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Scientific Studies and Research
Series Mathematics and Informatics
Vol. 30 (2020), No. 1, 151 - 162

COMMON FIXED POINTS FOR ABSORBING MAPPINGS SATISFYING A COINCIDENCE RANGE PROPERTY IN DISLOCATED METRIC SPACES

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Abstract. In this paper a general fixed point theorem for two pairs of pointwise absorbing mappings in dislocated metric space is proved. As applications we obtain new results for mappings satisfying contractive conditions of integral type and for φ-contractive mappings.

1. Introduction

In 1994 Mathews [17] introduced the notion of partial metric space as a part of the study of denotational semantics of dataflows and proved the Banach principle in this paper.

The partial metric space play an important role in constructing models in the theory of computation. There exist a vaste literature in the study of fixed points in partial metric spaces.

In 2000, Hitzler and Seda [11] introduced the notion of dislocated metric space as a generalization of metric spaces. Also, they generalized the Banach contraction principle in this spaces. In 2012, Amini-Haradi [3] reintroduced the notion of dislocated space under the name of metric like space.

Recently, some results for the existence of fixed points in dislocated metric spaces (metric like spaces) are obtained in [10], [13], [14].

Keywords and phrases: fixed point, dislocated metric space, absorbing mappings, implicit relation, coincidence range property.
(2020) Mathematics Subject Classification: 54H25, 46H10.

Quite recently, Bennani et al. [4],[5], established new common fixed points theorems for two pairs of weakly compatible meppings in dislocated metric spaces which improved the results by [3] without continuity requirement.

The notion of absorbing mappings are introduced in [7], [8], [9] and other papers.

Some classical fixed point theorems and common fixed point theorems have been unified considering a general condition by an implicit relation [21],[22].

Some results for pairwise absorbing mappings satisfying implicit relations are obtained in [19].

Aamri and El-Moutawakil, [1], introduced the notion of (E.A)-property for a pair of mappings. Liu et al. [16] extend this notion for two pairs of mappings.

In 2011, Sintunavarat and Kumam [29] introduced the notion of common range property as a generalization of (E.A)-property for a pair of mappings. In [23] a new type of common limit range property is introduced. In [12, [16], [29], [23] and other papers there exist some convergents sequences in X.

Quite recently in [26], [27] the presents authors introduced a new common range property without notions of convergent sequences named common coincidence range property.

The purpose of this paper is to prove a common fixed point theorem for two pairs of absorbing mappings satisfying a common coincidence range property in dislocated metric space. As applications we obtain some results for mappings satisfying contractive conditions of integral type and for φ-contractive mappings in dislocated metric spaces.

2. Preliminaries

Definition 2.1.([17]) Let X be a nonempty set and $p : X \times X \to \mathbb{R}_+$. p is a partial metric on X if for any $x, y, z \in X$, the following conditions hold:

(P_1) $x = y$ if and only if $p(x,x) = p(x,y) = p(y,y)$;

(P_2) $p(x,x) \le p(x,y)$;

(P_3) $p(x,y) = p(y,x)$;

(P_4) $p(x,z) \le p(x,y) + p(y,z) - p(y,y)$.

The pair (X,p) is called a partial metric space. If $p(x,y) = 0$, then $x = y$ follows by (P_1) and (P_2), but the converse is not true.

Definition 2.2. Let X be a nonempty set and $d : X \times X \to \mathbb{R}_+$. d is said to be a dislocated metric on X [11] or a metric like on X [3] if for any $x, y \in X$ the following properties hold:
1) (D_1) $d(x, y) = 0$ implies $x = y$.
2) (D_2) $d(x, y) = d(y, x)$,
3) (D_3) $d(x, z) \leq d(x, y) + d(y, z)$.

The pair (X, d) is called a dislocated metric space [11] or a metric like space [4].

Remark 2.1. Every partial metric space is dislocated metric space but the converse is not true (Ex.2.2 [3]).

Let X be a nonempty set and $A, S : X \to X$ two mappings of X. A point $x \in X$ is a coincidence point of A and S if $w = Ax = Sx$. The set of all coincidence points of A and S is denoted by $C(A, S)$ and w is said to be a point of coincidence of A and S.

We introduce a new type of common coincidence range property in dislocated metric spaces.

Definition 2.3. Let (X, d) be a dislocated metric space and A, S, T be self mappings of (X, d). The pair (A, S) is said to have coincidence range property with respect to T, denote $CRP_{(A,S)T}$ if there exists $z = Bx = Sx$ for some $x \in X$ with $z \in T(X)$ and $d(z, z) = 0$.

Example 2.1. Let $X = [0, 1]$ and $Ax = 0$, $Sx = \frac{x}{x+1}$, $Tx = x$ with $d(x, y) = max\{x, y\}$. Then (X, d) is dislocated metric space. If $Ax = Sx$ then $x = 0$ and $z = A0 = S0 = T0 = 0 \in [0, 1]$.

Definition 2.4. ([8],[9]) Let (X, d) be a metric space and f, g be self mappings of X.
1) f is called g absorbing if there exists $R > 0$ such that $d(gx, gfx) \leq Rd(fx, gx)$. Similarly g is f absorbing.
2) f is called pointwise g-absorbing if for given $x \in X$, there exists $R > 0$ such that $d(gx, gfx) \leq Rd(fx, gx)$.

Remark 2.2. A similar definition we have for dislocated metric spaces. **Definition 2.5. ([15])** An altering distance is a mapping $\varphi : [0, \infty) \to [0, \infty)$ which satisfies:

(ψ_1) : ψ is increasing and continuous,

(ψ_2) : $\psi(t) = 0$ if and only if $t = 0$.

Fixed points theorems involving altering distances have been obtained [25] and [28].

Definition 2.6. A weak altering distance is a mapping $\psi : [0, \infty) \to [0, \infty)$ which satisfies:

ψ_1: $\psi(t)$ is increasing.
ψ_2: $\psi(t) = 0$ if and only if $t = 0$.

Remark 2.3. Every altering distance is weak altering distance but converse is not true:

$$f(x) = \begin{cases} t & \text{if} \quad t \in [0, 1) \\ e^t & \text{if} \quad t \in [1, \infty) \end{cases}$$

3. Implicit relations

In 2008, Ali and Imdad introduced a new class of implicit relations:

Definition 3.1. **([2])** Let $\mathcal{F}$ be the lower semi-continuous functions $F : {\mathbb{R}_+}^6 \to \mathbb{R}$ satisfying:

(F_1) $F(t, 0, 0, t, t, 0) > 0 \forall t > 0$
(F_2) $F(t, 0, t, 0, 0, t) > 0 \forall t > 0$
(F_3) $F(t, t, 0, 0, t, t) > 0 \forall t > 0$

Example 3.1. $F(t_1, ..., t_6) = t_1 - k \max\{t_2, t_3, ..., t_6\}$, where $k \in [0, 1)$,

Example 3.2. $F(t_1, ..., t_6) = t_1 - k \max\{t_2, t_3 t_4, \frac{t_5+t_6}{2}\}$, where $k \in [0, 1)$,

Example 3.3. $F(t_1, ..., t_6) = t_1 - k \max\{t_2 \frac{t_3+t_4}{2}, \frac{t_5+t_6}{2}\}$, where $k \in [0, 1)$,

Example 3.4. $F(t_1, ..., t_6) = t_1 - at_2 - b \max\{t_3, t_4\} - c \max\{t_5, t_6\}$ where $a, b, c \geq 0$ and $a + b + c < 1$

Example 3.5. $F(t_1, ..., t_6) = t_1 - \alpha \max\{t_2, t_3, t_4\} - (1-\alpha)(at_5 + bt_6)$ where $\alpha \in (0, 1)$ $a, b \geq 0$ and $a + b < 1$

Example 3.6. $F(t_1, ..., t_6) = t_1 - at_2 - b(t_3 + t_4) - c \max\{t_5, t_6)\}$ where $a, b, c \geq 0$ and $a + b + c < 1$

Example 3.7. $F(t_1, ..., t_6) = t_1 - at_2 - b \frac{t_5+t_6}{1+t_3+t_4}$ where $a, b \geq 0$ and $a + b < 1$.

Example 3.8. $F(t_1, ..., t_6) = t_1 - \max\{ct_2, ct_3, ct_4, at_5 + bt_6\}$ where $c \in (0, 1)$ $a, b \geq 0$ and $a + b + c < 1$.

For other examples, see [2].

4. Main results

Theorem 4.1. Let (X, d) be a dislocated metric space and A, B, S and T be self mappings of X such that for all $x, y \in X$

(4.1) $F(\psi(d(Ax, By)), \psi(d(Sx, Ty)), \psi(d(Sx, Ax)), \psi(d(Ty, By)), \psi(d(Sx, By)), \psi(d(Ax, Ty)) \leq 0$

for some $F \in \mathcal{F}$ and ψ is a weak altering distance.

If $(A, S), T$ satisfy $CRP_{(A,S)T}$-property then $C(B, T) \neq \phi$.

Moreover, if A is pointwise S-absorbing and B is pointwise T-absorbing then A, B, S, T have a unique common fixed point z with $d(z, z) = 0$.

Proof. Since (A, S) and T satisfy $CRP_{(A,S)T}$-property there exists $z = Av = Sv$ for some $v \in X$ such that $z \in T(X)$ and $d(z, z) = 0$ Since $z \in T(X)$, there exists $u \in X$ such that $z = T(u)$. Then by (4.1) for $x = v$ and $y = u$ we obtain

$$F(\psi(d(Av, Bu)),\ \psi(d(Sv, Tu)),\ \psi(d(Sv, Av)),\ \psi(d(Tu, Bu)),\ \psi(d(Sv, Bu)),\ \psi(d(Av, Tu))\ ) \leq 0,$$

$$F(\psi(d(z, Bu)), 0, 0, \psi(d(z, Bu)), \psi(d(z, Bu)), 0) \leq 0$$

a contradiction of (F_1) if $\psi(d(z, Bu)) > 0$. Hence $\psi(d(z, Bu)) = 0$ which implies $\psi(d(z, Bu)) = 0$. Hence $z = Bu = Tu = Av = Sv$ and $C(B, T) \neq \phi$.

Moreover, if A is pointwise S-absorbing, there exists $R_1 > 0$ such that $d(Sv, S(Av)) \leq R_1 d(Sv, Av) = R_1 d(z, z) = 0$.

Hence $d(Sv, SAv) = 0$ and by $(D_1) Sv = SAv$. Therefore $z = Sv = SAv = Sz$ and z is a fixed point of S with $d(z, z) = 0$.

Again, by (4.1) for $x = z$ and $y = u$ we obtain:

$$F(\psi(d(Az, Bu)), \psi(d(Sz, Tu)), \psi(d(Sz, Az)),$$
$$\psi(d(Tu, Bu)), \psi(d(Sz, Bu)), \psi(d(Az, Tu)) \leq 0,$$
$$F(\psi(d(Az, z), 0, \psi(d(Az, z)), 0, 0, \psi(d(Az, z)) \leq 0.$$

A contradiction of (F_2) if $\psi(d(Az, z)) > 0$. Hence $\psi(d(Az, z)) = 0$ which implies $z = Az$ and z is a fixed point of A. Hence z is a common fixed point of A and S with $d(z, z) = 0$.

Let B pointwise T the absorbing , then there exists $R_2 > 0$ such that $d(Tu, TBu) \leq R_2\ d(Tu, Bu) = R\ d(z, z) = 0$. Hence $z = Tu = TBu = Tz$ and z is a fixed point of T with $d(z, z) = 0$.

By (4.1) for $x = v$ and $y = z$ we obtain:

$$F(\psi(d(Av, Bz)), \psi(d(Sv, Tz)), \psi(d(Sv, Tv)),$$
$$\psi(d(Tz, Bz)), \psi(d(Sv, Bz), \psi(d(Av, Tz)) \leq 0,$$
$$F(\psi(d(z, Bz)), 0, 0, \psi(d(z, Bz)), \psi(d(z, Bz)), 0) \leq 0$$

A contradiction of (F_1) if $\psi(d(z, Bz)) > 0$. Hence $\psi(d(z, Bz)) = 0$ which implies $z = Bz$ and z is a common fixed point of B and T with $d(z, z) = 0$.

Suppose that exists an other common fixed point z_1 with $d(z_1, z_1) = 0$. By (4.1) for $x = z$ and $y = z_1$ we obtain:

$$F(\psi(d(Az, Bz_1)), \psi(d(Sz, Tz_1)), \psi(d(Sz, Az)),$$
$$\psi(d(Tz_1, Bz_1)), \psi(d(Sz, Bz_1), \psi(d(Az, Tz_1)) \leq 0,$$

$F(\psi(d(z,z_1)),\psi(d(z,z_1)),0,0,\psi(d(z,z_1)),\psi(d(z,z_1)))\leq 0$,
a contradiction of F_3 if $\psi(d(z_1,z_1))>0$, hence $\psi(d(z,z_1))\leq 0$ which implies $z=z_1$. Hence, z is the unique common fixed point of A,B,S,T with $d(z,z)=0$.

If $\psi(t)=t$, by Theorem 4.1 we obtain:

Theorem 4.2. Let (X,d) be a dislocated metric space such that:
$F(d(Ax,By)),d(Sx,Ty),d(Sx,Ax),d(Ty,By),d(Sx,By),d(Ax,Ty))\leq 0$ for all $x,y\in X$ and $F\in\mathcal{F}$.
If (A,S) and T satisfy $CRP_{(A,S)T}$-property , then $C(B,T)\neq\phi$.
Moreover if A is pointwise S absorbing and B is pointwise T absorbing, then A,B,S and T have an unique common fixed point z with $d(z,z)=0$.

Remark 4.1. For the proof of this theorem we have to do the following steps:
Step 1. Solve equation $Ax=Sx$ and establish $C(A,S)$, If the $C(A,S)=\phi$ the theorem is not applicable.
Step 2. If $C(A,S)\neq\phi$ we have to select $z\in C(A,S)$ such that $z\in T(X)$ and $d(z,z)=0$. As a consequence (A,S) and T satisfy $CRP_{(A,S)T}$-property.
Step 3. Verify that (A,S) and (B,T) are pointwise absorbing at z.If one of these pairs is not pairwise absorbing, the theorem can not be applied. Stop.
Step 4. If the Theorem 4.1 is satisfied then A,B,S,T have a unique common fixed point z with $d(z,z)=0$.

Example 4.1. Let $X=[0,1]$ and $d(x,y)=\max\{x,y\}$. Let $A,B,S,T:X\to X$, $Ax=0$, $Bx=\frac{x}{3}$, $Sx=\frac{x}{x+1}$, $Tx=x$.
Is $Ax=Sx$ then $z=0\in T(X)=X$ and $d(z,z)=0$. Hence (A,S) and T satisfy $CRP_{A,S}T-property$. On the other hand $d(Sx,SAx)=\max\{\frac{x}{x+1},0\}=\frac{x}{x+1}$ and $d(Ax,Sx)=\frac{x}{x+1}$ which implies $d(Sx,SAx)\leq R_1$ $d(Ax,Sx)$ for $R_1\geq 1$. Hence A is pointwise S absorbing. Similarly, $d(Tx,TBx)=\max\{x,\frac{x}{3}\}=x$ and $d(Tx,Bx)=\max\{x,\frac{x}{3}\}=x$. Hence $d(Tx,TBx)\leq R_2$ $d(Tx,By)$ for $R_2\geq 1$. Hence B is T absorbing. On the other hand $d(Ax,By)=\max\{0,\frac{y}{3}\}=\frac{y}{3}$ and $d(Ty,By)=\max\{y,\frac{y}{3}\}=y$. Hence $d(Ax,By)\leq k$ $d(Ty,By)$ for $k\in[\frac{1}{3},1)$ which implies:
$d(Ax,By)\leq k\max\{d(Sx,Ty),d(Sx,Ax),d(Ty,By),d(Sx,By),d(Ax,Ty)\}$
where $k\in[\frac{1}{3},1)$. By Theorem 4.2 and example 3.1 A,B,S,T have an unique fixed point $z=0$ with $d(z,z)=0$.

5. Applications

5.1. **Fixed point theorems of two pairs of pointwise absorbing mappings satisfying contractive conditions of integral type.** In [6], Branciari established the following theorem which opened the way to the study of fixed points satisfying contractive conditions of integral type.

Theorem 5.1 ([6]) Let (X,d) be a complete metric space $c \in [0,1)$ and $f : X \to X$ such that for all $x, y \in X$.

$$\int_0^{d(fx,fy)} h(t)dt \leq \int_0^{d(x,y)} h(t)dt$$

whenever $h : [0,\infty) \to [0,\infty)$ is a Lebesgue measurable mapping which is summable (with finite integral) on each compact subset of $[0,\infty)$ such that $\int_0^{\epsilon} h(t)dt > 0$ for all $\epsilon > 0$. Then f has an unique fixed point.

Some results for mappings satisfying contractive conditions are obtained in [24], [25] and other papers.

Lemma 5.1. Let $h : [0,\infty) \to [0,\infty)$ as in Theorem 5.1. Then $\psi(t) = \int_0^t h(t)dt$ is a weak altering distance.

Proof. The proof is similar to the proof of Lemma 2.5 [25].

Theorem 5.2. Let A, B, S and T be self mappings of a dislocated space such that

(5.1)

$$F(\int_0^{d(Ax,By)} h(t)dt, \int_0^{d(Sx,Ty)} h(t)dt, \int_0^{d(Sx,Ax)} h(t)dt,$$

$$\int_0^{d(Ty,By)} h(t)dt, \int_0^{d(Sx,By)} h(t)dt, \int_0^{d(Ax,Ty)} h(t)dt) \leq 0$$

for all $x, y \in X$, $h(t)$ as in Theorem 5.1 and some $F \in \mathcal{F}$.

If (A,S) and T satisfy $CRP_{(A,S)T}$ property, then $C(B,T) \neq \phi$.

Moreover if A is pointwise S absorbing and B is pointwise T absorbing , then A, B, S, T have a unique common fixed point z with $d(z,z) = 0$.

Proof. By Lemma 5.1 $\psi(t) = \int_0^t h(t)dt$ is an weak altering distance. Hence

$\int_0^{d(Ax,By)} h(t)dt = \psi(d(Ax,By))$, $\int_0^{d(Sx,Ty)} h(t)dt = \psi(d(Sx,Ty))$,

$\int_0^{d(Ax,Sx)} h(t)dt = \psi(d(Sx,Ax))$, $\int_0^{d(Ty,By)} h(t)dt = \psi(d(Ty,By))$,

$\int_0^{d(Sx,By)} h(t)dt = \psi(d(Sx,By)),\ \int_0^{d(Ax,Ty)} h(t)dt = \psi(d(Ax,Ty))$.

By 5.1 we obtain

$$F(\psi(d(Ax,By)),\psi(d(Sx,Ty)),\psi(d(Sx,Ax)),$$
$$\psi(d(Ty,By)),\psi(d(Sx,Ty)),\psi(d(Ax,Ty))) \le 0$$

which is inequality (4.1). Hence the conditions of Theorem 4.1 are satisfied and Theorem 5.2 follows by Theorem 4.1.

For example, by Theorem 5.2 and Example 3.1 we obtain:

Theorem 5.3. Let A, B, S, T be self mappings of a dislocated metric space such that

$$\int_0^{d(Ax,By)} h(t)dt \le k \max\{\int_0^{d(Sx,Ty)} h(t)dt, \int_0^{d(Sx,Ax)} h(t)dt,$$
$$\int_0^{d(Ty,By)} h(t)dt, \int_0^{d(Sx,Ty)} h(t)dt, \int_0^{d(Ax,Ty)} h(t)dt\}$$

where $k \in [0,1)$ and $h(t)$ is as in Theorem 5.1.

If (A,S) and T satisfy $CRP_{(A,S)T}$-property, then $C(B,T) \ne \phi$.

Moreover, if A is pointwise S absorbing and B is pointwise T absorbing, then A, B, S, T have a unique fixed point z with $d(z,z) = 0$.

Remark 5.1. By Theorem 5.2 and Examples 3.2-3.8 we obtain other particular results.

5.2. **Fixed points for pointwise absorbing mappings satisfying φ-contractive conditions.** As in [16] let Φ be the set of all $\varphi : [0,\infty) \to [0,\infty)$ such that

1) $\varphi(t) < t$ for $t \in (0,\infty)$,

2) $\varphi(t) = 0$ if and only if $t = 0$.

The following functions $F : \mathbb{R}_+^6 \to \mathbb{R}$ satisfy conditions $(F_1), (F_2), (F_3)$.

Example 5.1. $F(t_1,...,t_6) = t_1 - \varphi(\max\{t_2,t_3,...,t_6\})$.

Example 5.2. $F(t_1,...,t_6) = t_1 - \varphi(\max\{t_2,t_3,t_4,\frac{t_5+t_6}{2}\})$.

Example 5.3. $F(t_1,...,t_6) = t_1 - \varphi(\max\{t_2,\frac{t_3+t_4}{2},\frac{t_5+t_6}{2}\})$.

Example 5.4. $F(t_1,...,t_6) = t_1 - \varphi(\max\{\sqrt{t_2t_4},\sqrt{t_5t_6},\sqrt{t_3t_5},\sqrt{t_4t_6}\})$.

Example 5.5. $F(t_1,...,t_6) = t_1 - \varphi(at_2 + bt_3 + ct_4 + dt_5 + et_6)$ where $a,b,c,d,e \ge 0$ and $a+b+c+d+e \le 1$.

Example 5.6. $F(t_1,...,t_6) = t_1 - \varphi(a\,t_2 + b\max\{t_3,t_4\} + c\max\{t_5,t_6\})$ where $a,b,c \ge 0$ and $a+b+c \le 1$.

Example 5.7. $F(t_1,...,t_6) = t_1 - \varphi(a\ t_2 + b\ \frac{t_5t_6}{1+t_3+t_4})$, where $a,b \ge 0$ $a+b \le 1$.

Example 5.8 $F(t_1,...,t_6) = t_1 - \varphi(a\ t_2 + b\max\{2t_4+t_5, 2t_4+t_6, 2t_5+t_3\})$ where $a,b \ge$ and $a+2b \le 1$.

By Theorem 4.2 and Example 5.1 we obtain

Theorem 5.4. Let A, B, S and T be self mappings of a dislocated metric space (X, d) such that

$d(Ax, By) \leq \varphi(max\{d(Sx, Ty),\ d(Sx, Ax),\ d(Ty, By),\ d(Sx, By),\ d(Ax, Ty)\})$ for all $x, y \in X$ and $\varphi \in \Phi$.

If (A, S) and T satisfy $CRP_{(A,S)T}$ property then $C(B, T) \neq \Phi$.

Moreover, if A is pointwise S absorbing and B is pointwise T-absorbing, then A, B, S, T have a unique common fixed point z with $d(z, z) = 0$.

Remark 5.2. By Example 5.2-5.8 and Theorem 4.2 we obtain new particular results.

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