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COMMON FIXED POINT THEOREMS IN FUZZY METRIC SPACE USING INTEGRAL TYPE

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ABSTRACT

In this paper, the concept of common fixed point theorem in fuzzy metric space using integral type.

Key Words: *contraction condition, fuzzy metric space, weakly compatible mapping, common fixed point*

AMS subject classification: *47H10, 54H25.*

1. INTRODUCTION

Zadseh in 1965 was introduced fuzzy set. This concept in topology and analysis many authors have developed the theory of fuzzy set and applications. Recently many authors have also studied the fixed point theory in fuzzy metric spaces ([11], [12]15], [22], [28], [29]. Grabiec[15] followed kramsoil and michalek[17] and obtained the banasch's fixed theorem using fuzzy sets. jungck[6] established common fixed point theorems for commuting maps generalizing the banach's fixed point theorems. sessa [25] defined a generalization of commutatively which is called weak commuativity. The study of common fixed point of mappings satisfying contractive type conditions has been a very active field of research during recent years. Several authors [5], [16], [17], [32] proved some fixed point theorems for various generalizations of contraction mapping in probabilistic and fuzzy metric metric space. In this paper, we prove some common fixed point theorems for mappings by using contracting condition of integral type for class of weakly compatible maps in non complete intutionistic fuzzy metric spaces

2. PRELIMINARIES

Definition 2.1:[5].A binary operation *:[0,1] x [0,1]→[0,1] is called a continuous t- norm if ([0,1],*)is an abelian topological monoid with the uni9t 1 such that $a*b\le c*d$ whenever $a \le c$ and $b\le d$ for all $a,b,c,d \in [0,1]$.. Examples of t- norms are a*b =ab and a*b = min{a, b}

Definition 2.2 ([21]): the 3 –tuples (x, M,*) is called a fuzzy metric space if X is an arbitrary set * is a continuous t-norm, and M is fuzzy set in X^2 x [0,∞] satisfying the following conditions for all x, y, z∈X and t, s > 0.

1. M(x, y, 0) =0
2. M(x, y, 1) =1 ∀ t > 0 ⇔ x =y
3. M(x, y, t) = M(y, x, t)
4. M(x, y, t) * M(y, z, s) ≤ M(x, z, t+s) and
5. M(x, y, *): [0, ∞) → [0,1] is left continous.
6. $Lim_{t\leftrightarrow\infty}$M(x, y, t) =1

In what follow (X, M,*) will denote a fuzzy metric space. Note that M(x, y, t) can be thought as the degree of nearness between x and y with respect to t. We identify x =y with M(x, y, t) =1 for al t. 0 and M(x, y, t) =0 with ∞ and we can find some topological properties and examples of fuzzy metric spaces in George and veeramani [3].

In the following example, we know that every metric induces a fuzzy metric.

$$M\left(x, y, t\right) = \frac{t}{t + d\left(x, y\right)}, \qquad (A)$$

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Then M(x, y, *) is a fuzzy metric space. We call the fuzzy metric M induced by the metric d the standard fuzzy metric. On the other hand note that there exists no metric on x satisfying (A)

Lemma 2.1([15]): for all x, y∈X, M(x, y,*) is non decreasing.

Definition 2.3: ([15]) Let M(x, y, *) is a fuzzy metric space:

(i). A sequence $\{X_n\}$ in X is said to be convergent to a point x,∈X (denoted by $Lim_{t\leftrightarrow\infty}\ X_n$ =x) if for t > 0 and $Lim_{t\leftrightarrow\infty}$M(x, y, t) =1

(ii) A sequence $\{X_n\}$ in X is said to be Cauchy sequence if, for all t > 0 and p > 0, $Lim_{t\leftrightarrow\infty}$M ($x_{n+p}$,$x_n$t) =1

(iii).A fuzzy metric space in which every Cauchy sequence is convergent is said to be complete.

Note 2.1: since * is continuous, it follow from definition 2.2(4) that the limit of the sequence in fuzzy metric space is uniquely determined

Lemma 2.2 ([23] [33]): Let $\{y_n\}$ be a sequence in a fuzzy metric space M(x,y,*) with the condition Definition 2.2(6) . If there exisats a number k∈(0,1) such that M(y_{n+2},y_{n+1} ,kt) ≥M(y_{n+1},y_n ,t) for all t .) and n =1, 2,…. Then $\{y_n\}$ is a Cauchy sequence in X.

Lemma 2.3 ([23][33]): if for all x, y∈ X, t >0 and for a number k∈(0,1)

M(x, y, k t) ≥ M(x, y, t)

Then x = y.

Definition 2.4 ([23]): Let A and B be mappings from a fuzzy metric space M(x, y, *) into it self. The mapping A and B are said to be compatible if $Lim_{t\leftrightarrow\infty}$M($ABx_n$,$BAx_n$,t) =1For all t > 0 , whenever $\{X_n\}$ is a sequence in X such that $Lim_{t\leftrightarrow\infty}Ax_n$ = $Lim_{t\leftrightarrow\infty}Bx_n$ = Z for some z ∈X.

Definition 2.5 ([33]): Let A and B be mappings from a fuzzy metric space M(x, y, *) into it self. The mapping A and B are said to be compatible of type (α if for all t > 0)

if $Lim_{t\leftrightarrow\infty}$M($ABx_n$,$BBx_n$,t) =1 and $Lim_{t\leftrightarrow\infty}$M($BAx_n$,$AAx_n$,t) =1

For all t > 0, whenever $\{X_n\}$ is a sequence in X such that $Lim_{t\leftrightarrow\infty}Ax_n$ = $Lim_{t\leftrightarrow\infty}Bx_n$ = Z for some z ∈X.

Definition 2.6 ([34]): Let A and B be mappings from a fuzzy metric space M(x, y,*) into it self . The mapping A and B are said to be compatible of type (β) if for all t > 0)

if $Lim_{t\leftrightarrow\infty}$M($AAx_n$,$BBx_n$,t) =1 when everFor all t > 0 , whenever $\{X_n\}$ is a sequence in X such that $Lim_{t\leftrightarrow\infty}Ax_n$ = $Lim_{t\leftrightarrow\infty}Bx_n$ = Z for some z ∈X.

Definition 2.6 ([9]): two self mappings S and T are said to be weakly compatible if they commute at their coincidence points, i.e, if Tu=Su for u ∈ X. TSu=Stu

Examples 2.2: Let X [0, 2] with the metric d define by d(x, y) = l x- y l. For each t∈(0,∞)

$$M\ (x, y, t) = \frac{t}{t + d(x, y)},$$

And define M(x, y, 0) =0 x, y ∈ X

Clearly, M(x, y,*) is a fuzzy metric space on X where * is defined by a*b =ab or a*b min{a, b}

$$AX = \begin{cases} x, & if\ x \in [0,\frac{1}{4} \\ \frac{1}{4}, if\ x \geq \frac{1}{4} \end{cases} \qquad Bx = \frac{x}{1+x}\ 1$$

For all x∈[0,2]. Consider the sequence $\{X_n$ = 1/3 + 1/n: n≥} in X. Then

$Lim_{n\leftrightarrow\infty}\ Ax_n, = \frac{1}{4}$, $Lim_{n\leftrightarrow\infty}, Bx_n\ = \frac{1}{4}$

$Lim_{t\leftrightarrow\infty}$M($ABx_n$,$BAx_n$,t) = $\frac{1}{t+\ l\frac{1}{4}-\frac{1}{5}l}$ ≠1 and

$Lim_{t\leftrightarrow\infty}$ M(BAx_n,AAx_n ,t) = $\frac{1}{t+\ l\frac{1}{5}-\frac{1}{4}l}$ $\neq$1 . Thus A and B are

non compatable, but A and B are commuting at their. Coincidencce point, That is weakly compatible at x = 0. also Thus A and B are not compatible of type (β). in view of this example, we observe weakly compatible maps need not be be compatible. or compatible of type (α) and type (β)

3. MAIN THEOREM

Theorem 3.1: Let (X, M,*) be a fuzzy metric space with continuous t – norm * defined by t*t for all t∈ [0, 1]. Let A, B, S, T, P and Q be mappings from X into itself such that

(a) P(X)⊂ST(X),Q(X) ⊂ AB(X)

(b) there exists a constant k∈(0,1) such that

$$\int_0^{M(Px,Qy,qt)} \varphi(t)dt \geq \int_0^{m(x,y,t)} \varphi(t)dt$$

Where $\varphi: \mathbb{R}^+ \rightarrow \mathbb{R}^+$is a lebesque – integrable mapping which is summable, non negative, and such that

$\int_0^{\varepsilon} \varphi(t)dt$ > 0 for each $\varepsilon > 0$

Where m(x, y, t)= min{M(ABx,Sty,t),M(Px.ABX,t),M(Qy,Sty,t),M(Px,ABX,t),M(Px,Sty,t)} For all x, y∈ X and t > 0

(c) P(x),Q(x),AB(x),ST(x) is complete subspace of X, then
(i). P and AB have a coincidence point, and
(ii). Q and St have a coincidence point.

(d) AB=BA, ST=TS, PB=BP, QT=TQ,

(e). the pair {P,AB} is weakly compatible ,

Then A, B, S, T, P and Q have a unique common fixed point in X.

Proof: let $\boldsymbol{x_0}$ ∈ X, from (a) there exist $\boldsymbol{x_1}, \boldsymbol{x_2}$ ∈ X such that

$Px_0 = STx_1$ And $Qx_1 = ABx_2$

Inductively, we can construct sequence $\{X_n\}$and $\{y_n\}$in X such that

$Px_{2n-2} = STx_1$=$y_{2n-1}$and

$Qx_{2n-1} = ABx_{2n}$=y_{2n} for n=1,2,3……..

Step - 1: put x=x_{2n} and y=y_{2n+1} in (e), we get

$$\int_0^{M(Px_{2n},Qx_{2n+1},qt)} \varphi(t)dt \geq \int_0^{M(ABx_{2n},STx_{2n+1},t)M(Px_{2n},ABx_{2n},t)M(Qx_{2n+1},STx_{2n+1},t)M(Px_{2n},STx_{2n+1},t),)} \varphi(t)dt$$

$$= \int_0^{M(y_{2n},y_{2n+1},t)M(y_{2n+1},y_{2n},t)M(y_{2n+2},y_{2n+1},t)M(y_{2n+1},y_{2n+1},t),)} \varphi(t)dt$$

$$\geq \int_0^{M(y_{2n},y_{2n+1},t)M(y_{2n+1},y_{2n+2},t))} \varphi(t)dt$$

Form lemma 2, 1 and 2, 2, we have

Similarly, we have

$$\int_0^{M(y_{2n+2},y_{2n+3},qt)} \varphi(t)dt \geq \int_0^{M(y_{2n+1},y_{2n+2},t)} \varphi(t)dt$$

Thus, we have

$\int_0^{M(y_{n+1},y_{n+3},qt)} \varphi(t)dt \geq \int_0^{M(y_n,y_{n+1},t)} \varphi(t)dt$ for n=1,2,…….

.

$$\int_0^{M(y_n,y_{n+1},t)} \varphi(t)dt \geq \int_0^{M\left(y_n,y_{n+1},\frac{t}{q}\right)} \varphi(t)dt$$

$$\geq \int_0^{M\left(y_{n-2},y_{n-1},\frac{t}{Q^2}\right)} \varphi(t)dt$$

…………………………

……………………………

$$\geq \int_0^{M\left(y_1,y_2,\frac{t}{Q^N}\right)} \varphi(t)dt \to 1\ as\ n \to \infty$$

And hence $\int_0^{M(y_n,y_{n+1},t)} \varphi(t)dt \to 1$as $n \to \infty$for any t > 0.

For each $\varepsilon > 0$ and t.> o, we choose $n_0 \in n$ such that $\int_0^{M(y_n,y_{n+1},t)} \varphi(t)dt > 1 - \varepsilon$ for all n $>\ n_0$

For m. n∈ N, we suppose m≥ n. Then we have

$$\int_0^{M(y_n,y_m,t)} \varphi(t)dt \geq \int_0^{M\left(y_n,y_{n+1},\frac{t}{m-n}\right)M\left(y_n+1,y_{n+2},\frac{t}{m-n}\right)\ldots\ldots M\left(y_{m-1},y_m,\frac{t}{m-n}\right)} \varphi(t)dt$$

$$\geq(1-\varepsilon) * (1-\varepsilon)*\ldots\ldots(1-\varepsilon)(m-n)times$$

$$\geq(1-\varepsilon)$$

And hence $\{y_n\}$is a Cauchy sequence in X

Since (X,M,*) is complete , $\{y_n\}$ converges to some point $z\varepsilon\ X$. Also its subsequence converges to the same point

$i.e. z \in X$

i.e. {Qx_{2n+1}}→Z and {STx_{2n+1}}→Z (1)

{Px_{2n}}→Z and {ABx_{2n}}→Z (2)

Case - I: suppose AB is continuous, we have

$(AB)^2x_{2n} \to AB$Z and

AB$x_{2n} \to AB$Z

As (P, AB) is compatible pair, we have PAB$x_{2n} \to AB$Z

Step -2: put x= ABx_{2n} and y=x_{2n+1} in (e), we get

$$\int_0^{M(PABx_{2n},Qx_{2n+1},qt)} \varphi(t)dt \geq \int_0^{M(ABAB\,x_{2n},STx_{2n+1},t)M(PABx_{2n},ABABx_{2n},t)M(Qx_{2n+1},STx_{2n+1},t)M(PABx_{2n},STx_{2n+1},t),)} \varphi(t)dt$$

Taking $n \to \infty$, we get

$$\int_0^{M(ABZ,,Z,qt)} \varphi(t)dt \geq \int_0^{M(ABz.Z,,t)M(ABz,ABZ,,t)Mz,z,,t)M(ABz,z,,t),)} \varphi(t)dt$$

$$\int_0^{M(ABZ,,Z,qt)} \varphi(t)dt \geq \int_0^{M(ABz.Z,,t),M(ABz.Z,,t))} \varphi(t)dt$$

$$\int_0^{M(ABZ,,Z,qt)} \varphi(t)dt \geq \int_0^{M(ABz.Z,,t),)} \varphi(t)dt$$

Therefore, by using lemma 2.2., we get ABz=z

Step - 3: put x=z and y =x_{2n+1} In (b), we have

$$\int_0^{M(z,z,,t)M(Pz,z,t))} \varphi(t)dt \geq \int_0^{M(z,z,,t)M(Pz,z,t)M(z,z,t)M(Pz,z,t),)} \varphi(t)dt \ \geq \int_0^{M(Pz,z,,t)M(Pz,z,t))} \varphi(t)dt$$

$\int_0^{M(Pz,z,,t)} \varphi(t)dt \ \ \geq \int_0^{M(Pz,z,,t))} \varphi(t)dt$

Therefore by using lemma 2.2., we get Pz=z, therreofre ABz=Pz=z

Step - 4: putting x=Bz and y =x_{2n+1} in condition (e) we get

$$\int_0^{M(PBz,Qx_{2n+1},qt)} \varphi(t)dt \geq \int_0^{M(ABBz,,STx_{2n+1},t)M(PZ,ABBz,t)M(Qx_{2n+1},STx_{2n+1},t)M(PBz,STx_{2n+1},t),)} \varphi(t)dt$$

As BP=PB, AB=BA, so we have P(Bz)=B(Pz)=Bz and

(AB)(Bz)= (BA) (Bz) =B(ABZ)=Bz

Taking $n \to \infty$ and using (1), we get

$$\int_0^{M(Bz,z,qt)} \varphi(t)dt \geq \int_0^{M(Bz,,z,t)M(BZ,Bz,t)M(z,z,,,t)M(Bz,z,t),)} \varphi(t)dt \geq \int_0^{M(Bz,,z,t)M(Bz,z,t),)} \varphi(t)dt$$

$$\int_0^{M(Bz,z,qt)} \varphi(t)dt \geq \int_0^{M(Bz,z,qt)} \varphi(t)dt$$

Therefore, by using lemma 2.2, we get

Bz = z

And also we have ABz=z

⟹Az=z, Therefore Az=Bz=Pz=z (4)

Step - 5: As P(X)⊆ ST(X), there exists u∈ X such that

Z=PZ=STU. Putting x=x_{2n} and y=u in (e) we get

$$\int_0^{M(Px_{2n},Qu,qt)} \varphi(t)dt \geq \int_0^{M(ABx_{2n},STu,t)M(Px_{2n},ABx_{2n},t)M(Qu,STu,t)M(Px_{2n},STu,t),)} \varphi(t)dt$$

Taking $n \to \infty$ and using (1) and (2), we get

$$\int_0^{M(z,Qu,qt)} \varphi(t)dt \geq \int_0^{M(z,z,,t)M(z,z,,t)M(Qu,z,t)M(z,z,t),)} \varphi(t)dt$$

$$\geq \int_0^{M(Qu,z,t)} \varphi(t)dt$$

$$\int_0^{M(z,Qu,qt)} \varphi(t)dt \geq \int_0^{M(z,Qu,t)} \varphi(t)dt$$

Therefore, by using lemma 2.2. we get Qu=z hence Stu=z=Qu

Thus Qz=STz,

Step - 6: putting x=x_{2n} and y=z in (e)

$$\int_0^{M(Px_{2n},Qu,qt)} \varphi(t)dt \geq \int_0^{M(ABx_{2n},STu,t)M(Px_{2n},ABx_{2n},t)M(Qu,STu,t)M(Px_{2n},STu,t),)} \varphi(t)dt$$

Taking $n \to \infty$ and using (2) and step 5, we get

$$\int_0^{M(z,Qz,qt)} \varphi(t)dt \geq \int_0^{M(z,,Qz,t)M(z,z,,t)M(Qz,Qz,t)M(z,qz,t),)} \varphi(t)dt$$

$$\geq \int_0^{M(z,Qz,qt)M(z,Qz,qt))} \varphi(t)dt$$

$$\int_0^{M(z,Qz,qt)} \varphi(t)dt \geq \int_0^{M(z,Qz,t)} \varphi(t)dt$$

Therefore, by using lemma 2.2, we get Qz=z

Step - 7: putting x=x_{2n} and y= Tz in (e), we get

$$\int_0^{M(Px_{2n},QTz,qt)} \varphi(t)dt \geq \int_0^{M(ABx_{2n},STTz,t)M(Px_{2n},ABx_{2n},t)M(QTz,STTz,t)M(Px_{2n},STTz,t),)} \varphi(t)dt$$

As QT=TQ and ST=Ts, we have QTz=TQz =Tz and ST(Tz)=T(STz)=TQz=Tz

Taking $n \to \infty$, we get

$$\int_0^{M(Pz,,Tz,qt)} \varphi(t)dt \geq \int_0^{M(z,Tz,t)M(z,z,t)M(Tz,Tz,t)M(z,Tz,t),)} \varphi(t)dt$$

$$\geq \int_0^{M(z,,Tz,t)M(z,,Tz,t)} \varphi(t)dt$$

$$\int_0^{M(z,,Tz,qt)} \varphi(t)dt \geq \int_0^{M(z,,Tz,t)} \varphi(t)dt\, t$$

Therefore, by using lemma 2.2. we get Tz=z now STz=Tz=z implies Sz=z hence Sz=Tz=Qz=Z (5)

Combining (4) and (5) we get

Az = Bz = Pz = Qz = Tz = Sz = z

Hence, z is the common fixed point of A, B, S, T, P and Q

Case - II: suppose P is continuous

As P is continuous

$P^2 x_{2n}$ → Pz and P(AB) x_{2n} → Pz

As (P, AB) is compatible pair. (AB) P x_{2n} → Pz

Step - 8: putting x= Px_{2n} and y=x_{2n+1}in condition (e), we have

$$\int_0^{M(PPx_{2n},Q,x_{2n}+1qt)} \varphi(t)dt \geq \int_0^{M(ABPx_{2n},STx_{2n+1},t)M(PPx_{2n},ABPx_{2n},t)M(Qx_{2n+1},STTx_{2n+1},t)M(PPx_{2n},STTx_{2n+1},t),)} \varphi(t)dt$$

Taking n→ ∞, $we\ get$

$$\int_0^{M(Pz,,z,qt)} \varphi(t)dt \geq \int_0^{M(Pz,z,t)M(Pz,Pz,t)M(z,z,t)M(Pz,z,t),)} \varphi(t)dt$$

$$\geq \int_0^{M(Pz,,z,t)M(Pz,,z,t)} \varphi(t)dt$$

$$\int_0^{M(Pz,,z,qt)} \varphi(t)dt \geq \int_0^{M(Pz,,z,t)} \varphi(t)dt$$

Therefore by using lemma 2.2, we have Pz=z further, using step 5, 6, 7 we get Qz=STz=Sz=Tz=z

Step - 9: Q(X)⊆ AB(X), there exists w belongs to X such that

Z=Qz=ABw

Put x=w and y=x_{2n+1} in (e), we have

$$\int_0^{M(Pw,,Qx_{2n+1},qt)} \varphi(t)dt \geq \int_0^{M(ABw,,STx_{2n+1},t)M(Pw,ABw,t)M(Qx_{2n+1},STx_{2n+1},t)M(Pw,STx_{2n+1},t),)} \varphi(t)dt$$

Taking n→ ∞,, we get

$$\int_0^{M(Pw,,z,qt)} \varphi(t)dt \geq \int_0^{M(z,z,t)M(Pw,z,t)M(z,z,t)M(Pw,z,t),)} \varphi(t)dt$$

$$\geq \int_0^{M(Pw,,z,t)M(Pw,,z,t)} \varphi(t)dt$$

$$\int_0^{M(Pw,,z,qt)} \varphi(t)dt \geq \int_0^{M(Pw,,z,t)} \varphi(t)dt$$

Therefore, buy using ABw=Pw=z

As (P, AB) is compatible pair. We have Pz=ABz

Also, from step4, we get Bz=z.

Thus Az = Bz =Pz z and we see that z is the common fixed point in this case also.

Uniqueness: Let u be another common fixed point of A,B,S,T,P and Q put x=z and y=uy in (e) we get

$$\int_0^{M(Pz,,Qu,qt)} \varphi(t)dt \geq \int_0^{M(ABzSTu\,,,t)M(Pz,ABz,t)M(Qu,STu,,t)M(Pz,STu,,t),)} \varphi(t)dt$$

Taking n →∞, we get

$$\int_0^{M(z,,u,qt)} \varphi(t)dt \geq \int_0^{M(z,u,,t)M(z,z,t)M(u,u,,t)M(z,u,,t),)} \varphi(t)dt$$

$$\geq \int_0^{M(z,,u,t)M(z,,u,t)} \varphi(t)dt$$

$$\int_0^{M(z,,u,qt)} \varphi(t)dt \geq \int_0^{M(z,,u,t)} \varphi(t)dt$$

Therefore by using lemma (2.2), we get z=u

Therefore z is the unique common fixed point of self maps A, B, S, T, P and Q.

Corollary 3.1: Let (X, M, *) be a fuzzy metric space with continuous t – norm * defined by t*t for all t∈ [0,1]. Let A, S, P and Q be mappings from X into itself such that

(a) P(X)⊂S(X),Q(X) ⊂ A(X)

(b) there exists a constant k∈(0,1) such that

$$\int_0^{M(Px,Qy,qt)} \varphi(t)dt \geq \int_0^{m(x,y,t)} \varphi(t)dt$$

Where $\varphi: \mathbb{R}^+ \to \mathbb{R}^+$is a lebesque – integrable mapping which is summable, non negative, and such that

$\int_0^{\varepsilon} \varphi(t)dt$ > 0 for each $\varepsilon > 0$

Where m(x,y,t)=min{M(Px,Qy,qt),M(Ax.Sy,t),M(Px,Ax,t),M(Qy,Sy,t),M(Px,Sy,t)}

For all x, y∈ X and t > 0
(c). P(x), AB(x), or ST(x) is complete subspace of X, then
(i). P and AB have a coincidence point, and
(ii). Q and St have a coincidence point.

(d). the pair {P, A and (Q, S) are compatible, Then A, S, P and Q have a unique common fixed point in X.

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