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Common Fixed Point Theorems for Two Pair of Weakly Compatible Mappings in Modified Intuitionistic Fuzzy Metric Space

Bharti Mishra[1], Arun Kumar Garg[1*] and Z.K. Ansari[2]
[1]Department of Mathematics, Madhyanchal University, Bhopal (Madhya Pradesh), India.
[2]Department of Mathematics, JSS academy of technical, Noida (Uttar Pradesh), India.

(Corresponding author: Arun Kumar Garg)*
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ABSTRACT. In present paper, we introduce common property (E.A) in modified intuitionistic fuzzy metric spaces and utilize the same to prove common fixed point theorems in modified intuitionistic fuzzy metric space besides discussing related results and illustrative examples. We are not aware of any paper dealing with same conditions modified intuitionistic fuzzy metric spaces
Mathematics Subject Classification (MSC): 47H10, 54H25.

Keywords: Property (E.A), Common property (E.A), Fuzzy metric space, modified intuitionistic fuzzy metric space.

I. INTRODUCTION AND PRELIMINARIES

The concept of fuzzy Sets is introduced by Zadeh [1]. Kramosil and Michlek [2] introduced the concept of Fuzzy sets, Fuzzy metric spaces. George and Veeramani [3] modified the concept of fuzzy metric space due to Kramosil and Michalek [2] and defined a Hausdorff topology on modified fuzzy metric space which is often used in current researches. Abbas *et al.* [4] proved weak contractions in fuzzy metric spaces, Altun, [5]. Some fixed point theorems for single and multivalued mappings on ordered non Archimedean fuzzy metric space. Park [6] proved some point theorems for Intuitionistic fuzzy metrics spaces. Jungck [7, 8] introduced the concept of compatible mappings for self mappings. Lots of the theorems were proved for the existence of common fixed points in classical and fuzzy metric spaces. Aamri and Moutawakil [9] introduced the concept of non-compatibility using E.A. property and proved several fixed point theorems under contractive conditions. Atanassov [10] introduced the concept of Intuitionistic fuzzy sets which is a generalization of fuzzy sets.

Saadatiand Park [11] defined Intuitionistic fuzzy metric spaces using t-norms and t-conorms as a generalization of fuzzy metric spaces. Turkoglu [12] generalized Junkck common fixed point theorem to Intuitionistic fuzzy metric spaces. Grabiec [13] extended classical fixed point theorems of Banach and Edelstein to complete and compact fuzzy metric spaces respectively. Sedghi *et al*. [14] proved some common fixed point theorems for weakly compatible maps using contractive conditions of integral type.

Saadati *et al.* [9] modified the notion of intuitionistic fuzzy metric and defined the notion of modified intuitionistic fuzzy metric spaces with the help of continuous *t*-representable and proved some fixed point theorems for compatible and weakly compatible maps. Imdad *et al.* [15] proved some fixed point theorems for modified intuitionistic fuzzy metric space using the concept of implicit function. In this modified setting of intuitionistic fuzzy metric space, Jain *et al*. [16] discussed the notion of the compatibility of type (P); Sedghi *et al.* [9] proved some common fixed point theorems for weakly compatible maps using contractive conditions of integral type. In this paper, we prove some common fixed point theorems in modified intuitionistic fuzzy metric space for four mappings when two satisfies the property (E.A) and share the common property E.A.

Definition 1.1 A binary operation $*: [0;1]\times[0;1] \to [0;1]$is called continuous t-norm if $([0;1];*)$is an abelian topological monoid with unit 1 such that $a*b \leq c*d$whenever$a \leq c \,\&\, b \leq d \;\forall\, a;b;c;d \in [0;1]$

Definition 1.2 A binary operation $\diamond : [0;1]\times[0;1] \to [0;1]$ is called continuous t- co-norm if $([0;1];*)$ is an abelian topological monoid with unit 0 such that $a\diamond b \leq c\diamond d$ whenever $a \leq c \,\&\, b \leq d \;\forall\, a;b;c;d \in [0;1]$

Proposition 1.3 Consider the set L^* and the operation $\leq_{L^*}$defined by$L^*\{(x_1;x_2):(x_1;x_2) \in [0;1]^2; x_1+x_2 \leq 1\}$;$(x_1;x_2) \leq_{L^*} (y_1;y_2) \Leftrightarrow x_1 \leq y_1 \,\&\, x_2 \geq y_2 \forall (x_1;x_2),(y_1;y_2) \in L^*$.
Then,$(L^*;\leq_{L^*})$ is a complete lattice. One denotes its units by $0_{L^*} = (0;1) \,\&\, 1_{L^*} = (1;0)$.

Definition 1.4. A triangular norm on $L^*$is a mapping $T: L^* \times L^* \to L^*$satisfying;
[i] $T(x;1_{L^*}) = x \;\;\forall\, x \in L^*$
[ii] $T(x;y) = T(y;x) \;\;\forall\, x;y \in L^*$
[iii] $T(x;T(y;z)) = T(T(x;y);z) \;\forall\, x;y;z \in L^*$
[iv] $\forall\, x;\, x';y;\, y' \in L^*;x \leq_{L^*} x';\, y \leq_{L^*} y' \Rightarrow T(x;y) \leq_{L^*} T(x';y')$

Definition 1.5. A continuous t-norm T on L^* is called continuous t-representable if and only if there exists a continuous t-norm* and a continuous t-conorm$\diamond$ on [0; 1] such that for all $x = (x_1;x_2);y = (y_1;y_2) \in L^* \Rightarrow T(x;y) = (x_1 * y_1;\, x_2\diamond y_2)$

Definition 1.6. The 3-tuple $(X;\zeta_{M;N};\mathrm{T})$ is called a modified intuitionistic fuzzy metric space (modified IFMS) if *X* is an arbitrary non-empty set, *M* and *N* are fuzzy sets from $X\times X\times(0;\infty) \to [0;1]$ such that $M(x;y;t)+N(x;y;t) \leq$

$1 \forall x; y \in X$; T is a continuous t-representable and mapping $\zeta_{M;N}: X \times X \times (0;\infty) \to L^*$ is a mapping from defined by $\zeta_{M;N}(x;y;t) = \big(M(x;y;t); N(x;y;t)\big)$ satisfying the following conditions $\forall x; y; z \in X$ & $\forall s$ and t

[i] $\zeta_{M;N}(x;y;t) >_{L^*} 0_{L^*}$;

[ii] $\zeta_{M;N}(x;y;t) = 1_{L^*}$ *if* and only *if* $x = y$;

[iii] $\zeta_{M;N}(x;y;t) = \zeta_{M;N}(y;x;t)$;

[iv] $\zeta_{M;N}(x;y;s+t) \geq_{L^*} \mathrm{T}\,(\zeta_{M;N}(x;y;s) * \zeta_{M;N}(x;y;t)$;

[v] $\zeta_{M;N}(x;y;t): (0;\infty) \to L^*$ is continuous;

$\zeta_{M;N}$ called an intuitionistic fuzzy metric and $(X; \zeta_{M;N}; \mathrm{T})$ called intuitionistic fuzzy metric space. **Note** [20] In an intuitionistic fuzzy metric space $(X; \zeta_{M;N}; \mathrm{T})$**;** $M(x;y;t)$ is non- decreasing and $N(x;y;t)$ is non - increasing $\forall x; y \in X$. Hence $(X; \zeta_{M;N}; \mathrm{T})$ is non-decreasing function $\forall x; y \in X$.

Example 1.7. Let (*X; d*) be a metric space. Denote

$$T(x;y) = (a_1 b_1 \,; min(1\,; a_2 + b_2) \forall a = (a_1;\, a_2) \,\&\, b = (b_1;\, b_2) \in L^*$$

and let *M* and *N* be fuzzy sets on $X \times X \times (0;1)$. Then an intuitionistic fuzzy metric can be defined as $\forall x; y; \in X$

$$\zeta_{M;N}(x;y;t) = \big(M(x;y;t); N(x;y;t)\big) = \left(\frac{ht^n}{ht^n + md(x;y)}\,;\, \frac{m\,.d(x;y)}{ht^n + md(x;y)}\right) \forall\, h; m; n; t \in R^+;$$

So that $\zeta_{M;N}(x;y;t)$ is modified IFMS.

Example 1.8. Let $X = N$. Denote

$$T(x;y) = (\max(0;\, a_1 +\, b_1 - 1)\,; (a_2 + b_2 - a_2 b_2) \forall a = (a_1;\, a_2) \& b = (b_1;\, b_2) \in L^*$$

and let *M* and *N* be fuzzy sets on $X \times X \times (0;1)$. Then an intuitionistic fuzzy metric can be defined as

$$\zeta_{M;N}(x;y;t) = \big(M(x;y;t); N(x;y;t)\big) = \begin{cases} \frac{x}{y};\ \frac{y-x}{y} & if\ x \leq y \\ \frac{y}{x};\ \frac{x-y}{x} & if\ y \leq x \end{cases}$$

So that $\zeta_{M;N}(x;y;t)$ is modified IFMS.

Definition 1.8. A negator on L^* is a decreasing mapping $N: L^* \to L^*$ satisfying $N(0_{L^*}) = 1_{L^*} \& N(1_{L^*}) = 0_{L^*}$ A negator on [0; 1] is a decreasing mapping $N: [0;1] \to [0;1]$ satisfying $N(0) = 1 \,\&\, N(1) = 0$. In what follows, *Ns* denotes the standard negator on [0;1] defined as $N_s(x) = 1 - x \;\forall\, x \in [0;1]$.

Definition 1.10. Let$(X; \zeta_{M;N}; \mathrm{T})$ be a modified IFMS. For $t > 0$, define the open ball $B(x;r;t)$; with center $x \in X$ and radius $0 < r < 1$ as

$$B(x;r;t) = \{\, y \in X :\ \ \zeta_{M;N}(x;y;t) >_{L^*} (N_s(r);r)\}$$

A subset $A \subseteq X$ is called open if for each $x \in A$ there exist $t > 0$ and $0 < r < 1$ such that $B(x;r;t) \subset A$. Let $\tau_{\zeta_{M;N}}$ denote the family of all open subset of *X*. Then, $\tau_{\zeta_{M;N}}$ is called the topology induced by modified intuitionistic fuzzy metric $\zeta_{M;N}$. This topology is Hausdorff.

Definition 1.11. A sequence $\{x_n\}$ in a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$ is called a Cauchy sequence if for each $t > 0$and $0 < r < 1$; there exists $n_0 \in N$ such that

$\zeta_{M;N}(x_n; x_m; t) >_{L^*} (N_s(r);r)\}$ and for each$n; m \geq\, n_0$

Where *Ns* is the standard Negator. The sequence$\{x_n\}$ is said to be convergent to$x \in X$in the intuitionistic fuzzy metric space $(X; \zeta_{M;N}; \mathrm{T})$ and is generally denoted by $x \to^{\zeta_{M;N}} x$if $\zeta_{M;N}(x_n;x;t) \to 1_{L^*}$whenever $n \to \infty$ for every $t > 0$.I FMS is said to be complete if and only if every Cauchy sequence is convergent.

Proposition 1.12. Let $(X; \zeta_{M;N}; \mathrm{T})$ be an intuitionistic fuzzy metric space. If for a sequence $\{x_n\} \in X$ there exists $\kappa \in (0;1)$such that

$$\zeta_{M;N}(x_n; x_{n+1}; \alpha t) \geq_{L^*}\ \zeta_{M;N}(x_{n-1}; x_n; t)\ \forall\, n \,\&\, t$$

Then $\{x_n\}$ is a Cauchy sequence in X.

Proof. Let $(X; \zeta_{M;N}; \mathrm{T})$ be an intuitionistic fuzzy metric space. If for a sequence; $\{x_n\} \in X$there exists $\kappa \in (0;1)$ such that

$\zeta_{M;N}(x_n; x_{n+1}; \alpha t) \geq_{L^*}\ \zeta_{M;N}(x_{n-1}; x_n; t)\ \forall\, n \,\&\, t$;

Then $\zeta_{M;N}(x_n; x_{n+1}; t) \geq_{L^*}\ \zeta_{M;N}\left(x_{n-1}; x_n; \frac{t}{\alpha}\right) \geq_{L^*}\ \zeta_{M;N}\left(x_{n-2}; x_n - 1; \frac{t}{\alpha^2}\right) \ldots.$

$$\geq_{L^*}\ \zeta_{M;N}\left(x_{n-2}; x_n - 1; \frac{t}{\alpha^n}\right) \forall\, n \,\&\, t$$

Now for κ

$$\begin{aligned} E_\kappa(x_{n+1}; x_n) &= Inf\{t > 0 :\ \zeta_{M;N}(x_{n+1}; x_n; t) \geq_{L^*} (1-\kappa;\kappa)\} \\ &\leq Inf\{t > 0 :\ \zeta_{M;N}\left(x_1; x_0; \frac{t}{\kappa^n}\right) \geq_{L^*} (1-\kappa;\kappa)\} \\ &= Inf\{\kappa^n\, t > 0 :\ \zeta_{M;N}(x_1; x_0; t) \geq_{L^*} (1-\kappa;\kappa)\} \\ &= \kappa^n Inf\{\, t > 0 :\ \zeta_{M;N}(x_1; x_0; t) \geq_{L^*} (1-\kappa;\kappa)\} \\ &= \kappa^n E_\kappa(x_1; x_0) \\ \Rightarrow E_\kappa(x_{n+1}; x_n) &\leq \kappa^n E_\kappa(x_1; x_0) \end{aligned}$$

Again for $\kappa \in (0;1) \exists\, \partial \in (0;1)$such that

$$\begin{aligned} E_\kappa(x_n; x_{n+p}) &\leq E_\partial\ \ (x_n; x_{n+1}) + E_\partial\ \ (x_{n+1}; x_{n+2}) + \cdots + E_\partial\ \ (x_{n+p-1}; x_{n+p}) \\ &\leq \kappa^n\ E_\partial\ \ (x_0; x_1) + \kappa^{n+1} E_\partial\ \ (x_0; x_1) + \cdots + \kappa^{n+p-1} E_\partial\ \ (x_0; x_1) \\ &\leq (\kappa^n + \kappa^{n+1} + \cdots + \kappa^{n+p-1})\ E_\partial\ \ (x_0; x_1) \end{aligned}$$

$$\leq \frac{\kappa^n}{1-\kappa} E_\partial \quad (x_0; x_1) \to 0 \; as \; n \to \infty \; since \quad \partial \in (0;1)$$

Hence $\{x_n\}$ is a Cauchy sequence.

Proposition 1.13. Let $(X; \zeta_{M;N}; \mathrm{T})$ be an intuitionistic fuzzy metric space. If for a sequence $\{x_n\} \in X$ there exists $\kappa \in (0;1)$ such that

$\zeta_{M;N}(x; y; \kappa\, t) \geq_{L^*} \zeta_{M;N}(x; y; t) \; \forall \; t;$

Then $x = y$.

Proof: for $\kappa \in (0;1)$; Then from Proposition 1.12;

$$E_\kappa(x;y) = Inf\{t > 0 : \; \zeta_{M;N}(x;y;t) \geq_{L^*} (1-\kappa;\kappa)\}$$
$$\leq Inf\{t > 0 : \; \zeta_{M;N}\left(x; y; \frac{t}{\kappa}\right) \geq_{L^*} (1-\kappa;\kappa)\}$$
$$= Inf\{\kappa\, t > 0 : \zeta_{M;N}(x;y;t) \geq_{L^*} (1-\kappa;\kappa)\}$$
$$= \kappa\, Inf\{\, t > 0 : \zeta_{M;N}(x;y;t) \geq_{L^*} (1-\kappa;\kappa)\}$$
$$E_\kappa(x;y) == \kappa\, E_\kappa(x;y) \Rightarrow E_\kappa(x;y) = 0 \Rightarrow x = y$$

Proposition 1.14. In a Modified IFMS for all $x = (x_1; x_2)\; ; y = (y_1; y_2)\; ; x\mathrm{T}y = \mathrm{x}$

Proof: for all $x = (x_1; x_2)\; ; y = (y_1; y_2) \; \in L^* \Rightarrow x\mathrm{T}y = T(x;y) = (\, x_1 * \, y_1 \; ; \, x_2 \diamond y_2)$

Therefore $\quad x\mathrm{T}y = (x_1 * \, y_1 \; ; \, x_2 \diamond y_2)$

$x\mathrm{T}y \leq_{L^*} (x_1; x_2)$ since $x_1 * \, y_1 \leq x_1 \& x_2 \diamond y_2 \geq x_2$

$\Rightarrow x\mathrm{T}y = \mathrm{x}$

Definition 1.15. Let $(X; \zeta_{M;N}; \mathrm{T})$ be a modified IFMS. Then mapping $\zeta_{M;N}: X \times X \times (0;\infty) \to L^*$ is said tobe continuous if

$$\lim_{n\to\infty} \zeta_{M;N}(x_n; y_n; t_n) = \zeta_{M;N}(x;y;t)$$

whenever a sequence $\{(x_n; y_n; t_n)\}$ in $X \times X \times (0;\infty)$ converges to a point $(x;y;t)$ in $X \times X \times (0;\infty)$ such that $\lim_{n\to\infty} \zeta_{M;N}(x_n; x; t) = \lim_{n\to\infty} \zeta_{M;N}(y_n; y; t) = 1_{L^*}$ and $\lim_{n\to\infty} \zeta_{M;N}(x; y; t_n) = \zeta_{M;N}(x;y;t)$

Definition 1.16. Let $f \,\&\, g$ be two self mappings for a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$**.** Then mappings are said to be compatible if

$$\lim_{n\to\infty} \zeta_{M;N}(fgx_n; gfx_n; t) = 1_{L^*} \; \forall \, t \; > 0$$

Whenever a sequence $\{x_n\} \in X$ such that

$$\lim_{n\to\infty} fx_n = \lim_{n\to\infty} gx_n = x \in X$$

Definition 1.17. Let $f \,\&\, g$ be two self mappings for a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$**.** Then mappings are said to be non-compatible if there is at least one sequence $\{x_n\} \in X$ such that

$\lim_{n\to\infty} fx_n = \lim_{n\to\infty} gx_n = x \in X$ but $\lim_{n\to\infty} \zeta_{M;N}(fgx_n; gfx_n; t) \neq 1_{L^*}$ for at least one $t \; > 0$.

Definition 1.18. Let $f \,\&\, g$ be two self mappings for a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$**.** Then mappings are said to be weak compatible if they commute at their point of coincident; that is $fx = gx \; \Rightarrow fgx = gfx$.

Remark 1.19. every pair of compatible self mappings *f* and *g* of a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$ is weak compatible. But the converse is not true.

Example Let $(X; \zeta_{M;N}; \mathrm{T})$ be a modified IFMS; where $X = [0;2]$; $\zeta_{M;N}(x;y;t) = \left(\frac{t}{t+|x-y|} \; ; \; \frac{|x-y|}{t+|x-y|}\right)$. For $t > 0; x; y \in X; T(x;y) = (a_1 b_1 \; ; \min(1\; ; a_2 + b_2) \; \forall \; a = (a_1;\, a_2)$ and $b = (b_1;\, b_2) \in L^*$. Define mappings as

$f(x) = \begin{cases} 2 & if \; 0 \leq x \leq 1 \\ \frac{x}{2} & if \; 1 < x \leq 2 \end{cases}$ and $g(x) = \begin{cases} 2 & if \; x = 1 \\ \frac{x+3}{5} & if \; x \neq 1 \end{cases}$

So we have $f(1) = g(1) = 2$ and $f(2) = g(2) = 1$. Again $fg(1) = gf(1) = 2$ and $fg(2) = gf(2) = 1$ implies $(f; g)$ is weak compatible. If we define fx_n and gx_n as

$fx_n = 1 - \frac{1}{4n}$ and $gx_n = 1 - \frac{1}{10n} \Rightarrow \lim_{n\to\infty} fx_n = \lim_{n\to\infty} gx_n = 1$. Again $fgx_n = 2$

And $gfx_n = \frac{4}{5} - \frac{1}{20n}$.

$$\lim_{n\to\infty} \zeta_{M;N}(x;y;t) = \lim_{n\to\infty}\left(2; \frac{4}{5} - \frac{1}{20n}; t\right) = \left(\frac{t}{t+\frac{6}{5}} \; ; \; \frac{\frac{6}{5}}{t+\frac{6}{5}}\right) \neq 1_{L^*} \; \forall \, t > 0$$

Implied that. Hence the pair (*f; g*) is not compatible.

Definition 1.20. Let *f* and *g* be two self mappings of a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$ We say that *f* and *g* have the property (E.A) if there exists a sequence $\{x_n\} \in X$ such that

$$\lim_{n\to\infty} \zeta_{M;N}(fx_n; u; t) = \lim_{n\to\infty} \zeta_{M;N}(gx_n; u; t) = 1_{L^*} \; \forall \, t \; > 0 \; and \; u \in X$$

Definition 1.21. Two pairs $(A;S)$ and $(B;T)$ of self mappings of a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$ are said to satisfy the common property (E.A) if there exist two sequences $\{x_n\} \,\&\, \{y_n\} \in X$ such that

$$\lim_{n\to\infty} \zeta_{M;N}(Ax_n; u; t) = \lim_{n\to\infty} \zeta_{M;N}(Sx_n; u; t) = \lim_{n\to\infty} \zeta_{M;N}(Bx_n; u; t) = \lim_{n\to\infty} \zeta_{M;N}(Tx_n; u; t) \; \forall \, t > 0 \text{ and } u \in X$$

II. MAIN RESULT

We begin with the following lemma.

Lemma 2.1.[15] Let $A; B; S$ and T be self mappings of a modified IFMS $(X; \zeta_{M;N}; \mathrm{T})$ satisfying the following conditions:

[i] the pair $(A;S)$ or $(B;T)$ satisfies the property (E.A);

[ii] $A(x) \subset S(X)$or $B(x) \subset T(X)$;
[iii] $B(y_n)$ Converges for every sequence $\{y_n\} \in X$ whenever $T(y_n)$ converges or $A(x_n)$ converges for every sequence $\{x_n\} \in X$ whenever $S(x_n)$ converses;
[iv] $\forall\, x; y \in X$ s

$$\zeta_{M;N}(Ax; By; t) \geq_{L^*} \alpha\{\zeta_{M;N}(Sx; Ty; t); \zeta_{M;N}(Ax; Sx; t);\ \zeta_{M;N}(By; Ty; t);$$
$$\zeta_{M;N}(Sx; By; t); \zeta_{M;N}(Ax; Ty; t) \text{ where } \alpha > 1 \quad (2.11)$$

Then the pairs $(A; S)$ and $(B; T)$ share the common property $(E\ A)$.

Proof: Suppose the pair$(A; S)$enjoy the property$(E\ A)$; then there exists a sequence

$$\lim_{n\to\infty} Ax_n = \lim_{n\to\infty} Sx_n = z \in X\,; x \in X$$

i.e. $\lim_{n\to\infty} \zeta_{M;N}(Ax_n; Sx_n; t) = 1$. Since$A(X) = S(X)$; then for each $\{x_n\} \in X$;Their exists $\{y_n\} \in X$ Such that $x_n = Ty_n$. So we have $\lim_{n\to\infty} Ax_n = \lim_{n\to\infty} Ty_n = z \in X$.

Thus in all we have $\lim_{n\to\infty} Ax_n = \lim_{n\to\infty} Sx_n = \lim_{n\to\infty} Ty_n = z \in X$. Thus in view $\{By_n\}$ converses; i.e. $\lim_{n\to\infty} \zeta_{M;N}(By; z\,; t) = 1$. If not; then using inequality (2.11); we have

$$\zeta_{M;N}(Ax_n; By_n; t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sx_n; Ty_n; t); \zeta_{M;N}(Ax_n; Sx_n; t); \zeta_{M;N}(By_n; Ty_n; t);$$
$$\zeta_{M;N}(Sx_n; By_n; t); \zeta_{M;N}(Ax_n; Ty_n; t)\}$$
$$\lim_{n\to\infty} \zeta_{M;N}(Ax_n; By_n; t) \geq_{L^*} \alpha \min\{\lim_{n\to\infty} \zeta_{M;N}(Sx_n; Ty_n; t); \lim_{n\to\infty} \zeta_{M;N}(Ax_n; Sx_n; t); \lim_{n\to\infty} \zeta_{M;N}(By_n; Ty_n; t);$$
$$\lim_{n\to\infty} \zeta_{M;N}(Sx_n; By_n; t); \lim_{n\to\infty} \zeta_{M;N}(Ax_n; Ty_n; t)\}$$
$$\zeta_{M;N}(Ty_n; By_n; t) \geq_{L^*} \alpha \min\{1; 1; \zeta_{M;N}(By_n; Ty_n; t); \zeta_{M;N}(By_n; By_n; t); 1\}$$
$$\zeta_{M;N}(Ty_n; By_n; t) \geq_{L^*} \alpha\, \zeta_{M;N}(By_n; Ty_n; t)$$

$\Rightarrow \zeta_{M;N}(By_n; Ty_n; t) = 1$ i.e. $\lim_{n\to\infty} \zeta_{M;N}(By_n) = z$. Which shows pairs $(A; S)$ and $(B; T)$ share the common property$(E\ A)$.

Now we will prove the common fixed point theorem for Modified IFMS.

Theorem 2.2: Let $A; B; S$ and T be self mappings of a modified IFMS$(X; \zeta_{M;N};\ T)$ satisfying the conditions

(i) pairs $(A; S)$ and $(B; T)$ share the common property$(E\ A)$;
(ii) $A(x) \subset X$ and $S(x) \subset X$;
(iii) $\forall x; y \in X$
$\zeta_{M;N}(Ax; By; t) \geq_{L^*} \alpha\{\zeta_{M;N}(Sx; Ty; t); \zeta_{M;N}(Ax; Sx; t);\ \zeta_{M;N}(By; Ty; t);\ \zeta_{M;N}(Sx; By; t); \zeta_{M;N}(Ax; Ty; t)$ where $\alpha > 1$ (2.21)

Then the pairs $(A; S)$ and $(B; T)$ have a coincidence point. Moreover, $A; B; S$ *and* T have a Unique common fixed point in X provided both the pairs $(A; S)$ and $(B; T)$ are weakly compatible.

Proof: Since the pairs $(A; S)$ and $(B; T)$share the common property $(E\ A)$; therefore there exists two sequences $\{x_n\}; \{y_n\} \in X$ such that

$$\lim_{n\to\infty} Ax_n = \lim_{n\to\infty} Sx_n = \lim_{n\to\infty} By_n = \lim_{n\to\infty} Ty_n = z \in X$$

Since$S(x) \subset X$; $\lim_{n\to\infty} Sx_n = z \in S(X)$; therefore there exists $v \in X$such that $Sv = z$. Now we assume $\zeta_{M;N}(Av; z; t) = 1$. If not; then using (2.21)

$$\zeta_{M;N}(Av; By_n; t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sv; Ty_n; t); \zeta_{M;N}(Av; Sv; t); \zeta_{M;N}(By_n; Ty_n; t);$$
$$\zeta_{M;N}(Sv; By_n; t); \zeta_{M;N}(Av; Ty_n; t)\}$$
$$\lim_{n\to\infty} \zeta_{M;N}(Av; By_n; t) \geq_{L^*} \alpha \min\{\lim_{n\to\infty} \zeta_{M;N}(Sv; Ty_n; t); \lim_{n\to\infty} \zeta_{M;N}(Av; Sv; t); \lim_{n\to\infty} \zeta_{M;N}(By_n; Ty_n; t);$$
$$\lim_{n\to\infty} \zeta_{M;N}(Sv; By_n; t); \lim_{n\to\infty} \zeta_{M;N}(Av; Ty_n; t)\}$$
$$\zeta_{M;N}(Av; z; t) \geq_{L^*} \alpha \min\{1; \zeta_{M;N}(Av; z; t); 1; 1; \zeta_{M;N}(Av; z; t)\}$$
$$\zeta_{M;N}(Av; z; t) \geq_{L^*} \alpha\zeta_{M;N}(Av; z; t)$$

a contradiction. So that $\zeta_{M;N}(Av; z; t) = 1 \Rightarrow Av = z = Sv$.Hence v is a coincident point for the pair$(A; S)$.

Since $T(x) \subset X$; $\lim_{n\to\infty} Tx_n = z \in T(X)$; therefore there exists $w \in X$ such that $Sw = z$. Now we assume$\zeta_{M;N}(Bw; z; t) = 1$. If not ; then using (2.21)

$$\zeta_{M;N}(Ax_n; Bw; t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sx_n; Tw; t); \zeta_{M;N}(Ax_n; Sx_n; t); \zeta_{M;N}(Bw; Tw; t);$$
$$\zeta_{M;N}(Sx_n; Bw; t); \zeta_{M;N}(Ax_n; Tw; t)\}$$
$$\lim_{n\to\infty} \zeta_{M;N}(Ax_n; Bw; t) \geq_{L^*} \alpha \min\{\lim_{n\to\infty} \zeta_{M;N}(Sx_n; Tw; t); \lim_{n\to\infty} \zeta_{M;N}(Ax_n; Sx_n; t); \lim_{n\to\infty} \zeta_{M;N}(Bw; Tw; t);$$
$$\lim_{n\to\infty} \zeta_{M;N}(Sx_n; Bw; t); \lim_{n\to\infty} \zeta_{M;N}(Ax_n; Tw; t)\}$$
$$\zeta_{M;N}(z; Bw; t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(z; Bw; t); 1; 1; \zeta_{M;N}(z; Bw; t); \zeta_{M;N}(z; Bw; t)\}$$
$$\zeta_{M;N}(Bz; z; t) \geq_{L^*} \alpha\zeta_{M;N}(Bz; z; t)$$

a contradiction. So that $\zeta_{M;N}(z; Bw; t) = 1 \Rightarrow Bw = z = Tw$.Hence w is a coincident point for the pair $(B; T)$.

Again $Av = Sv$ and the pair $(A; S)$ is weak compatible; therefore $Az = SAv = SAv = Sz$. Now we are to show that z is a common fixed point of the pair$(A; S)$. To accomplish that we assume that $\zeta_{M;N}(Az; z; t) = 1$. If not; then using (2.21)

$$\zeta_{M;N}(Az; Bw; t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sz; Tw; t); \zeta_{M;N}(Az; Sz; t); \zeta_{M;N}(Bw; Tw; t);$$
$$\zeta_{M;N}(Sz; Bw; t); \zeta_{M;N}(Az; Tw; t)\}$$
$$\lim_{n\to\infty} \zeta_{M;N}(Az; Bw; t) \geq_{L^*} \alpha \min\{\lim_{n\to\infty} \zeta_{M;N}(Sz; Tw; t); \lim_{n\to\infty} \zeta_{M;N}(Az; Sz; t); \lim_{n\to\infty} \zeta_{M;N}(Bw; Tw; t);$$
$$\lim_{n\to\infty} \zeta_{M;N}(Sz; Bw; t); \lim_{n\to\infty} \zeta_{M;N}(Az; Tw; t)\}$$
$$\zeta_{M;N}(Az; z; t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Az; z; t); \zeta_{M;N}(Az; Sz; t); \zeta_{M;N}(Bw; Tw; t);$$

$$\zeta_{M;N}(Az;z;t);\zeta_{M;N}(Az;z;t)\}$$
$$\zeta_{M;N}(Az;z;t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Az;z;t);1;1;\zeta_{M;N}(Az;z;t);\zeta_{M;N}(Az;z;t)\}$$
$$\zeta_{M;N}(Az;z;t) \geq_{L^*} \alpha\, \zeta_{M;N}(Az;z;t)$$
A contraction. Therefore $\zeta_{M;N}(Az;z;t) = 1 \Rightarrow Az = z$. Hence z is a common point for pair
$$(A;S) \Rightarrow Az = z = Sz$$
Again $Bw = Tw$ and the pair$(B;T)$ is weak compatible; therefore $Bz = BTw = TBw = Tz$. Now we are to show that z is a common fixed point of the pair$(B;T)$. To accomplish that we assume that$\zeta_{M;N}(Bz;z;t) = 1$. If not; then using (2.21)
$$\zeta_{M;N}(Av;Bz;t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sv;Tz;t);\zeta_{M;N}(Av;Sv;t);\zeta_{M;N}(Bz;Tz;t);$$
$$\zeta_{M;N}(Sv;Bz;t);\zeta_{M;N}(Av;Tz;t)\}$$
$$\lim_{n\to\infty}\zeta_{M;N}(Av;Bz;t) \geq_{L^*} \alpha \min\{\lim_{n\to\infty}\zeta_{M;N}(Sv;Tz;t);\lim_{n\to\infty}\zeta_{M;N}(Av;Sv;t);\lim_{n\to\infty}\zeta_{M;N}(Bz;Tz;t);$$
$$\lim_{n\to\infty}\zeta_{M;N}(Sv;Bz;t);\lim_{n\to\infty}\zeta_{M;N}(Av;Tz;t)\}$$
$$\zeta_{M;N}(z;Bz;t) \geq_{L^*} \alpha \min\{\zeta_{M;N}(z;Bz;t);1;1;\zeta_{M;N}(z;Bz;t);\zeta_{M;N}(z;Bz;t)\}$$
$$\zeta_{M;N}(z;Bz;t) \geq_{L^*} \alpha\zeta_{M;N}(z;Bz;t)$$
A contraction. Therefore $\zeta_{M;N}(Bz;z;t) = 1 \Rightarrow Bz = z$. Hence z is a common point for pair $(B;T) \Rightarrow Bz = z = Tz$. Hence z is a common fixed point for $A;B;S$ and T.

Uniqueness: Let u be another fixed point for$A;B;S$ and T i.e. $Au = Bu = Su = Tu = u$. Putting $x = z \,\&\, y = u$in (2.21); we have
$$\zeta_{M;N}(Az;Bu;t) \geq_{L^*} \alpha\, min\{\zeta_{M;N}(Sz;Tu;t);\zeta_{M;N}(Az;Sz;t);\ \zeta_{M;N}(Bu;Tu;t);$$
$$\zeta_{M;N}(Sz;Bu;t);\zeta_{M;N}(Az;Tu;t)$$
$$\zeta_{M;N}(z;u;t) \geq_{L^*} \alpha\{\zeta_{M;N}(z;u;t);1;\ 1;\zeta_{M;N}(z;u;t);\zeta_{M;N}(z;u;t)\}$$
$$\zeta_{M;N}(z;u;t) \geq_{L^*\,\alpha} \zeta_{M;N}(z;u;t)$$
$$\zeta_{M;N}(z;u;t) = 1 \Rightarrow z = u$$
Hence z is a unique common fixed point for $A;B;S$ and T.

Theorem 2.3: Let $A;B;S$ *and* T be self mappings of a modified IFMS$(X;\zeta_{M;N};\ \mathrm{T})$satisfying the conditions

(i) the pair $(A;S)$ or $(B;T)$satisfies the property (E.A);

(ii) $A(x) \subset S(X)$ or $B(x) \subset T(X)$;

(iii) $\zeta_{M;N}(Ax;By;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Sx;Ty;t)^2;\zeta_{M;N}(Ax;Sx;t)^2;\zeta_{M;N}(By;Ty;t)^2\}$
$+\alpha_2\min\{\zeta_{M;N}(By;Ty;t).\zeta_{M;N}(Sx;By;t);\zeta_{M;N}(Ax;Sx;t).\zeta_{M;N}(Ax;Ty;t)\}$

$\forall\, x;y \in X\, ;\alpha_1;\alpha_2 > 1\, ;\alpha_1 + \alpha_2 \geq 1$and $\alpha_1 \geq 1$ (2.31)

Then the pairs $(A;S)$ and $(B;T)$ have a coincidence point. Moreover, $A;B;S$ and T have a Unique common fixed point in X provided both the pairs$(A;S)$and $(B;T)$ are weak compatible.

Proof: Since the pairs $(A;S)$ and $(B;T)$ share the common property$(E\ A)$; therefore there exists two sequences $\{x_n\};\{y_n\} \in$ X such that
$$\lim_{n\to\infty} Ax_n = \lim_{n\to\infty} Sx_n = \lim_{n\to\infty} By_n = \lim_{n\to\infty} Ty_n = z \in X$$
Since$S(x) \subset X$; $\lim_{n\to\infty} Sx_n = z \in S(X)$; therefore there exists $v \in X$ such that $Sv = z$. Now we assume $\zeta_{M;N}(Av;z;t) = 1$. If not; then using (2.31)
$$\zeta_{M;N}(Ax_n;By_n;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Sx_n;Ty_n;t)^2;\zeta_{M;N}(Ax_n;Sx_n;t)^2;\zeta_{M;N}(By_n;Ty_n;t)^2\}$$
$$+\alpha_2\min\{\zeta_{M;N}(By_n;Ty_n;t).\zeta_{M;N}(Sx_n;By_n;t);\zeta_{M;N}(Ax_n;Sx_n;t).\zeta_{M;N}(Ax_n;Ty_n;t)\}$$
$$\lim_{n\to\infty}\zeta_{M;N}(Ax_n;By_n;t)^2 \geq_{L^*} \alpha_1 \min\{\lim_{n\to\infty}\zeta_{M;N}(Sx_n;Ty_n;t)^2;\zeta_{M;N}(Ax_n;Sx_n;t)^2;\lim_{n\to\infty}\zeta_{M;N}(By_n;Ty_n;t)^2\}$$
$$+\alpha_2 \min\{\lim_{n\to\infty}\{\zeta_{M;N}(By_n;Ty_n;t).\lim_{n\to\infty}\{\zeta_{M;N}(Sx_n;By_n;t);\lim_{n\to\infty}\{\zeta_{M;N}(Ax_n;Sx_n;t).\lim_{n\to\infty}\{\zeta_{M;N}(Ax_n;Ty_n;t)\}$$
$$\zeta_{M;N}(Av;z\,;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Av;z;t)^2;1;1\} + \alpha_2\min\{1.\zeta_{M;N}(Av;z;t);1.\zeta_{M;N}(Av;z;t)\}$$
$$\zeta_{M;N}(Av;z;t) \geq_{L^*} (\alpha_1 + \alpha_2)\zeta_{M;N}(Av;z;t)$$
a contradiction $(\alpha_1 + \alpha_2) > 1$. So that $\zeta_{M;N}(Av;z;t) = 1 \Rightarrow Av = z = Sv$.Hence v is a coincident point for the pair $(A;S)$. Since $T(x) \subset X; \lim_{n\to\infty} Tx_n = z \in T(X)$; therefore there exists $w \in X$ such that $Bw = z$. Now we assume $\zeta_{M;N}(Bw;z;t) = 1$. If not; then using (2.31)
$$\zeta_{M;N}(Ax_n;Bw;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Sx_n;Tw;t)^2;\zeta_{M;N}(Ax_n;Sx_n;t)^2;\zeta_{M;N}(Bw;Tw;t)^2\}$$
$$+\alpha_2\min\{\zeta_{M;N}(Bw;Tw;t).\zeta_{M;N}(Sx_n;Bw;t);\zeta_{M;N}(Ax_n;Sx_n;t).\zeta_{M;N}(Ax_n;Tw;t)\}$$
$$\lim_{n\to\infty}\zeta_{M;N}(Ax_n;Bw;t)^2 \geq_{L^*} \alpha_1 \min\{\lim_{n\to\infty}\zeta_{M;N}(Sx_n;Tw;t)^2;\lim_{n\to\infty}\zeta_{M;N}(Ax_n;Sx_n;t)^2\,;$$
$$\lim_{n\to\infty}\zeta_{M;N}(Bw;Tw;t)^2\}$$
$$+\alpha_2\min\{\lim_{n\to\infty}\zeta_{M;N}(Bw;Tw;t).\lim_{n\to\infty}\zeta_{M;N}(Sx_n;Bw;t)\};\lim_{n\to\infty}\zeta_{M;N}(Ax_n;Sx_n;t).\lim_{n\to\infty}\zeta_{M;N}(Ax_n;Tw;t)\}$$
$$\zeta_{M;N}(z;Bw;t)^2 \geq_{L^*} \alpha_1\min\{\zeta_{M;N}(z;Bw;t)^2;1;1\} + \alpha_2\min\{1.(z;Bw;t)\,;1.\zeta_{M;N}(z;Tw;t)\}$$
$$\zeta_{M;N}(z;Bw;t)^2 \geq_{L^*} (\alpha_1 + \alpha_2).\min\{\zeta_{M;N}(z;Bw;t)^2;1;1\}$$
$$\zeta_{M;N}(z;Bw;t) \geq_{L^*} (\alpha_1 + \alpha_2)\zeta_{M;N}(Bw;z;t)$$
a contradiction since $\alpha_1 > 1$. So that $\zeta_{M;N}(z;Bw;t) = 1 \Rightarrow Bw = z = Tw$.Hence w is a coincident point for the pair $(B;T)$. Again $Av = Sv$ and the pair$(A;S)$ is weak compatible; therefore $Az = ASv = SAv = Sz$. Now we are to show that z is a common fixed point of the pair $(A;S)$. To accomplish that we assert that $\zeta_{M;N}(Az;z;t) = 1$. If not; then using (2.31)
$$\zeta_{M;N}(Az;Bw;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Sz;Tw;t)^2;\zeta_{M;N}(Az;Sz;t)^2;\zeta_{M;N}(Bw;Tw;t)^2\}$$
$$+\alpha_2\min\{\zeta_{M;N}(Bw;Tw;t).\zeta_{M;N}(Sz;Bw;t);\zeta_{M;N}(Az;Sz;t).\zeta_{M;N}(Az;Tw;t)\}$$
$$\lim_{n\to\infty}\zeta_{M;N}(Az;Bw;t)^2 \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sz;Tw;t)^2;\lim_{n\to\infty}\zeta_{M;N}(Az;Sz;t)^2\,;\lim_{n\to\infty}\zeta_{M;N}(Bw;Tw;t)^2\}$$

$$+\alpha_2 \min\{\lim_{n\to\infty} \zeta_{M;N}(Bw;Tw;t).\lim_{n\to\infty} \zeta_{M;N}(Sz;Bw;t)\};\lim_{n\to\infty} \zeta_{M;N}(Az;Sz;t).\lim_{n\to\infty} \zeta_{M;N}(Az;Tw;t).\}\}$$

$$\zeta_{M;N}(Az;z;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Az;z;t)^2;1;1\} + \alpha_2 \min\{1.(Az;z;t);1.\zeta_{M;N}(Az;z;t)\}$$

$$\zeta_{M;N}(Az;z;t)^2 \geq_{L^*} (\alpha_1+\alpha_2).\zeta_{M;N}(Az;z;t)^2$$

A contraction since $\alpha_1 > 1$. Therefore $\zeta_{M;N}(Az;z;t) = 1 \Rightarrow Az = z$. Hence z is a common point for pair $(A;S) \Rightarrow Az = z = Sz$

Again $Bw = Tw$ and the pair$(B;T)$ is weak compatible; therefore $Bz = BTw = TBw = Tz$. Now we are to show that z is a common fixed point of the pair$(B;T)$. To accomplish that we assume that$\zeta_{M;N}(Bz;z;t) = 1$. If not; then using (2.31)

$$\zeta_{M;N}(Av;Bz;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Sv;Tz;t)^2;\zeta_{M;N}(Av;Sv;t)^2;\zeta_{M;N}(Bz;Tz;t)^2\}$$

$$+\alpha_2 \min\{\zeta_{M;N}(Bz;Tz;t).\zeta_{M;N}(Sv;Bz;t);\zeta_{M;N}(Av;Sv;t).\zeta_{M;N}(Av;Tz;t)\}$$

$$\lim_{n\to\infty} \zeta_{M;N}(Av;Bz;t)^2 \geq_{L^*} \alpha \min\{\zeta_{M;N}(Sv;Tz;t)^2;\lim_{n\to\infty} \zeta_{M;N}(Av;Sv;t)^2;\lim_{n\to\infty} \zeta_{M;N}(Bz;Tz;t)^2\}$$

$$+\alpha_2 \min\{\lim_{n\to\infty} \zeta_{M;N}(Bz;Tz;t).\lim_{n\to\infty} \zeta_{M;N}(Sv;Bz;t)\};\lim_{n\to\infty} \zeta_{M;N}(Av;Sv;t).\lim_{n\to\infty} \zeta_{M;N}(Av;Tz;t)\}$$

$$\zeta_{M;N}(z;Bz;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(z;Bz;t)^2;1;1\} + \alpha_2 \min\{1.(z;Bz;t);1.\zeta_{M;N}(z;Bz;t)\}$$

$$\zeta_{M;N}(z;Bz;t)^2 \geq_{L^*} (\alpha_1+\alpha_2).\zeta_{M;N}(z;Bz;t)^2$$

A contraction. Therefore $\zeta_{M;N}(Bz;z;t) = 1 \Rightarrow Bz = z$. Hence z is a common point for pair $(B;T) \Rightarrow Bz = z = Tz$. Hence z is a common fixed point for$A;B;S\ and\ T$.

Uniqueness: Let u be another fixed point for$A;B;S\ and\ T$ i.e. $Au = Bu = Su = Tu = u$. Putting $x = z\ \&\ y = u$in (2.31); we have

$$\zeta_{M;N}(Az;Bu;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Sz;Tu;t)^2;\zeta_{M;N}(Az;Sz;t)^2;\zeta_{M;N}(Bu;Tu;t)^2\}$$

$$+\alpha_2 \min\{\zeta_{M;N}(Bu;Tu;t).\zeta_{M;N}(Sz;Bu;t);\zeta_{M;N}(Az;Sz;t).\zeta_{M;N}(Az;Tu;t)\}$$

$$\zeta_{M;N}(Az;Bu;t)^2 \geq_{L^*} \alpha_1 \min\{\zeta_{M;N}(Az;Tu;t)^2;1;1\}$$

$$+\alpha_2 \min\{1.\zeta_{M;N}(Az;Bu;t);1.\zeta_{M;N}(Az;Tu;t)\}$$

$$\zeta_{M;N}(Az;Bu;t)^2 \geq_{L^*} (\alpha_1+\alpha_2).\zeta_{M;N}(Az;Tu;t)^2$$

$$\zeta_{M;N}(z;u;t)^2 \geq_{L^*} (\alpha_1+\alpha_2).\zeta_{M;N}(z;u;t)^2$$

$$\zeta_{M;N}(z;u;t) = 1 \Rightarrow z = u$$

Hence z is a unique common fixed point for $A;B;S$ and T.

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