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Common Fixed Point Theorems for Sequence of Mappings in Intuitionistic Generalized Fuzzy Metric Spaces

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Abstract

In this paper we prove some common fixed point theorems for sequence of mappings in complete intuitionistic generalized fuzzy metric spaces.

Keywords: *Common fixed point, Intuitionistic generalized Fuzzy Metric Spaces, Sequence of maps, Sub sequential continuity.*

1 Introduction

The concept of fuzzy sets was introduced by Zadeh[11] following the concept of fuzzy sets, fuzzy metric spaces have been introduced by Kramosil and Michalek [4] and George and Veeramani [3] modified the notion of fuzzy metric spaces with the help of continuous t-norms. As a generalization of fuzzy sets, Atanassove [2] introduced and studied the concept of intuitionistic fuzzy sets. Park [6] using the idea of intuitionistic fuzzy sets defined the notion of intuitionistic fuzzy metric spaces with the help of continuous t-norms and continuous t-conorms as a generalized fuzzy metric spaces, George and Veeramani [3] showed that every metric induces an intuitionistic fuzzy metric, every fuzzy metric space in an intuitionistic fuzzy metric space.

In 2006, Sedghi and Shobe [8] defined $\mathcal{M}$-fuzzy metric spaces and proved a common fixed point theorem for four weakly compatible mappings in this spaces. In 2012, Veerapandi etc.,[11] defined common fixed point theorem for sequence of mappings in $\mathcal{M}$-fuzzy metric spaces. Our result is generalized some common fixed point theorem for the sequence of mappings in complete intuitionistic generalized fuzzy metric spaces. Our results intuitionistically fuzzify the result of Veerapandi etc., [11].

2 Preliminaries

Definition 2.1 *A binary operation* $* : [0,1] \times [0,1] \to [0,1]$ *is a continuous t-norm if it satisfies the following conditions :*

(1) $*$ *is associative and commutative,*

(2) $*$ *is continuous,*

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

(4) $a * b \leq c * d$ *Whenever* $a \leq c$ *and* $b \leq d$, *for each* $a, b, c, d \in [0,1]$.

Two typical examples of a continuous t-norm are $a * b = ab$ *and* $a * b = min\,\{a, b\}$

Definition 2.2 *A binary operation* $\diamond : [0,1] \times [0,1] \to [0,1]$ *is a continuous t-conorm if it satisfies the following conditions :*

(1) $\diamond$ *is associative and commutative,*

(2) $\diamond$ *is continuous,*

(3) $a \diamond 0 = a$ *for all* $a \in [0,1]$,

(4) $a \diamond b \leq c \diamond d$ *Whenever* $a \leq c$ *and* $b \leq d$, *for each* $a, b, c, d \in [0,1]$.

Two typical examples of a continuous t-conorm are $a \diamond b = min\,\{1, a + b\}$ *and* $a \diamond b = max\,\{a, b\}$

Definition 2.3 *A 5-tuple* $(X, \mathcal{M}, \mathcal{N}, *, \diamond)$ *is called an intuitionistic generalized fuzzy metric space if* X *is an arbitrary (non-empty) set,* $*$ *is a continuous t-norm,* $\diamond$ *a continuous t-conorm and* $\mathcal{M}, \mathcal{N}$ *are fuzzy sets on* $X^3 \times (0, \infty)$, *satisfying the following conditions:*
for each $x, y, z, a \in X$ *and* $t, s > 0$.

a) $\mathcal{M}(x, y, z, t) + \mathcal{N}(x, y, z, t) \leq 1$,

b) $\mathcal{M}(x, y, z, t) > 0$,

c) $\mathcal{M}(x, y, z, t) = 1$ if and only if $x = y = z$,

d) $\mathcal{M}(x, y, z, t) = \mathcal{M}(p\{x, y, z\}, t)$ where p is permutation function,

e) $\mathcal{M}(x, y, z, a, t) * \mathcal{M}(a, z, z, s) \leq \mathcal{M}(x, y, z, t + s)$,

f) $\mathcal{M}(x, y, z, .) : (0, \infty) \to [0, 1]$ is continuous,

g) $\mathcal{N}(x, y, z, t) > 0$,

h) $\mathcal{N}(x, y, z, t) = 0$ if and only if $x = y = z$,

i) $\mathcal{N}(x, y, z, t) = \mathcal{N}(p\{x, y, z\}, t)$ where p is permutation function,

j) $\mathcal{N}(x, y, z, a, t) \diamond \mathcal{N}(a, z, z, s) \geq \mathcal{N}(x, y, z, t + s)$,

k) $\mathcal{N}(x, y, z, .) : (0, \infty) \to [0, 1]$ is continuous.

Then $(\mathcal{M}, \mathcal{N})$ is called an intuitionistic generalized fuzzy metric on X.

Definition 2.4 *Let $(X, \mathcal{M}, \mathcal{N}, *, \diamond)$ be an intuitionistic generalized fuzzy metric space. Then $\mathcal{M}, \mathcal{N}$ is called of first type if for every $x, y \in X$ we have*
$\mathcal{M}(x, x, y, t) \geq \mathcal{M}(x, y, z, t)$ for every $z \in X$ and
$\mathcal{N}(x, x, y, t) \leq \mathcal{N}(x, y, z, t)$
Also it is called of second type if for every $x, y, z \in X$ we have
$\mathcal{M}(x, y, z, t) = \mathcal{M}(x, y, t) * \mathcal{M}(y, z, t) * \mathcal{M}(z, x, t)$ and
$\mathcal{N}(x, y, z, t) = \mathcal{N}(x, y, t) \diamond \mathcal{N}(y, z, t) \diamond \mathcal{N}(z, x, t)$

Lemma 2.5 *Let $(X, \mathcal{M}, \mathcal{N}, *, \diamond)$ be an intuitionistic generalized fuzzy metric space. Then $\mathcal{M}(x, y, z, t)$ and $\mathcal{N}(x, y, z, t)$ are non-decreasing with respect to t, for all x, y, z in X.*

Definition 2.6 *Let $(X, \mathcal{M}, \mathcal{N}, *, \diamond)$ be a intuitionistic generalized fuzzy metric spaces and $\{x_n\}$ be a sequence in X.*

(a) $\{x_n\}$ is said to be converge to a point $x \in X$ if $\lim_{n\to\infty} \mathcal{M}(x, x, x_n, t) = 1$ and $\lim_{n\to\infty} \mathcal{N}(x, x, x_n, t) = 0$ for all $t > 0$.

(b) $\{x_n\}$ is called Cauchy sequence if $\lim_{n\to\infty} \mathcal{M}(x_{n+p}, x_{n+p}, x_n, t) = 1$ and $\lim_{n\to\infty} \mathcal{N}(x_{n+p}, x_{n+p}, x_n, t) = 0$ for all $t > 0$ and $p > 0$.

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

3 Main Results

Theorem 3.1 *Let $(X, \mathcal{M}, \mathcal{N}, *, \diamond)$ be a complete intuitionistic generalized fuzzy metric space and $T_n : X \to X$ be a sequence of mappings such that for all $t > 0$ and $0 < k < 1$ satisfying the condition.*

$$3\mathcal{M}\Big(T_ix, T_jy, T_jy, t\Big) \leq \Big\{\mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, T_ix, \frac{t}{k}\Big) + \mathcal{M}\Big(y, y, T_jy, \frac{t}{k}\Big)\Big\}$$

and $$3\mathcal{N}\Big(T_ix, T_jy, T_jy, t\Big) \geq \Big\{\mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, T_ix, \frac{t}{k}\Big) + \mathcal{N}\Big(y, y, T_jy, \frac{t}{k}\Big)\Big\}$$

for all $i \neq j$ for all $x, y \in X$. Then $\{T_n\}$ have a unique common fixed point.
Proof: Let $x_0 \in X$ be any arbitrary element.
Define a sequence $\{x_n\}$ in X as $x_{n+1} = T_{n+1}x_n$ for $n = 0, 1, 2, ...$
Now we prove that $\{x_n\}$ is a Cauchy sequence in X. For $n \geq 0$, we have

$$\begin{aligned}
3\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+2}, t) &= 3\mathcal{M}(T_{n+1}x_n, T_{n+2}x_{n+1}, T_{n+2}x_{n+1}, t)\\
&\geq \left\{\begin{array}{c} \mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_n, x_n, T_{n+1}x_n, \frac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+1}, x_{n+1}, T_{n+2}x_{n+1}, \frac{t}{k}\Big) \end{array}\right\}\\
&= \left\{\begin{array}{c} \mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_n, x_n, x_{n+1}, \frac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+1}, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) \end{array}\right\}\\
&= 2\mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_{n+1}, x_{n+2}, x_{n+2}, \frac{t}{k}\Big)\\
&\geq 2\mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{M}(x_{n+1}, x_{n+2}, x_{n+2}, t)
\end{aligned}$$

Therefore $2\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+2}, t) \geq 2\mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big)$
That is $\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+2}, t) \geq \mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big)$ and

$$\begin{aligned}
3\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+2}, t) &= 3\mathcal{N}(T_{n+1}x_n, T_{n+2}x_{n+1}, T_{n+2}x_{n+1}, t)\\
&\leq \left\{\begin{array}{c} \mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_n, x_n, T_{n+1}x_n, \frac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+1}, x_{n+1}, T_{n+2}x_{n+1}, \frac{t}{k}\Big) \end{array}\right\}\\
&= \left\{\begin{array}{c} \mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_n, x_n, x_{n+1}, \frac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+1}, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) \end{array}\right\}\\
&= 2\mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_{n+1}, x_{n+2}, x_{n+2}, \frac{t}{k}\Big)\\
&\leq 2\mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) + \mathcal{N}(x_{n+1}, x_{n+2}, x_{n+2}, t)
\end{aligned}$$

Therefore $2\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+2}, t) \leq 2\mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big)$
That is $\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+2}, t) \leq \mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big)$

Contuining this way, we get

$$\begin{aligned}
\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+2}, t) &\geq \mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) \\
&\geq \mathcal{M}\Big(x_{n-1}, x_n, x_n, \frac{t}{k^2}\Big) \\
&\vdots \\
&\geq \mathcal{M}\Big(x_0, x_1, x_1, \frac{t}{k^{n+1}}\Big)
\end{aligned}$$

Now for any positive integer p and $t > 0$, we have

$$\begin{aligned}
\mathcal{M}(x_n, x_{n+p}, x_{n+p}, t) &\geq \mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{p}\Big) * \underline{p\ times} * \mathcal{M}\Big(x_{n+p-1}, x_{n+p}, x_{n+p}, \frac{t}{p}\Big) \\
&\geq \mathcal{M}\Big(x_0, x_1, x_1, \frac{t}{pk^n}\Big) * \underline{p\ times} * \mathcal{M}\Big(x_0, x_1, x_1, \frac{t}{pk^{n+p-1}}\Big)
\end{aligned}$$

Therefore
$\lim_{n\to\infty} \mathcal{M}(x_n, x_{n+p}, x_{n+p}, t) \geq 1 * \underline{p\ times} * 1 = 1$
Continuing this way, we get

$$\begin{aligned}
\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+2}, t) &\leq \mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{k}\Big) \\
&\leq \mathcal{N}\Big(x_{n-1}, x_n, x_n, \frac{t}{k^2}\Big) \\
&\vdots \\
&\leq \mathcal{N}\Big(x_0, x_1, x_1, \frac{t}{k^{n+1}}\Big)
\end{aligned}$$

Now for any positive integer p and $t > 0$, we have

$$\begin{aligned}
\mathcal{N}(x_n, x_{n+p}, x_{n+p}) &\leq \mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{p}\Big) \diamond \underline{p\ times} \diamond \mathcal{N}\Big(x_{n+p-1}, x_{n+p}, x_{n+p}, \frac{t}{p}\Big) \\
&\leq \mathcal{N}\Big(x_0, x_1, x_1, \frac{t}{pk^n}\Big) \diamond \underline{p\ times} \diamond \mathcal{N}\Big(x_0, x_1, x_1, \frac{t}{pk^{n+p-1}}\Big)
\end{aligned}$$

Therefore
$\lim_{n\to\infty} \mathcal{N}(x_n, x_{n+p}, x_{n+p}, t) \leq 0 \diamond \underline{p\ times} \diamond 0 = 0$
Which implies that $\{x_n\}$ is a Cauchy sequence in intuitionistic generalized fuzzy metric space X. Since X is intuitionistic generalized fuzzy complete,

sequence $\{x_n\}$ converges to a point $x \in X$. Now we prove that x is a fixed point of $\{T_n\}$ for all n. Now we have

$$\begin{aligned}
3\mathcal{M}(T_m x, x, x, t) &= \lim_{n\to\infty} 3\mathcal{M}(T_m x, x_{n+2}, x_{n+2}, t)\\
&= \lim_{n\to\infty} 3\mathcal{M}(T_m x, T_{n+2}x_{n+1}, T_{n+2}x_{n+1}, t)\\
&\geq \lim_{n\to\infty} \left\{ \begin{array}{c} \mathcal{M}\Big(x, x_{n+1}, x_{n+1}, \tfrac{t}{k}\Big) + \mathcal{M}\Big(x, x, T_m x, \tfrac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+1}, x_{n+1}, T_{n+2}x_{n+1}, \tfrac{t}{k}\Big) \end{array} \right\}\\
&= \lim_{n\to\infty} \left\{ \begin{array}{c} \mathcal{M}\Big(x, x_{n+1}, x_{n+1}, \tfrac{t}{k}\Big) + \mathcal{M}\Big(x, x, T_m x, \tfrac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+1}, x_{n+1}, x_{n+2}, \tfrac{t}{k}\Big) \end{array} \right\}\\
&= \left\{\mathcal{M}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, T_m x, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, x, \frac{t}{k}\Big)\right\}\\
&= \left\{1 + \mathcal{M}\Big(x, x, T_m x, \frac{t}{k}\Big) + 1\right\}\\
&= 2 + \mathcal{M}\Big(x, x, T_m x, \frac{t}{k}\Big)\\
&\geq 2 + \mathcal{M}(x, x, T_m x, t)
\end{aligned}$$

Therefore, $2\mathcal{M}(T_m x, x, x, t) \geq 2$, That is, $\mathcal{M}(T_m x, x, x, t) \geq 1$
Hence $\mathcal{M}(T_m x, x, x, t) = 1$ for all $t > 0$. Therefore $T_m x = x$.
Hence $T_n x = x$ for all n and

$$\begin{aligned}
3\mathcal{N}(T_m x, x, x, t) &= \lim_{n\to\infty} 3\mathcal{N}(T_m x, x_{n+2}, x_{n+2}, t)\\
&= \lim_{n\to\infty} 3\mathcal{N}(T_m x, T_{n+2}x_{n+1}, T_{n+2}x_{n+1}, t)\\
&\leq \left\{ \begin{array}{c} \mathcal{N}\Big(x, x_{n+1}, x_{n+1}, \tfrac{t}{k}\Big) + \mathcal{N}\Big(x, x, T_m x, \tfrac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+1}, x_{n+1}, T_{n+2}x_{n+1}, \tfrac{t}{k}\Big) \end{array} \right\}\\
&= \lim_{n\to\infty} \left\{ \begin{array}{c} \mathcal{N}\Big(x, x_{n+1}, x_{n+1}, \tfrac{t}{k}\Big) + \mathcal{N}\Big(x, x, T_m x, \tfrac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+1}, x_{n+1}, x_{n+2}, \tfrac{t}{k}\Big) \end{array} \right\}\\
&= \left\{\mathcal{N}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, T_m x, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, x, \frac{t}{k}\Big)\right\}\\
&= \left\{0 + \mathcal{N}\Big(x, x, T_m x, \frac{t}{k}\Big) + 0\right\}\\
&= 0 + \mathcal{N}\Big(x, x, T_m x, \frac{t}{k}\Big)\\
&\leq \mathcal{N}(x, x, T_m x, t)
\end{aligned}$$

Therefore, $2\mathcal{N}(T_m x, x, x, t) \leq 0$. That is, $\mathcal{N}(T_m x, x, x, t) \leq 0$
Hence $\mathcal{N}(T_m x, x, x, t) = 0$ for all $t > 0$. Therefore $T_m x = x$.

Hence $T_n x = x$ for all n. Therefore x is a common fixed point of $\{T_n\}$.

Uniqueness: Suppose $x \neq y$ such that $T_n y = y$ for all n. Then

$$\begin{aligned}
3\mathcal{M}(x, y, y, t) &= 3\mathcal{M}(T_i x, T_j y, T_j y, t) \\
&\geq \left\{\mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, T_i x, \frac{t}{k}\Big) + \mathcal{M}\Big(y, y, T_j y, \frac{t}{k}\Big)\right\} \\
&= \left\{\mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{M}\Big(y, y, y, \frac{t}{k}\Big)\right\} \\
&= \mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + 2 \\
&\geq \mathcal{M}(x, y, y, t) + 2
\end{aligned}$$

Therefore $2\mathcal{M}(x, y, y, t) \geq 2$. That is $\mathcal{M}(x, y, y, t) \geq 1$
Hence $\mathcal{M}(x, y, y, t) = 1$ for all $t > 0$ and

$$\begin{aligned}
3\mathcal{N}(x, y, y, t) &= 3\mathcal{N}(T_i x, T_j y, T_j y, t) \\
&\leq \left\{\mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, T_i x, \frac{t}{k}\Big) + \mathcal{N}\Big(y, y, T_j y, \frac{t}{k}\Big)\right\} \\
&= \left\{\mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{N}\Big(y, y, y, \frac{t}{k}\Big)\right\} \\
&= \mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + 0 \\
&\leq \mathcal{N}(x, y, y, t) + 0
\end{aligned}$$

Therefore $2\mathcal{N}(x, y, y, t) \leq 0$. That is $\mathcal{N}(x, y, y, t) \leq 0$
Hence $\mathcal{N}(x, y, y, t) = 0$ for all $t > 0$.
Therefore, $x = y$. Which is a contradiction to $x \neq y$.
Hence $\{T_n\}$ have a unique common fixed point.

Corollary 3.2 *Let $(X, \mathcal{M}, \mathcal{N}, *, \diamond)$ be a complete intuitionistic generalized fuzzy metric space and $T_n : X \to X$ be a sequence of maps such that for all $t > 0$ and $0 < k < 1$ satisfying the condition.*

$$\mathcal{M}\Big(T_i x, T_j y, T_j y, t\Big) \geq min\left\{\mathcal{M}\Big(x, y, y, \frac{t}{k}\Big), \mathcal{M}\Big(x, x, T_i x, \frac{t}{k}\Big), \mathcal{M}\Big(y, y, T_j y, \frac{t}{k}\Big)\right\}$$

$$and \;\; \mathcal{N}\Big(T_i x, T_j y, T_j y, t\Big) \leq max\left\{\mathcal{N}\Big(x, y, y, \frac{t}{k}\Big), \mathcal{N}\Big(x, x, T_i x, \frac{t}{k}\Big), \mathcal{N}\Big(y, y, T_j y, \frac{t}{k}\Big)\right\}$$

for all $i \neq j$ and for all $x, y \in X$. Then $\{T_n\}$ have unique common fixed point.

Corollary 3.3 *Let $(X,\mathcal{M},\mathcal{N},*,\diamond)$ be a complete intuitionistic generalized fuzzy metric space with continuous t-norm $*$ is defined by $a*b=min\{a,b\}$ and continuous t-conorms $\diamond$ is defined by $a\diamond b=max\{a,b\}$ and $T_n:X\rightarrow X$ be a sequence of maps such that for all $t>0$ and $0<k<1$ satisfying the condition.*

$$\mathcal{M}\Big(T_ix,T_jy,T_jy,t\Big)\geq\Big\{\mathcal{M}\Big(x,y,y,\frac{t}{k}\Big)*\mathcal{M}\Big(x,x,T_ix,\frac{t}{k}\Big)*\mathcal{M}\Big(y,y,T_jy,\frac{t}{k}\Big)\Big\}$$

$$and\ \ \mathcal{N}\Big(T_ix,T_jy,T_jy,t\Big)\leq\Big\{\mathcal{N}\Big(x,y,y,\frac{t}{k}\Big)\diamond\mathcal{N}\Big(x,x,T_ix,\frac{t}{k}\Big)\diamond\mathcal{N}\Big(y,y,T_jy,\frac{t}{k}\Big)\Big\}$$

for all $i\neq j$ and for all $x,y\in X$. Then $\{T_n\}$ have unique common fixed point.

Corollary 3.4 *Let $(X,\mathcal{M},\mathcal{N},*,\diamond)$ be a complete intuitionistic generalized fuzzy metric space with continuous t-norm $*$ is defined by $a*b=min\{a,b\}$ and continuous t-conorms $\diamond$ is defined by $a\diamond b=max\{a,b\}$ and $T_n:X\rightarrow X$ be a sequence of maps such that for all $t>0$ and $0<k<1$ satisfying the condition.*

$$\mathcal{M}\Big(T_ix,T_jy,T_jy,t\Big)\geq min\left\{\begin{array}{c}\mathcal{M}\Big(x,y,y,\frac{t}{k}\Big),\mathcal{M}\Big(x,x,T_ix,\frac{t}{k}\Big),\\ \mathcal{M}\Big(y,y,T_jy,\frac{t}{k}\Big),\mathcal{M}\Big(x,x,T_jy,\frac{2t}{k}\Big)\end{array}\right\}and$$

$$\mathcal{N}\Big(T_ix,T_jy,T_jy,t\Big)\leq max\left\{\begin{array}{c}\mathcal{N}\Big(x,y,y,\frac{t}{k}\Big),\mathcal{N}\Big(x,x,T_ix,\frac{t}{k}\Big),\\ \mathcal{N}\Big(y,y,T_jy,\frac{t}{k}\Big),\mathcal{N}\Big(x,x,T_jy,\frac{2t}{k}\Big)\end{array}\right\}$$

for all $i\neq j$ and for all $x,y\in X$. Then $\{T_n\}$ have unique common fixed point.

Theorem 3.5 *Let $(X,\mathcal{M},\mathcal{N},*,\diamond)$ be a complete first type intuitionistic generalized fuzzy metric space and $T_n:X\rightarrow X$ be a sequence of maps such that for all $t>0$ and $0<k<1$ satisfying the condition.*

$$3\mathcal{M}(T_ix,T_jy,T_kz,t)\geq\left\{\begin{array}{c}\mathcal{M}\Big(x,y,z,\frac{t}{k}\Big)+\mathcal{M}\Big(x,T_ix,T_jy,\frac{t}{k}\Big)\\ +\frac{1}{2}\Big[\mathcal{M}\Big(y,T_jy,T_kz,\frac{t}{k}\Big)+\mathcal{M}\Big(z,T_kz,T_ix,\frac{t}{k}\Big)\Big]\end{array}\right\}and$$

$$3\mathcal{N}(T_ix,T_jy,T_kz,t)\leq\left\{\begin{array}{c}\mathcal{N}\Big(x,y,z,\frac{t}{k}\Big)+\mathcal{N}\Big(x,T_ix,T_jy,\frac{t}{k}\Big)\\ +\frac{1}{2}\Big[\mathcal{N}\Big(y,T_jy,T_kz,\frac{t}{k}\Big)+\mathcal{N}\Big(z,T_kz,T_ix,\frac{t}{k}\Big)\Big]\end{array}\right\}$$

for all $i\neq j\neq k$ and for all $x,y,z\in X$. Then $\{T_n\}$ have unique common fixed point.

Proof: Let $x_0 \in X$ be any arbitrary element.
Define a sequence $\{x_n\}$ in X as $x_{n+1} = T_{n+1}x_n$ for $n = 0, 1, 2...$
now we prove that $\{x_n\}$ is a Cauchy sequence in X.
For $n \geq 0$, we have

$$\begin{aligned}
3\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+3}, t) &= 3\mathcal{M}(T_{n+1}x_n, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, t) \\
&\geq \left\{ \begin{array}{c} \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_n, T_{n+1}x_n, T_{n+2}x_{n+1}, \frac{t}{k}\Big) + \\ \frac{1}{2}\left[\begin{array}{c} \mathcal{M}\Big(x_{n+1}, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, \frac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+2}, T_{n+3}x_{n+2}, T_{n+1}x_n, \frac{t}{k}\Big) \end{array} \right] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\mathcal{M}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_{n+2}, x_{n+3}, x_{n+1}, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) \end{array} \right\} \\
&= 2\mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) \\
&\geq 2\mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}(x_{n+1}, x_{n+2}, x_{n+3}, t)
\end{aligned}$$

Therefore
$2\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+3}, t) \geq 2\mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big)$
That is $\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+3}, t) \geq \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big)$ and

$$\begin{aligned}
3\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+3}, t) &= 3\mathcal{N}(T_{n+1}x_n, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, t) \\
&\leq \left\{ \begin{array}{c} \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_n, T_{n+1}x_n, T_{n+2}x_{n+1}, \frac{t}{k}\Big) + \\ \frac{1}{2}\left[\begin{array}{c} \mathcal{N}\Big(x_{n+1}, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, \frac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+2}, T_{n+3}x_{n+2}, T_{n+1}x_n, \frac{t}{k}\Big) \end{array} \right] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\mathcal{N}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_{n+2}, x_{n+3}, x_{n+1}, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) \end{array} \right\} \\
&= 2\mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) \\
&\leq 2\mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}(x_{n+1}, x_{n+2}, x_{n+3}, t)
\end{aligned}$$

Therefore
$2\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+3}, t) \leq 2\mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big)$
That is $\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+3}, t) \leq \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big)$
continuing this way, we get

$$\begin{aligned}\mathcal{M}(x_{n+1}, x_{n+2}, x_{n+3}, t) &\geq \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big)\\ &\geq \mathcal{M}\Big(x_{n-1}, x_n, x_{n+1}, \frac{t}{k^2}\Big)\\ &\vdots\\ &\geq \mathcal{M}\Big(x_0, x_1, x_2, \frac{t}{k^{n+1}}\Big)\\ &\to 1 \ as\ n \to \infty \ \ and\end{aligned}$$

Continuing this way, we get

$$\begin{aligned}\mathcal{N}(x_{n+1}, x_{n+2}, x_{n+3}, t) &\leq \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big)\\ &\leq \mathcal{N}\Big(x_{n-1}, x_n, x_{n+1}, \frac{t}{k^2}\Big)\\ &\vdots\\ &\leq \mathcal{N}\Big(x_0, x_1, x_2, \frac{t}{k^{n+1}}\Big)\\ &\to 0 \ as\ n \to \infty \ \ and\end{aligned}$$

Since $\mathcal{M}$ is first type, we have
$\mathcal{M}(x_{n+1}, x_{n+1}, x_{n+2}, t) \geq \mathcal{M}(x_{n+1}, x_{n+2}, x_{n+3}, t)$
Therefore, $\mathcal{M}(x_{n+1}, x_{n+1}, x_{n+2}, t) \to 1 \ as\ n \to \infty$
Since $\mathcal{N}$ is first type, we have
$\mathcal{N}(x_{n+1}, x_{n+1}, x_{n+2}, t) \leq \mathcal{N}(x_{n+1}, x_{n+2}, x_{n+3}, t)$
Therefore, $\mathcal{N}(x_{n+1}, x_{n+1}, x_{n+2}, t) \to 0 \ as\ n \to \infty$
Now for any positive integer p and $t > 0$, we have
$\mathcal{M}(x_n, x_{n+p}, x_{n+p}, t) \geq \mathcal{M}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{p}\Big) * \underline{p\ times} * \mathcal{M}\Big(x_{n+p-1}, x_{n+p}, x_{n+p}, \frac{t}{p}\Big)$
Taking limit as $n \to \infty$ we get
$\lim\limits_{n\to\infty} \mathcal{M}(x_n, x_{n+p}, x_{n+p}, t) \geq 1 * \underline{p\ times} * 1 = 1$
Therefore $\lim\limits_{n\to\infty} \mathcal{M}(x_n, x_{n+p}, x_{n+p}, t) = 1$ and
Now for any positive integer p and $t > 0$, we have
$\mathcal{N}(x_n, x_{n+p}, x_{n+p}, t) \leq \mathcal{N}\Big(x_n, x_{n+1}, x_{n+1}, \frac{t}{p}\Big) \diamond \underline{p\ times} \diamond \mathcal{N}\Big(x_{n+p-1}, x_{n+p}, x_{n+p}, \frac{t}{p}\Big)$
Taking limit as $n \to \infty$ we get
$\lim\limits_{n\to\infty} \mathcal{N}(x_n, x_{n+p}, x_{n+p}, t) \leq 0 \diamond \underline{p\ times} \diamond 0 = 0$
Therefore $\lim\limits_{n\to\infty} \mathcal{N}(x_n, x_{n+p}, x_{n+p}, t) = 0$

which implies that $\{x_n\}$ is a Cauchy sequence in intuitionistic generalized fuzzy metric space X.
Since X is a intuitionistic generalized fuzzy complete, sequence $\{x_n\}$ converges to a point $x \in X$. Now we prove that x is a fixed point of $\{T_n\}$ for all n.
Now we have

$$
\begin{aligned}
3\mathcal{M}\Big(T_m x, x, x, t\Big) &= \lim_{n\to\infty} 3\mathcal{M}\Big(T_m x, x_{n+2}, x_{n+3}, t\Big) \\
&= \lim_{n\to\infty} 3\mathcal{M}\Big(T_m x, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, t\Big) \\
&\geq \lim_{n\to\infty} \left\{ \begin{array}{c} \mathcal{M}\Big(x, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}\Big(x, T_m x, T_{n+2}x_{n+1}, \frac{t}{k}\Big) + \\ \frac{1}{2}\left[\begin{array}{c} \mathcal{M}\Big(x_{n+1}, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, \frac{t}{k}\Big) + \\ \mathcal{M}\Big(x_{n+2}, T_{n+3}x_{n+2}, T_m x, \frac{t}{k}\Big) \end{array} \right] \end{array} \right\} \\
&= \lim_{n\to\infty} \left\{ \begin{array}{c} \mathcal{M}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{M}\Big(x, T_m x, x_{n+2}, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\mathcal{M}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) + \mathcal{M}\Big(x_{n+2}, x_{n+3}, T_m x, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{M}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{M}\Big(x, T_m x, x, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\mathcal{M}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, T_m x, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \left\{1 + \mathcal{M}\Big(T_m x, x, x, \frac{t}{k}\Big) + \frac{1}{2}\Big[1 + \mathcal{M}\Big(T_m x, x, x, \frac{t}{k}\Big)\Big]\right\} \\
&= \frac{1}{2}\Big[3\mathcal{M}\Big(T_m x, x, x, \frac{t}{k}\Big) + 3\Big] \\
6\mathcal{M}\Big(T_m x, x, x, t\Big) &\geq 3\mathcal{M}\Big(T_m x, x, x, \frac{t}{k}\Big) + 3 \\
&\geq 3\mathcal{M}(T_m x, x, x, t) + 3
\end{aligned}
$$

Therefore, $3\mathcal{M}(T_m x, x, x, t) \geq 3$. That is $\mathcal{M}(T_m x, x, x, t) \geq 1$.
Hence $\mathcal{M}(T_m x, x, x, t) = 1$ for all $t > 0$. That is $T_m x = x$.

Hence $T_n x = x$ for all n.

$$\begin{aligned}
3\mathcal{N}\Big(T_m x, x, x, t\Big) &= \lim_{n\to\infty} 3\mathcal{N}\Big(T_m x, x_{n+2}, x_{n+3}, t\Big)\\
&= \lim_{n\to\infty} 3\mathcal{N}\Big(T_m x, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, t\Big)\\
&\le \lim_{n\to\infty}\left\{\begin{array}{c} \mathcal{N}\Big(x, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}\Big(x, T_m x, T_{n+2}x_{n+1}, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\begin{array}{c} \mathcal{N}\Big(x_{n+1}, T_{n+2}x_{n+1}, T_{n+3}x_{n+2}, \frac{t}{k}\Big) + \\ \mathcal{N}\Big(x_{n+2}, T_{n+3}x_{n+2}, T_m x, \frac{t}{k}\Big) \end{array}\Big] \end{array}\right\}\\
&= \lim_{n\to\infty}\left\{\begin{array}{c} \mathcal{N}\Big(x_n, x_{n+1}, x_{n+2}, \frac{t}{k}\Big) + \mathcal{N}\Big(x, T_m x, x_{n+2}, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\mathcal{N}\Big(x_{n+1}, x_{n+2}, x_{n+3}, \frac{t}{k}\Big) + \mathcal{N}\Big(x_{n+2}, x_{n+3}, T_m x, \frac{t}{k}\Big)\Big] \end{array}\right\}\\
&= \left\{\begin{array}{c} \mathcal{N}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{N}\Big(x, T_m x, x, \frac{t}{k}\Big) + \\ \frac{1}{2}\Big[\mathcal{N}\Big(x, x, x, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, T_m x, \frac{t}{k}\Big)\Big] \end{array}\right\}\\
&= \left\{0 + \mathcal{N}\Big(T_m x, x, x, \frac{t}{k}\Big) + \frac{1}{2}\Big[0 + \mathcal{N}\Big(T_m x, x, x, \frac{t}{k}\Big)\Big]\right\}\\
&= \frac{1}{2}\Big[3\mathcal{N}\Big(T_m x, x, x, \frac{t}{k}\Big) + 0\Big]\\
6\mathcal{N}\Big(T_m x, x, x, t\Big) &\le 3\mathcal{N}\Big(T_m x, x, x, \frac{t}{k}\Big) + 0\\
&\le 3\mathcal{N}(T_m x, x, x, t) + 0
\end{aligned}$$

Therefore, $3\mathcal{N}(T_m x, x, x, t) \le 0$. That is $\mathcal{N}\Big(T_m x, x, x, t) \le 0$.
Hence $\mathcal{N}(T_m x, x, x, t) = 0$ for all $t > 0$. That is $T_m x = x$.
Hence $T_n x = x$ for all n.
Therefore x is a common fixed point of $\{T_n\}$.
Uniqueness: Suppose $x \ne y$ such that $T_n y = y$ for all n. Then

$$\begin{aligned}
3\mathcal{M}(x, y, y, t) &= 3\mathcal{M}(T_i x, T_j y, T_k y, t)\\
&\ge \left\{\begin{array}{c} \mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(x, T_i x, T_j y, \frac{t}{k}\Big) \\ +\frac{1}{2}\Big[\mathcal{M}\Big(y, T_j y, T_k z, \frac{t}{k}\Big) + \mathcal{M}\Big(y, T_k z, T_i x, \frac{t}{k}\Big)\Big] \end{array}\right\}\\
&= \left\{\begin{array}{c} \mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(x, x, y, \frac{t}{k}\Big) \\ +\frac{1}{2}\Big[\mathcal{M}\Big(y, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(y, y, x, \frac{t}{k}\Big)\Big] \end{array}\right\}\\
&= \left\{\begin{array}{c} \mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) \\ +\frac{1}{2}\Big[1 + \mathcal{M}\Big(x, y, y, \frac{t}{k}\Big)\Big] \end{array}\right\}
\end{aligned}$$

$$
\begin{aligned}
&= \frac{1}{2}\Big[5\mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + 1\Big] \\
6\mathcal{M}(x, y, y, t) &\geq 5\mathcal{M}\Big(x, y, y, \frac{t}{k}\Big) + 1 \\
&\geq 5\mathcal{M}(x, y, y, t) + 1
\end{aligned}
$$

Therefore $\mathcal{M}(x, y, y, t) \geq 1$. Hence $\mathcal{M}(x, y, y, t) = 1$ for all $t > 0$ and

$$
\begin{aligned}
3\mathcal{N}(x, y, y, t) &= 3\mathcal{N}(T_i x, T_j y, T_k y, t) \\
&\leq \left\{ \begin{array}{c} \mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(x, T_i x, T_j y, \frac{t}{k}\Big) \\ +\frac{1}{2}\Big[\mathcal{N}\Big(y, T_j y, T_k z, \frac{t}{k}\Big) + \mathcal{N}\Big(y, T_k z, T_i x, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(x, x, y, \frac{t}{k}\Big) \\ +\frac{1}{2}\Big[\mathcal{N}\Big(y, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(y, y, x, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \left\{ \begin{array}{c} \mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + \mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) \\ +\frac{1}{2}\Big[0 + \mathcal{N}\Big(x, y, y, \frac{t}{k}\Big)\Big] \end{array} \right\} \\
&= \frac{1}{2}\Big[5\mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + 0\Big] \\
6\mathcal{N}(x, y, y, t) &\leq 5\mathcal{N}\Big(x, y, y, \frac{t}{k}\Big) + 0 \\
&\leq 5\mathcal{N}(x, y, y, t) + 0
\end{aligned}
$$

Therefore $\mathcal{N}(x, y, y, t) \leq 0$
Hence $\mathcal{N}(x, y, y, t) = 0$ for all $t > 0$.
Therefore $x = y$. Which is a contradiction to $x \neq y$.
Hence $\{T_n\}$ have a unique common fixed point.

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