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Integral Type Inequlity in Fuzzy Metric Space Using Occasionally Weakly Compatible Mapping

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Abstract: ***In this paper we use integral type inequality in fuzzy metric spaces and generalization of result [12] and the condition for three pairs of occasionally weakly compatible mapping (OWC) {F, S} , {G, T } and {H, U)} with integral type inequality have unique common fixed point.***

Keywords: Fuzzy metric space, common fixed point, Fuzzy topology, completeness of Fuzzy metric space, weakly compatible maps, occasionally weakly compatible mapping (OWC).

AMS Mathematics Subject Classification: 47H10, 54H25

1. Introduction

Fuzzy set has been defined by Zadeh[17]. Kramosil and Michalek [7]introduced the concept of fuzzy metric space. Many authors extended their views as some George and Veera Mani [3].Grabiec (1988), Subramanyan (1995), Vasuki (1999), Pant and Jha (2004) obtained some analogous results proved by Balasubramaniam et al. subsequently, it was developed extensively by many authors and used in various fields. In 1986 Jungck introduced the notion of compatible maps for a pair of self maps.

Several papers have come up involving compatible maps in proving the existence of common fixed points both in the classical and fuzzy metric space. However, the study of common fixed points of non compatible mappings is also interesting. Pant (1994, 1999) initiated work along these lines by emplying the notion of point wise R-weak commutativity.

In the study of common fixed points of compatible mappings we often require assumption on completeness of the space or continuity of mappings involved besides some contractive condition but the study of fixed points of non-compatible mappings can be extend to the class of non expansive or Lipschitz type mapping pairs even without assuming the continuity of the mappings involved or completeness of the space. Aamri and EI Moutawakil (2004) generalized the concepts of non compatibility by defining the notion of (E.A.) property and proved common fixed point theorems under strict contractive condition. Manish Kumar Manish, Priyanka Sharma and D.B. Ojha,[10], established some common fixed point theorem's for occasionally weakly compatible mappings in fuzzy metric spaces satisfying integral type inequality. M. Rangamma and A. Padma[11], presented common fixed point theorems in fuzzy metric spaces for occasionally weakly compatible mapping with integral type inequality. Swati Choursiya, Dr. V.K. Gupta and Dr. V.H. Badshah (2014), established common fixed point theorems for six self maps by using compatible of type ($\propto$) with integral type inequality, without appeal to continuity in fuzzy metric space. Varun Singh, Arvind Gupta and Geeta Modi[16], proved common fixed point theorem for weakly compatible maps in Intuitionistic, fuzzy metric space satisfying integral type inequality but without using the completeness of space and using the concept of E.A. property. Jungck and Rhoades[5], introduced the concept of weakly compatible maps which were found to be more generalized than compatible maps. Pathak and Singh (2007), introduced some new results of fixed point theorem for weakly compatible mappings.

Malhotra and Singh[12], introduced some new results on occasionally weakly compatible mappings and fixed point theorem in Fuzzy metric space satisfying integral type inequality.

This paper presents some common fixed point theorem's which is occasionally weakly compatible mapping in fuzzy metric space and generalization of result [12] where three pairs *{F, S} , {G, T } and {H, U)}* be a occasionally weakly compatible mappings.

2. Preliminary

Definition 2.1 A 3-tuple $(X, M, *)$ is said to be a fuzzy metric space if X is an arbitrary set, $*$ is a continuous t-norm and M is a fuzzy set of $X^2 \times (0, \infty)$ satisfying the following conditions, for all $x, y, z \in X, s, t > 0$

1) $M(x, y, t) > 0$
2) $M(x, y, t) = 1$ if and only if $x = y$
3) $M(x, y, t) = M(y, x, t)$
4) $M(x, y,:) : (0, \infty) \rightarrow (0,1]$ is continuous.

Then M is called a fuzzy metric on X, and $M(x, y, t)$ denotes the degree of nearness between x and y with respect to t.

Definition 2.2 A binary operation $*$: $[0, 1] \quad [0, 1] \rightarrow [0, 1]$ is a continuous t-norm if $*$ is satisfying conditions:

(i) $*$ is an commutative and associative
(ii) $*$ is continuous
(iii) $a * 1 = a$ for all $a \in [0,1]$
(iv) $a * b \leq c * d$ whenever a $a \leq c$, $b \leq d$ and $a, b, c, d, \in [0,1]$

Example 2.2.1 Let $X = [0, 1]$, t-norm defined by $a*b = min\{a,b\}$ where $a, b, \in [0, 1]$ and M is the fuzzy set on $X^2 \times (0,$

∞) defined by $M(x, y, t) = (exp(|x - y|)/t)^{-1}$ for all $x, y \in X$, $t > 0$ then $(X, M, *)$ is a fuzzy metric space.

Example 2.2.2 Introduced fuzzy metric let (X, d) be a metric space, denote $a * b = a.b$ and for all $a, b, \in [0, 1]$ and let Md be fuzzy set on $X^2 \times (0, \infty)$ defined as follows
$Md(x, y, t) = \frac{t}{t+d(tx,y)}$

then $(X, M, *)$ is a fuzzy metric space we call this fuzzy metric induced by a metric d as the standard intuitionistic fuzzy metric.

Definition 2.3 A pair of self mappings (f, g) of a fuzzy metric space $(X, M, *)$ is said to be
(i) Weakly commuting if $M(fgx,gfx,t) \geq M(fx, gx, t)$ for all $x \in X$ and $t > 0$
(ii) R-weakly commuting if there exist some $R>0$ such that $M(fgx,gfx,t) \geq M(fx, gx, t/R)$ for all $x \in X$ and $t > 0$

Definition 2.4 To self mapping f and g of a fuzzy metric space $(X, M, *)$ are called reciprocally continuous on X if $lim_{n\to\infty} fgx_n=fx$ and $lim_{n\to\infty} gfx_n=gx$ whenever $\{x_n\}$ is a sequence in X.

Such that $lim_{n\to\infty} fx_n = lim_{n\to\infty} gx_n = x$ for some x in X.

Definition 2.5 Two self mapping f and g of a fuzzy metric space $(X, M, *)$ are called compatible if

$lim_{n\to\infty} M(fgx_n,gfx_n,t)=1$

whenever $\{x_n\}$ is a sequence in X such that

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

Definition 2.6 Two self mapping f and g of a set X are occasionally weakly compatible (*owc*) if there is a point x in X which is coincidence point of f and g at which f and g commute.

Definition 2.7 A sequence $\{x_n\}$ in a fuzzy metric space $(X, M, *)$ is called cauchy sequence if for every $\epsilon>0$ and each $t > 0$ there exist $n_0 \in N$ such that $M(x_n,x_{n+p}, t) > 1- \epsilon$ for all $n \geq n_0$ and $t > 0$.

Definition 2.8 A fuzzy metric space in which every cauchy sequence is convergent is said to be complete. A sequence $\{x_n\}$ in a fuzzy metric space $(X,M,*)$ is called cauchy sequence if for each $\epsilon> 0$ there exist $n_0 \in N$ such that

$M(x_n , x_m ,t) > 1- \epsilon$ for all $n, m > n_0$.

Definition 2.9 Let (X, d) be a compatible metric space, $\propto \in [0, 1]$, $f : X \to X$ a mapping such that for each $x, y \in X^{d(fx,fy)}$
$\int \emptyset(t)dt \leq \propto \int_0^{d(x,y)} \emptyset(t)dt$
where $\emptyset : R^T \to R$
lebesque integral mapping which is summable, $\epsilon >0$, $\int_0^{\epsilon} \emptyset(t)dt > 0$

nonnegative and such that, for each. Then f has a unique common fixed $z \in X$
such that for each $x \in X$ $lim_{n\to\infty} f^n x = z$

Rhodes [5] extended this result by replacing the above condition by the following

$$\int_0^{d(fx,fy)} \emptyset(t)dt \leq$$
$$\propto \int_0^{min\{d(x,y),d(x,fx),d(y,fy),\frac{1}{2}\{d(x,fy)+d(x,fx)\}} \emptyset(t)dt$$

Definition 2.10 Let X be a set f,g *OWC* self maps of X. If f and g have a unique point of coincidence, $w = fx=gx$, then w is the unique common fixed point of f and g.

Example 2.10.1 Let R be the usual metric space, define $S, T : R \to R$ by $Sx = 2x$ and $Tx = X^2$ for all $x \in R$ then $Sx = Tx$ for $x = 0,2$ but $ST0 = TSO$ and $ST2 \neq TS2$ hence S and T are occasionally weakly compatible self maps but not weakly compatible.

Definition 2.11 Let $(X,M,*)$ be a fuzzy metric space there exist $q \in (0,1)$ such that $M(x,y,qt) \geq M(x, y, t)$ for all $x, y \in X$ and $t > 0$ then $x = y$

3. Main Results

Theorem 3.1 Let $(X, M, *)$ be a complete fuzzy metric space and let F, G, H and S, T, U be self mapping of X. Let the pairs $\{F, S\}, \{G, T\}$ and $\{H, U\}$ be a *owc*. If there exist $q \in (0,1)$ such that

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$
$$\geq \int_0^{Min\left\{\begin{matrix} M(Sx,Ty,t),M(Sx,Fx,t)M(Ty,Uz,t),M(Ty,Gy,t) \\ M(Gy,Ty,t),M(Ty,Sx,t)M(Hz,Uz,t),M(Uz,Ty,t) \\ M(Fx,Ty,t),M(Gy,Sx,t)M(Gy,Uz,t),M(Hz,Ty,t)\end{matrix}\right\}} \emptyset(t)dt$$

for all $x, y, z \in X$ and for all $t > 0$ then there exist a unique point $a \in X$ such that $Fa = Sa = a$, unique point $b \in X$ such that $Gb = Tb = b$ and unique point $c \in X$ such that $Hc = Uc = c$ moreover $a = b = c$ so that there is a unique common fixed point of F, G, H, S, T and U.

Proof: Let the pairs $\{F,S\}, \{G,T\}$ and $\{H,U\}$ be *owc*, so there are points $x, y, z \in X$ such that $Fx=Sx=Tx$, $Gy=Ty=Sy$, $Gy=Ty=Uz$ and $Hz = Uz = Tz$ we claim that $Fx = Gy$ and $Gy = Hz$. If not by inequality.

$$\int_0^{M(Fx,Gx,Hx,qt)} \emptyset(t)dt$$
$$\geq \int_0^{Min\left\{\begin{matrix} M(Sx,Ty,t),M(Sx,Fx,t)M(Ty,Uz,t),M(Ty,Gy,t) \\ M(Gy,Ty,t),M(Ty,Sx,t)M(Hz,Uz,t),M(Uz,Ty,t) \\ M(Fx,Ty,t),M(Gy,Sx,t)M(Gy,Uz,t),M(Hz,Ty,t)\end{matrix}\right\}} \emptyset(t)dt$$
$$\geq \int_0^{Min\left\{\begin{matrix} M(Fx,Gy,t),M(Fx,Fx,t)M(Gy,Hz,t),M(Gy,Gy,t) \\ M(Gy,Gy,t),M(Gy,Fx,t)M(Hz,Hz,t),M(Hz,Gy,t) \\ M(Fx,Gy,t),M(Gy,Fx,t)M(Gy,Hz,t),M(Hz,Gy,t)\end{matrix}\right\}} \emptyset(t)dt$$
$$= \int_0^{Min\{M(Fx,Gy,t),M(Gy,Hz,t)\}} \emptyset(t)dt$$
$$= \int_0^{M(Fx,Gy,Hz,t)} \emptyset(t)dt$$

therefore $Fx = Gy = Hz$
i.e. $Fx = Sx = Tx = Gy = Ty = Sy = Uy = Hz = Tz = Uz$ ---(1)

Suppose that a such that $Fa = Sa$ so $Fx = Fa$ then $Fa = Sa = Ta = Gy =$
$Ty = Sy = Uy = Hz = Tz = Uz$, by (1) suppose that b such that $Gb = Tb$ so $Gy = Gb$ then $Fx = Sx = Tx = Gb = Tb = Sb = Ub = Hz = Tz = Uz$ and suppose that c such that $Hc = Uc$ then by (1)

$Fx = Sx = Tx = Gy = Ty = Sy = Uy = Hc = Tc = Uc$ ---(2)

So $Hz = Hc$

and $a = Fx = Sx$, $b = Gy = Ty$, $c = Hz = Uz$ is the unique point of coincidence of F and S, G and T and H, U respectively assume that $a \neq b \neq c$ we have

$$\int_0^{M(a,b,c,qt)} \emptyset(t)dt = \int_0^{M(Fa,Gb,Hc,qt)} \emptyset(t)dt$$

$$\geq \int_0^{Min\left\{\begin{matrix} M(Sa,Tb,t),M(Sa,Fa,t)M(Tb,Uc,t),M(Tb,Gb,t) \\ M(Gb,Tb,t),M(Tb,Sa,t)M(Hc,Uc,t),M(Uc,Tb,t) \\ M(Fa,Tb,t),M(Gb,Sa,t)M(Gb,Uc,t),M(Hc,Tb,t)\end{matrix}\right\}} \emptyset(t)dt$$

Replacing $x = a$, $y = b$, $z = c$

$$= \int_0^{Min\left\{\begin{matrix} M(a,b,t),M(a,a,t)M(b,c,t),M(b,b,t),M(b,b,t) \\ M(b,a,t),M(c,c,t)M(c,b,t),M(a,b,t),M(b,a,t) \\ M(b,c,t)M(c,b,t)\end{matrix}\right\}} \emptyset(t)dt$$

$$= \int_0^{M(a,b,c,t)} \emptyset(t)dt$$

therefore $a = b = c$ by [12].

So a is common fixed point of F, G, H, S, T and U the uniqueness of fixed point holds from 3.1.

Theorem 3.2 Let $(X, M, *)$be a complete fuzzy metric space and let F, G, H, S, T *and* U be self mapping of X. Let the pairs $\{F, S\}$, $\{G, T\}$ *and* $\{H, U\}$ be *owc*. If there exist $q \in (0, 1)$ such that

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\emptyset\left[Min\left\{\begin{matrix} M(Sx,Ty,t),M(Sx,Fx,t)M(Ty,Uz,t), \\ M(Ty,Gy,t)M(Fx,Ty,t),M(Gy,Uz,t) \\ M(Hz,Uz,t)M(Gy,Sx,t)M(Hz,Ty,t)\end{matrix}\right\}\right]} \emptyset(t)dt$$

for all $x, y, z \in X$ and $\emptyset : [0,1] \to [0,1]$ such that $\emptyset(t) > t$ for $0 < t < 1$ then there exist a unique common fixed point of F, G, H, S, T *and* U.

Proof:

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\emptyset\left[Min\left\{\begin{matrix} M(Sx,Ty,t),M(Sx,Fx,t)M(Ty,Uz,t),M(Ty,Gy,t) \\ M(Fx,Ty,t)M(Gy,Uz,t)M(Hz,Uz,t),M(Gy,Sx,t) \\ M(Hz,Ty,t)\end{matrix}\right\}\right]} \emptyset(t)dt$$

$$\geq \int^{\emptyset[M(Fx,Gy,Hz,qt)]} \emptyset(t)dt$$

Theorem 3.3 Let $(X, M, *)$ be a complete fuzzy metric space and let F, G, H, S, T *and* U be self mapping of X, let the pairs $\{F, S\}$, $\{G, T\}$ *and* $\{H, U\}$ are *owc*. If there exist $q \in (0,1)$ for all $x, y, z \in X$ and $t > 0$

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{Min\left\{\begin{matrix} M(Sx,Ty,t)M(Fx,Sx,t)M(Ty,Uz,t),M(Gy,Ty,t) \\ M(Hz,Uz,t)M(Fx,Ty,t),M(Gy,Uz,t)\end{matrix}\right\}} \emptyset(t)dt$$

then there exist a unique common fixed point of F, G, H, S, T and U.

Proof: Let the pairs $\{F, S\}$, $\{G, T\}$ and $\{H, U\}$ are *owc* and there are points $x, y, z \in X$ such that $Fx = Sx$, $Gy = Ty$, $Hz = Uz$ and claim that $Fx = Gy$ and $Gy = Hz$

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\left\{\begin{matrix} M(Sx,Ty,t)M(Fx,Sx,t)M(Ty,Uz,t),M(Gy,Ty,t) \\ M(Hz,Uz,t)M(Fx,Ty,t),M(Gy,Uz,t)\end{matrix}\right\}} \emptyset(t)dt$$

$$= \int_0^{\left\{\begin{matrix} M(Fx,Gy,t)M(Fx,Fx,t)M(Gy,Hz,t) \\ M(Gy,Gy,t)M(Hz,Hz,t),M(Fx,Gy,t) \\ M(Gy,Hz,t)\end{matrix}\right\}} \emptyset(t)dt$$

$$\geq \int_0^{M(Fx,Gy,t),M(Gy,Hz,t)} \emptyset(t)dt$$

$$\geq \int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

Thus we have $Fx = Gy = Hz$

i.e. $Fx = Sx = Gy = Ty = Hz = Uz$ ---(3)

Suppose that there is another point a such that $Ha = Ua$ then by (3) we have

$Fx = Sx = Gy = Ty = Ha = Ua$

So $Hx = Ha$

and $a = Hz = Uz$ is unique point of coincidence of H and U

Similarly $a \in X$ such that $Ga = Ta$ then by (3) we have

$Fx = Sx = Ga = Ta = Hz = Uz$

So $Ga = Gx$

and $a = Ga = Ta$ is unique point of coincidence of T and G.

Similarly there is a unique point $a \in X$ such that $Fa = Sa$ then by (3) we have $Fa = Sa = Gy = Ty = Hz = Uz$ so $Fa = Fx$ and $a = Fx = Sx$ is unique point of coincidence of F and S.

Corollary 3.3.1

Let $(X, M, *)$be a complete fuzzy metric space and let F, G, H, S, T *and* U be self mapping of X, let the pairs $\{F, S\}$, $\{G, T\}$ *and* $\{H, U\}$ are *owc*. If there exist $q \in (0, 1)$ for all $x, y, z \in X$ and $t > 0$

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\left\{\begin{matrix} M(Sx,Ty,t)M(Ty,Uz,t)M(Fx,Sx,t),M(Gy,Ty,t) \\ M(Gy,Ty,t)M(Hz,Uz,t)M(Fx,Ty,t),M(Gy,Uz,t) \end{matrix}\right\}} \emptyset(t)dt$$

then there exist a unique common fixed point of *F, G, H, S, T* and *U.*

Corollary 3.3.2

Let (*X, M,* *) be a complete fuzzy metric space and let *F, G, H, S, T and U* be self mapping of *X*, let the pairs *{F,S}, {G,T} and {H,U}* are *owc.* If there exist a point $q \in (0, 1)$ for all $x, y, z \in X$ and $t > 0$

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\left\{\begin{matrix} M(Sx,Ty,t)M(Ty,Uz,t)M(Sx,Fx,t) \\ M(Gy,Ty,t)M(Hz,Uz,t)M(Fx,Ty,t) \\ M(Gy,Sx,t)M(Gy,Uz,t)M(Hz,Ty,t) \end{matrix}\right\}} \emptyset(t)dt$$

Corollary 3.3.3

Let (*X, M,* *) be complete fuzzy metric space and let *F, G, H, S, T and U* be self mapping of *X*, let the pairs *{F, S} , {G, T } and {H, U}* are *owc.* If there exist a point $q \in (0, 1)$ for all $x, y, z \in X$ and $t > 0$

$$\int_0^{M(Fx,Gy,Hz,qt)} \emptyset(t)dt \geq \int_0^{M(Sx,Ty,Hz,t)} \emptyset(t)dt$$

then there exist a unique common fixed point of *F, G, H, S, T* and *U.*

Theorem 3.4

Let (*X, M,* *)be a complete fuzzy metric space and *H, U* be self mapping of *X*. Let *H and U* are *owc.* If there exist $q \in (0, 1)$ for all $x, y, z \in X$ and $t > 0$

$$\int_0^{M(Uz,Uy,Uz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\propto M(Hz,Hy,Hz,t)+\beta\left\{\begin{matrix} M(Hx,Hy,t),M(Hy,Hz,t) \\ M(Ux,Hx,t),M(Uy,Uy,t) \\ M(Uz,Hz,t) \end{matrix}\right\}+\gamma\left\{\begin{matrix} M(Gx,Gy,t),M(Gy,Gz,t) \\ M(Tx,Gx,t),M(Ty,Gy,t) \\ M(Tz,Gz,t) \end{matrix}\right\}} \emptyset(t)dt$$

for all $x, y, z \in X$ where $\propto, \beta, \gamma > 0$, $\propto + \beta + \gamma > 1$ then *H* and *U* have a unique common fixed point.

Proof

Let the pairs *{H, U}* be *owc* so there is a point $x \in X$ such that $Hx = Ux$,$y \in X$ such that $Hy = Uy$ and $z \in X$ such that $Hz = Uz$

we claim that $Ux = Uy = Uz$ --(4)

and the pair *{G, T }*be *owc* so there is a point $x \in X$ such that $Gx = Tx$, $y \in X$ such that $Gy = Ty$ and $z \in X$ such that $Gz = Tz$

we claim that $Tx = Ty = Tz$ ---(5)

by the equation

$$\int_0^{M(Ux,Uy,Uz,qt)} \emptyset(t)dt$$

$$\geq \int_0^{\propto M(Ux,Uy,Uz,t)+\beta \min\{M(Ux,Uy,t)(Uy,Uz,t)\}+\gamma \min\{M(Uz,Uy,t),M(Uy,Uz,t)} \emptyset(t)dt$$

Using (3),(4),(5) and (3.1)

$$= \int_0^{(\propto+\beta+\gamma)M(Ux,Uy,Uz,t)} \emptyset(t)dt$$

A contradiction since $\propto + \beta + \gamma > 1$ then $Ux = Uy = Uz$ therefore for $Hx = Hy = Hz$, therefore for $Ux = Uy = Uz$, and *Ux* is unique.

From [12] *H* and *U* have a unique common fixed point.

4. Conclusion

In this study, we proved some fixed point theorems for weakly compatible maps in fuzzy metric space satisfying integral type inequality but without assuming the completeness of the space or continuity of the mapping involved.

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