International J. of Math. Sci. & Engg. Appls. (IJMSEA)
ISSN 0973-9424, Vol. 10 No. II (August, 2016), pp. 31-41

FIXED POINT THEOREM IN INTUTIONISTIC FUZZY METRIC SPACE USING ABSORBING FUNCTIONS

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Abstract

In this paper, the concepts of fixed point theorem in intutionstic fuzzy metric space using absorbing functions. In this paper use the six functions. Our results generalized and improves other results.

1. Introduction

In 1965 Zadeh introduced the notion of fuzzy sets. After this during the last few decades many authors have established the existence of lots of fixed point theorems in fuzzy setting. Introduced the concept of intuitionistic fuzzy sets as a generalization of

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Key Words : *Fixed point,Ccommon fixed points, Fuzzy metric space, Weak compatible maps, absorbing Functions.*

AMS Subject Classification : 47H10,54H25.

fuzzy sets and later there has been much progress in the study of intuitionistic fuzzy sets. In 2004, Park [8] introduced a notion of intuitionistic fuzzy metric spaces with the help of continuous t-norms and continuous t-conorms as a generalization of fuzzy metric space due to Kramosil and Michalek [14] in fact the concepts of triangular norms (t-norm) and triangular conorms (t-conorm) are originally introduced by Schweizer and Sklar [2] in study of statistical metric spaces.

Introduced the concept of absorbing mapping in metric space and prove common fixed point theorem in this space. Moreover they observe that the new notion of absorbing map is neither a subclass of compatible maps nor a subclass of non compatible maps.

The aim of this paper is to introduce the new notion of absorbing maps in intuitionistic fuzzy metric space which is neither a subclass of compatible maps nor a subclass of non-compatible maps, it is not necessary that absorbing maps commute at their coincidence points however if the mapping pair satisfy the contractive type condition then point wise absorbing maps not only commute at their coincidence points but it becomes a necessary condition for obtaining a common fixed point of mapping pair.

Definition 1.1 : Let X be any non empty set. A fuzzy set A in X is a function with domain X and values in $[0, 1]$.

Definition 1.2 : Let a set E be fixed. An intuitionist fuzzy set (IFS) A of E is an object having the form $A = \{\langle x, \mu_A(x), v_A(x)\rangle : x \in E\}$ where the function $\mu_A : E \to [0, 1]$ and $v_A : E \to [0, 1]$ define respectively, the degree of membership and degree of non-membership of the element $x \in E$ to the set A, which is a subset of E, and for every $x \in E$, $0 \leq \mu_A(x) + v_A(x) \leq 1$.

Definition 1.3 : A binary operation $* : [0, 1] \times [0, 1] \to [0, 1]$ is a continuous t-norm, if $*$ is satisfying the following conditions :

(i) $*$ is commutative and associative.

(ii) $*$ is continuous.

(iii) $a * 1 = a$ for all $a \in [0, 1]$.

(iv) $a * b \leq c * d$ whenever $a \leq c$ and $b \leq d$, for $a, b, c, d \in [0, 1]$.

Definition 1.4 : A binary operation $\diamondsuit : [0, 1] \times [0, 1] \to [0, 1]$ is continuous t-conorm if $\diamondsuit$ it satisfies the following conditions:

(i) $\diamondsuit$ is commutative and associative.

(ii) $\diamondsuit$ is continuous.

(iii) $a\diamondsuit 0 = a$ for all $a \in [0, 1]$.

(iv) $a\diamondsuit b \leq c\diamondsuit d$ whenever $a \leq c$ and $b \leq d$, for $a, b, c, d \in [0, 1]$.

Note 1.5 : The concepts of triangular norms (t-norms) and triangular co norms (t-co norms) are known as the axiomatic skeletons that we use for characterizing fuzzy intersections and unions, respectively. These concepts were originally introduced by Menger [12] in his study of statistical metric spaces.

Definition 1.6 : A 5-tuple $(X, M, N, *, \diamondsuit)$ is said to be an intuitionist fuzzy metric space (shortly IFM-Space) if X is an arbitrary set, $*$ is a permanent t-norm, $\diamondsuit$ is a permanent t-co-norm and M, N are fuzzy sets on $X^2 \times (0, \infty)$ satisfying the following conditions: for all $x, y, z, s, t > 0$

(IFM-1) $M(x, y, t) + N(x, y, t) \leq 1$

(IFM-2) $M(x, y, 0) = 0$

(IFM-3) $M(x, y, t) = 1$ if and only if $x = y$.

(IFM-4) $M(x, y, t) = M(y, x, t)$

(IFM-5) $M(x, y, t) + M(y, z, s) \leq M(x, z, t + s)$

(IFM-6) $M(x, y, *) : [0, \infty) \to [0, 1]$ is left permanent.

(IFM-7) $\lim_{t\to\infty} M(x, y, r) = 1$

(IFM-8) $N(x, y, 0) = 1$

(IFM-9) $N(x, y, t) = 0$ if and only if $x = y$.

(IFM-10) $N(x, y, t) = N(y, x, t)$

(IFM-11) $N(x, y, t)\diamondsuit N(y, z, s) \geq N(x, s, t + s)$

(IFM-12) $N(x, y, *) : [0, \infty) \to [0, 1]$ is right permanent.

(IFM-13) $\lim_{t\to\infty} N(x, y, t) = 0$.

Then (M, N) is called an intuitionistic fuzzy metric on X. The functions $M(x, y, t)$ and $N(x, y, t)$ denote the degree of nearness and degree of non-nearness between x and y with respect to t, respectively.

Remark 1.7 : Every fuzzy metric space $(X, M, *)$ is an intuitionistic fuzzy metric space if X of the form $(X, M, 1 - M, *, \diamondsuit)$ such that t- norm $*$ and t-conorm $\diamondsuit$ are associated, that is,

$$x\Diamond y = 1 - ((1-x) * (1-y)) \text{ for any } x, y \in X.$$

But the converse is not true.

Example 1.8 : (Induced intuitionist fuzzy metric). Let (X, d) be a metric space. Define $a * b = ab$ and $a\Diamond b = \min\{1, a+b\}$ for all $a, b \in [0,1]$ and let M_d and N_d be fuzzy sets on $X^2 \times (0, \infty)$ defined as follows:

$$M_d(x,y,t) = \frac{ht^n}{ht^n + md(x,y)} \quad \text{and} \quad N_d(x,y,t) = \frac{d(x,y)}{kt^n + md(x,y)}$$

for all h, k, m and $n \in R^+$. Then $(X, M_d, N_d, *, \Diamond)$ is an intuitionistic fuzzy metric space.

Definition 1.9 : Let $(X, M, N, *, \Diamond)$ be an intuitionist fuzzy metric space.

(a) A sequence $\{x_n\}$ in X is called Cauchy sequence if for each $t > 0$ and $p > 0$,

$$\lim_{n\to\infty} M(x_{n+p}, x_n, t) = 1 \text{ and } \lim_{n\to\infty} N(x_{n+p}, x_n, t) = 0.$$

(b) A sequence $\{x_n\}$ in X is convergent to $x \in X$ if

$$\lim_{n\to\infty} M(x_n, x, t) = 1 \text{ and } \lim_{n\to\infty} N(x_n, x, t) = 0.$$

for each $t > 0$.

(c) An intuitionist fuzzy metric space is said to be complete if every Cauchy sequence is convergent.

(d) Then the mappings are said to be reciprocally continuous if

$$\lim_{n\to\infty} ABx_n = Az \text{ and } \lim_{n\to\infty} BAx_n = Bz,$$

whenever $\{x_n\}$ is a sequence in X such that $\lim_{n\to\infty} ABx_n = \lim_{n\to\infty} BAx_n = z$, for some $z \in X$.

Remark 1.10 : If A and B are both continuous then they are obviously reciprocally continuous. But the converse need not be true.

Example 1.11 : Let $X = [4, 30]$ and d be the usual metric space X. Define mappings $A, B : X \to X$ by

$$Ax = \begin{cases} x & \text{if } x = 4 \\ 13 & \text{if } x > 4 \end{cases} \quad \text{and} \quad Bx = \begin{cases} x & \text{if } x = 4 \\ 26 & \text{if } x > 4. \end{cases}$$

It may be noted that A and B are reciprocally continuous mappings but neither A nor B is continuous mappings.

We shall use the following lemmas to prove our next result without any further citation:

Lemma 1.12 : In an intuitionist fuzzy metric space $X, M(x, y, \cdot)$ is non-decreasing and $N(x, y, \cdot)$ is non increasing for all $x, y \in X$.

Lemma 1.13 : Let $(X, M, N, *, \diamondsuit)$ be an intuitionist fuzzy metric space.

(i) If there exists a constant $k \in (0, 1)$ such that

$$M(y_{n+2}, y_{n+1}, kt) = M(y_{n+1}, y_n, t)$$

and

$$N(y_{n+2}, y_{n+1}, kt) = N(y_{n+1}, y_n, t).$$

For every $t > 0$ and $n = 1, 2, \cdots$, then $\{y_n\}$ is a Cauchy sequence in X.

(ii) If there exists a constant $k \in (0, 1)$ such that $M(x, y, kt) = M(x, y, t)$ and $N(x, y, kt) = N(x, y, t)$ for $x, y \in X$, then $x = y$.

Definition 1.14 : Let $\mathcal{A}$ and $\mathcal{B}$ are two self maps on a intuitionistic fuzzy metric space $(X, M, N, *, \diamondsuit)$ then $\mathcal{A}$ is called $\mathcal{B}$-fascinating if there exists a positive integer $r > 0$ such that

$$M(\mathcal{B}x, \mathcal{B}\mathcal{A}x, t) \geq M(\mathcal{B}x, \mathcal{A}x, t/R)$$

$$N(\mathcal{B}x, \mathcal{B}\mathcal{A}x, t) \leq N(\mathcal{B}x, \mathcal{A}x, t/R)$$

for all $x \in X$.

Similarly $\mathcal{B}$ is called $\mathcal{A}$-fascinating if there exists a positive integer $R > 0$ such that

$$M(\mathcal{A}x, \mathcal{A}\mathcal{B}x, t) \geq M(\mathcal{A}x, \mathcal{B}x, t/R)$$

$$N(\mathcal{A}x, \mathcal{A}\mathcal{B}x, t) \leq N(\mathcal{A}x, \mathcal{B}x, t/R)$$

for all $x \in X$.

Definition 1.15 : The map $\mathcal{A}$ is called point wise $\mathcal{B}$-fascinating if for given $x \in X$, there exists a positive integer $R > 0$ such that

$$M(\mathcal{B}x, \mathcal{B}\mathcal{A}x, t) \geq M(\mathcal{B}x, \mathcal{A}x, t/R)$$

$$N(\mathcal{B}x, \mathcal{B}\mathcal{A}x, t) \leq N(\mathcal{B}x, \mathcal{A}x, t/R)$$

for all $x \in X$.

2. Main Results

Theorem 2.1 : Let A be point wise S-absorbing and B be point wise T. Absorbing self maps on a complete intuitionist fuzzy metric space $(X, M, N, *, \diamondsuit)$ with permanent t-norm defined by $a * b = \min\{a, b\}$ and $a \diamondsuit b = \max\{a, b\}$ where $a, b \in (0, 1)$, satisfying the conditions:

(I) $A(X) \subset T(X), B(X) \subset S(X)$.

(II) There exists $k \in (0, 1)$ such that for every $x, y \in X$ and $t > 0$,]

$$M(Ax, By, kt) \geq \min \left\{ \begin{array}{c} M(Sx, Ty, t), M(Ax, Sx, t), M(By, Ty, t), \\ \\ M(Ax, Ty, t), M(Ax, By, t), M(Sx, By, t) \end{array} \right\},$$

$$N(Ax, By, kt) \leq \min \left\{ \begin{array}{c} N(Sx, Ty, t), N(Ax, Sx, t), N(By, Ty, t), \\ \\ N(Ax, Ty, t), N(Ax, By, t), N(Sx, By, t) \end{array} \right\}$$

(III) for all $x, y \in X$, $\lim_{t \to \infty} M(x, y, t) = 1$ and $\lim_{t \to 0} N(x, y, t) = 0$.

If the pair of maps $A, S)$ is mutual permanent compatible maps then A, B, S and T have a unique common fixed point in X.

Proof : let x_0 be any arbitrary point in X, construct a sequence $y_n \in X$ such that

$$y_{2n-1} = Tx_{2n-1} = Ax_{2n-2} \text{ and } y_{2n} = Sx_{2n} = Bx_{2n+1}, \; n = 1, 2, 3, \cdots \quad (1)$$

This can be done by the virtue of (I).

By using contractive condition we obtain,

$$
\begin{aligned}
&M(y_{2n+1}, y_{2n+2}, kt) = M(Ax_{2n}, Bx_{2n+1}, kt)\\
&\geq \min \left\{ \begin{array}{l} M(Sx_{2n}, Tx_{2n+1}, t), M(Ax_{2n}, Sx_{2n}, t), M(Bx_{2n+1}, Tx_{2n+1}, t), \\ \\ M(Ax_{2n}, Tx_{2n+1}, t)M(Ax_{2n}, Bx_{2n}, t)M(x_{2n}, Tx_{2n+1}, t), \end{array} \right\}\\
&\geq \min \left\{ \begin{array}{l} M(y_{2n}, y_{2n+1}, M(y_{2n+1}, y_{2n}, t), M(y_{2n}, y_{2n+1}, t), \\ \\ M(y_{2n+1}, y_{2n+1}, t)M(y_{2n+1}, y_{2n}, t), 1 \end{array} \right\}\\
&\leq \min \left\{ \begin{array}{l} N(Sx_{2n}, Tx_{2n+1}, t), N(Px_{2n}, Sx_{2n}, t), N(Qx_{2n+1}, Tx_{2n+1}, t), \\ \\ N(Px_{2n}, Tx_{2n+1}, t)M(Ax_{2n}, Bx_{2n}, t)M(Sx_{2n}, Tx_{2n+1}, t)) \end{array} \right\}\\
&\leq \min \left\{ \begin{array}{l} N)y_{2n}, y_{2n+1}, t), N(y_{2n+1}, y_{2n}, t), N(y_{2n}, y_{2n+1}, t), \\ \\ M(y_{2n+1}, y_{2n+1}, t), 0, M(y_{2n}, y_{2n+1}, t) \end{array} \right\}
\end{aligned}
$$

Which implies,

$$M(y_{2n+1}, y_{2n+2}, kt) \geq M(y_{2n}, y_{2n+1}, t)$$

$$N(y_{2n+1}, y_{2n+2}, kt) \leq N(y_{2n}, y_{2n+1}, t)$$

in general

$$M(y_n, y_{n+1}, kt) \geq M(y_{n-1}, y_n, t)$$

$$N(y_{2n}, y_{2n+1}, kt) \leq N(y_{2n-1}, y_{2n}, t) \tag{1}$$

To prove $\{y_n\}$ is a Cauchy sequence, we have to show

$$M(y_n, y_{n+1}, t) \to 1 \quad \text{and} \quad N(y_n, y_{n+1}, t) \to 0$$

(for $t > 0$ as $n \to \infty$ uniformly on $p \in N$). For this from (1) we have,

$$
\begin{aligned}
M(y_n, y_{n+1}, t) &\geq M\left(y_{n-1}, y_n, \frac{t}{k}\right) \geq M\left(y_{n-2}, y_{n-1}, \frac{t}{k^2}\right)\\
&\geq \cdots \geq M\left(y_0, y_1, \frac{t}{k^2 n}\right) \to 1
\end{aligned}
$$

$$
\begin{aligned}
N(y_n, y_{n+1}, t) &\geq N\left(y_{n-1}, y_n, \frac{t}{k}\right) \geq N\left(y_{n-2}, y_{n-1}, \frac{t}{k^2}\right)\\
&\geq \cdots \geq N\left(y_0, y_1, \frac{t}{k^n}\right) \to 0.
\end{aligned}
$$

As $n \to \infty$ for $p \in N$, by (1) we have

$$\begin{aligned}
&M(y_n, y_{n+p}, t) \geq M(y_n, y_{n+1}, (1-k)t) * N(y_{n+1}, y_{n+p}, kt) \\
&\geq M\left(y_0, y_1, \frac{(1-k)t}{k^n}\right) * M(y_{n+1}, y_{n+2}, t) * M(y_{n+2}, y_{n+p}(k-1)t) \\
&\geq M\left(y_0, y_1, \frac{(1-k)t}{k^n}\right) * M\left(y_0, y_1, \frac{1}{k^n}\right) * M(y_{n+2}, y_{n+3}, t) * M(y_{n+3}, y_{n+p}, (k-2)t) \\
&\geq M\left(y_0, y_1, \frac{(1-k)t}{k^n}\right) * M\left(y_0, y_1, \frac{t}{k^n}\right) * M\left(y_0, y_1, \frac{(1-k)t}{k^{n+2}}\right) * \cdots * M\left(y_0, y_1, \frac{(k-p)t}{k^{n+p+1}}\right)
\end{aligned}$$

and

$$\begin{aligned}
&N(y_n, y_{n+p}, t) \leq N(y_n, y_{n+1}, (1-k)t) \Diamond N(y_{n+1}, y_{n+p}, kt) \\
&\leq N\left(y_0, y_1, \frac{(1-k)t}{k^n}\right) \Diamond N(y_{n+1}, y_{n+2}, t) \Diamond N(y_{n+2}, y_{n+p}(k-1)t) \\
&\leq N\left(y_0, y_1, \frac{(1-k)t}{k^n}\right) \Diamond N\left(y_0, y_1, \frac{t}{k^n}\right) \Diamond N(y_{n+2}, y_{n+3}, t) \cdots \Diamond N\left(y_0, y_1, \frac{(k-p)t}{k^{n+p+1}}\right)
\end{aligned}$$

Thus $M(y_n, y_{n+p}, t) \to 1$ and $N(y_n, y_{n+p}, t) \to 0$ (for all $t > 0$ as $n \to \infty$ uniformly on $p \in N$).
Therefore $\{y_n\}$ is a Cauchy sequence in X.
But $(X, M, N, *, \Diamond)$ is complete so there exists a point (say) z in X such that $\{y_n\} \to z$.
Also, using (I) we have $\{Ax_{2n-2}\}, \{Tx_{2n-1}\}, \{Sx_{2n}\}, \{Bx_{2n+1}\} \to z$.
Since the pair (A, S) is reciprocally continuous mappings, then we have, $\lim_{n\to\infty} ASx_{2n} = Az$ and $\lim_{n\to\infty} SAx_{2n} = Sz$ and compatibility of A and S yields,

$$\lim_{n\to\infty} M(ASx_{2n}, SAx_{2n}, t) = 1 \quad \text{and} \quad \lim_{n\to\infty} N(ASx_{2n}, SAx_{2n}, t) = 0$$

i.e. $M(az, Sz, t) = 1$ and $N(Az, Sz, t) = 0$. Hence $Az = Sz$.
Since $A(X) \subset T(X)$, then there exists a point u in X such that $Az = Tu$.
Now by contractive condition, we get,

$$M(Ax, By, kt) \geq \min\left\{\begin{array}{c} M(Sx, Ty, t), M(Ax, Sx, t), M(By, Ty, t), \\ \\ M(Ax, Ty, t), M(Ax, By, t), M(Sx, By, t) \end{array}\right\}$$

$$N(Ax, By, kt) \leq \min\left\{\begin{array}{c} N(Sx, Ty, t), N(Ax, Sx, t), N(By, Ty, t), \\ \\ N(Ax, Ty, t), N(Ax, By, t), N(Sx, By, t) \end{array}\right\}$$

i.e. $Az = Bu$. Thus $Az = Sz = Bu = Tu$.

Since P is S-absorbing then for $R > 0$, we have,

$$M(Sz, SAz, t) \geq M\left(Sz, Az, \frac{t}{R}\right) = 1$$

$$N(Sz, SAz, t) \leq N\left(Sz, Az, \frac{t}{R}\right) = 0$$

i.e. $Az = SAz = Sz$.

Now by contractive condition, we have,

$$\begin{aligned}
M(Ax, By, kt) &\geq \min\left\{\begin{array}{l} M(Sx, Ty, t), M(Ax, Sx, t), M(By, Ty, t), \\ \\ M(Ax, Ty, t), M(Ax, By, t), M(Sx, By, t) \end{array}\right\} \\
&= M(AAz, Az, t) \\
N(Az, AAz, t) &= N(AAz, Bu, t) \\
N(Ax, By, kt) &\leq \min\left\{\begin{array}{l} N(Sx, Ty, t), N(Ax, Sx, t), N(By, Ty, t), \\ \\ N(Ax, Ty, t), N(Ax, By, t), N(Sx, By, t) \end{array}\right\} \\
&= N(AAz, Az, t)
\end{aligned}$$

i.e. $AAz = Az = SAz$.

Therefore Az is a common fixed point of A and S.

Similarly, T is B-absorbing. Therefore we have,

$$M(Tu, TBu, t) \geq M\left(Tu, Bu, \frac{t}{R}\right) = 1$$

$$N9Tu, TBu, t) \leq N\left(Tu, Bu, \frac{t}{R}\right) = 0.$$

i.e. $Tu = TBu = Bu$.

Now by contractive condition, we have

$$\begin{aligned}
M(Ax, By, kt) &\geq \min\left\{\begin{array}{l} M(Sx, Ty, t), M(Ax, Sx, t), M(By, Ty, t), \\ \\ M(Ax, Ty, t), M(Ax, By, t), M(Sx, By, t) \end{array}\right\} \\
&= M(AAz, Az, t) \\
&= M(BBu, Az, t) \\
N(Ax, By, kt) &\leq \min\left\{\begin{array}{l} N(Sx, Ty, t), N(Ax, Sx, t), N(By, Ty, t), \\ \\ N(Ax, Ty, t), N(Ax, By, t), N(Sx, By, t) \end{array}\right\} \\
&= N(AAz, Az, t)
\end{aligned}$$

i.e. $BBu = Bu = TBu$.

Hence $Bu = Az$ is a common fixed point of A, B, S and T.

Uniqueness of Az can easily follows from contractive condition.

The proof is similar when B and T are assumed compatible and reciprocally permanent. This completes the proof. Now we prove the result by assuming the range of one of the mappings A, B, S or T to be a complete subspace of X.

Corroloary 2.2 : Let A be point wise S-absorbing and B be point wise Tabsorbing self maps on an intuitionist fuzzy metric space $(X, M, N, *, \diamondsuit)$ with continuous t-norm defined by $a * b = \min\{a, b\}$ and $a \diamondsuit b = \max\{a, b\}$ where $a, b \in [0, 1]$ satisfying the conditions:.

(I) $A(X) \subseteq T(X), B(X) \subseteq S(X)$.

(II) There exists $k \in (0, 1)$ such that for every $x, y \in X$ and $t > 0$

$$M(Ax, By, kt) \geq \min \left\{ \begin{array}{c} M(Sx, Ty, t), M(Ax, Sx, t), M(By, Ty, t), \\ \\ M(Ax, Ty, t), M(Ax, By, t), M(Sx, By, t) \end{array} \right\}$$

$$N(Ax, By, kt) \leq \min \left\{ \begin{array}{c} N(Sx, Ty, t), N(Ax, Sx, t), N(By, Ty, t), \\ \\ N(Ax, Ty, t), N(Ax, By, t), N(Sx, By, t) \end{array} \right\}$$

(III) for all $x, y \in X$, $\lim\limits_{n\to\infty} M(x, y, t) = 0$ and $\lim\limits_{n\to\infty} N(x, y, t) = 0$.

If the range of one of the mappings maps A, B, S or T be a complete subspace of X. Then A, B, S and T have a unique common fixed point in X.

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