. Therefore $(gof)^{-1}$(U) $\equiv$ $f^{-1}\{g^{-1}(U)\}$ is intuitionistic fuzzy pre open set of X because f is intuitionistic fuzzy M-precontinuous. Hence gof is intuitionistic fuzzy precontinuous. ■

Definition (3.2): A mapping f from an intuitionistic fuzzy topological space (X, $\Im$) to an intuitionistic fuzzy topological space (Y,σ) is called intuitionistic fuzzy M-preopen if f (V) is intuitionistic fuzzy pre open set of Y for every intuitionistic fuzzy set V is intuitionistic fuzzy pre open set of X.

Remark (3.1): Every intuitionistic fuzzy M-preopen mapping is intuitionistic fuzzy pre open but the converse may not be true for,

Example (3.4): Let X = {a,b} Y ={x,y} and **V** be a intuitionistic fuzzy set of Y defined as follows:

V= {< a, 0.4, 0.6 >, <b, 0.5, 0.5 >},

Let $\Im$ = {$\tilde{0}$, $\tilde{1}$} and σ = {$\tilde{0}$,V, $\tilde{1}$}. Then the mapping f: (X, $\Im$) $\rightarrow$(Y, σ) defined by f(a) = x, f(b) = y is intuitionistic fuzzy open and hence intuitionistic fuzzy preopen but not intuitionistic fuzzy M-preopen.

Consider the following example.

Example (3.5): Let X ={a,b} Y ={x,y} and **U** be a intuitionistic fuzzy set of X defined as follows:

U = {< a, 0.3, 0.7 >, <b, 0.4, 0.6 >},

Let $\Im$ = {$\tilde{0}$, U, $\tilde{1}$} and σ = {$\tilde{0}$, $\tilde{1}$}. Then the mapping f: (X, $\Im$) $\rightarrow$(Y, σ) defined by f(a) = x, f(b) = y is intuitionistic fuzzy M-preopen but not intuitionistic fuzzy open.

Remark (3.2): Example (3.4) and example (3.5) shows that the concepts of intuitionistic fuzzy open and intuitionistic fuzzy M- preopen mappings are independent.

Theorem (3.5): Let f: (X, $\Im$) $\rightarrow$(Y, σ) be an intuitionistic fuzzy M-preopen mapping. If Vis a intuitionistic fuzzy set of Y and U is intuitionistic fuzzy pre closed set of X containing f^{-1}(V), Then there exist a intuitionistic fuzzy set W in intuitionistic fuzzy pre closed set of Y such that V$\subseteq$W and f^{-1} (W) $\subseteq$ U.

Proof: Let W = $f(U^c)^c$. Since f^{-1} (V) $\subseteq$ U we have f(U^c) = V^c. Since f is intuitionistic fuzzy M – preopen, W is intuitionistic fuzzy pre closed set of Y andf^{-1}(W)= $(f^{-1}(f(U^c)))^c$ $\subseteq$$((U^c))^c$= U■.

Theorem (3.6): A mapping f: (X, $\Im$) $\rightarrow$(Y, σ) is intuitionistic fuzzy M-preopen if and only if f(pint(V)) $\subseteq$ pint f(V) for every intuitionistic fuzzy set V of X.

Proof: Necessity: If f: (X, $\Im$) $\rightarrow$(Y, σ) is intuitionistic fuzzy M-preopen then f(pint(V)) is intuitionistic fuzzy preopen set of Y Hence f(pint(V)) = pint(f(V)) $\subseteq$ pint f(V). ■

Sufficiency: Let V is intuitionistic fuzzy set in X. Then by hypothesis f(V)=f(pint(V)) $\subseteq$ pint f(V) Hence f(V) is intuitionistic fuzzy preopen set of Y. ■

Theorem (3.7): Let f: (X, $\Im$) $\rightarrow$(Y, σ) and g: (Y, σ) $\rightarrow$(Z,ω) are intuitionistic fuzzy M-preopen then gof : (X, $\Im$) $\rightarrow$(Z,ω) is also intuitionistic fuzzy M- preopen.

Proof: Obvious.■

Theorem (3.8): Let f: (X, $\Im$) $\rightarrow$(Y, σ) and g: (Y, σ) $\rightarrow$(Z,ω) be two mappings such that gof : (X, $\Im$) $\rightarrow$(Z,ω) is intuitionistic fuzzy M- preopen and g is intuitionistic fuzzy M-pre continuous and injective then f is intuitionistic fuzzy M-preopen.

Proof: Let V is intuitionistic fuzzy pre open set in X. Then (gof)(V) is intuitionistic fuzzy preopen set in Z because gof is intuitionistic fuzzy M-preopen. Since g is injective, we have g^{-1}((gof)(V))= f(V). Therefore f(V) is intuitionistic fuzzy pre open set in Y, because g is intuitionistic fuzzy M-precontinuous. Hence f is intuitionistic fuzzy M-preopen. ■

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