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SOME RESULTS ON $G-$CONTRACTION WITH PROPERTY (M)

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Abstract: Based on the results of Berinde and Păcurar, we present the notion of G_C- modified Reich contractions with property (M) in Banach spaces (curtly BS) including a graph. Our outcomes enlarge varied comparable consequences in the existing litterateur.

Keywords: Orbitally $G-$continuity, $G-$contaction, non-self map
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1. Introduction

In 2008, Jachymski [11] have given a catchy approach in theoric of fixed points in some overall forms by applying as part of metric spaces involving a graph. The author [11] has shown certain generalities on classical contraction mapping basis of Banach on a complete metric space through graph. Thereafter different contractions have been established by many researchers. In [12]-[10] and [15] the contraction basis for multivalued and set valued mappings, in [6], [7], [8] Reich and Kannan type contractions, Zamfirescu maps studied, resp. More precisely, let (X,d) be a metric space, $G=(V(G),E(G))$ be a graph such that $V(G)=X$, $E(G)$ subsumes entire loops. A map [11] $h:X\to X$ is orbitally $G-$continuity if $\forall r,s\in X$, $\{k_n\}_{n\in\mathbb{N}}\subseteq Z^+$,$h^{k_n}r\to s$, $\left(h^{k_n}r,h^{k_{n+1}}r\right)\in E(G)\Rightarrow h\left(h^{k_n}r\right)\to hs$.

Besides, Berinde and Păcurar [4] initiated study of fixed point theory for non-self contractions via Banach space (curtly BS) encorporing G. Balog and Berinde [2] established the notion of non-self Kannan contractions described on BS by of way G. Recently, a new type of non-self Catterjea is introduced and studied by Balog et al. [3]. Their results are more general than that of Berinde and Păcurar [4] and Balog and Berinde.

Inspired by former works, we define notion of modified non-self Reich type contractions on BS via G. The findings of this article enlarge varied known consequences in the literature.

2. Essential descriptions and facts in BS via G

Let X be BS, $C\neq\emptyset$ a closed of X, $h:C\to X$ a non-self map. If $r\in C$ is such that $hr\notin C$, here we mostly select $s\in\partial C$ such that $s=(1-\mu)r+\mu hr(\mu\in(0,1))$, which fairly express

$$d(hr,r)=d(hr,s)+d(s,r)\,,\ s\in\partial C. \tag{2.1}$$

The set B of points s supplying (2.1) can compass more than one element. Assume that $B\neq\emptyset$.

Definition 2.1. [5] Let X be BS, $C\neq\emptyset$ a closed of X, $h:C\to X$ a non-self map. Let $r\in C$ with $hr\notin C$, $s\in\partial C$ be the concerned elements endowed with (2.1). If, for any such terms r, we obtain

$$d(s,hs)\leq d(r,hr) \tag{2.2}$$

for all corresponding $s\in B$, then h enjoy *property* (M).

Definition 2.2. [4] Let X be BS, $C\neq\emptyset$ a closed of X. A map $h:C\to X$ is (i) well defined, if it holds the quality for the subgraph of G induced by C, viz,$\forall r,s\in C$,

$$(r,s)\in E(G)\ \text{ with } hr,\,hs\in C\Rightarrow(hr,hs)\in E(G)\cap(C\times C)\,. \tag{2.3}$$

(ii) G_C-contraction if h is (well) defined and there exists $z_1\in[0,1)$ such that $\forall r,s\in C$,

$$(r,s)\in E(G_C)\Rightarrow d(hr,hs)\leq z_1 d(r,s)\,. \tag{2.4}$$

Definition 2.3. (*Property* (L)) [4] Any sequence for $\forall n\in\mathbb{N}$, $\{r_n\}\subseteq X$ with $r_n\to r$ when $n\to\infty$ and $(r_n,r_{n+1})\in E(G)$, there appears a subsequence $\{r_{k_n}\}_{i=1}^{\infty}$ providing $(r_{k_n},r)\in E(G)$.

3. MAIN RESULTS

Theorem 3.1. *Let (X, d, G) be BS via weakly connected and simple directed G such that the property (L) acquires. Let $C \neq \emptyset$ be a closed of X, $h : C \to X$ be G_C-modified Reich contraction with property (M), namely, there appears η, ϑ, θ, nonnegative real numbers with $\eta + \vartheta + \theta < 1$ such that for $\forall\,(r, s) \in E\,(G_C)$*

$$d\,(hr, hs) \leq \eta d\,(r, s) + \vartheta d\,(r, hr) + \theta d\,(s, hs) + U_R\,(r, s)\,, \tag{3.1}$$

where

$$U_R\,(r, s) = R \min\left\{d\,(r, s)\,, d\,(r, hr)\,, d\,(s, hs)\,, d\,(r, hs)\,, d\,(s, hr)\right\}, R \geq 0$$

and G_C is the subgraph of G stated by C. If $C_h := \{r \in \partial C : (r, hr) \in E\,(G)\} \neq \emptyset$, h getting Rothe's baundary condition

$$C \supset h\,(\partial C)\,, \tag{3.2}$$

then h own a fixed point in C.

Proof. Let $C \supseteq h\,(C)$. Here h is substantially a self-map in closed set C, the consequence pursued by Reich fixed point theorem [13] to $X = C$. Hence, we only take into consideration $h\,(C) \nsubseteq C$. Moreover, we have $\forall n \in \mathbb{N}$

$$r_0 \in C_h \Rightarrow (r_0, hr_0) \in E\,(G) \Rightarrow \left(h^n r_0, h^{n+1} r_0\right) \in E\,(G)\,. \tag{3.3}$$

Express $\forall n \in \mathbb{N}$; $s_n := h^n r_0$.

Owing to (3.2), we get that $hr_0 \in C$.

Denote $r_1 := s_1 = hr_0$. Next, if $hr_1 \in C$, set $r_2 := s_2 = hr_1$. If $hr_1 \notin C$, we may seize a term r_2 on the segment $[r_1, hr_1]$ which also pertain to ∂C, i.e.,

$$r_2 = (1 - \mu)\,r_1 + \mu hr_1 (\mu \in (0, 1)).$$

Ongoing argumentums we create two sequences $\{r_n\}$ and $\{s_n\}$ whose elements fulfill one of the below particulars:

(1) $hr_{n-1} \in C \Rightarrow r_n := s_n = hr_{n-1}$;

(2) $hr_{n-1} \notin C \Rightarrow r_n = r_{n-1}\,(-\mu + 1) + \mu hr_{n-1} \in \partial C$ $(\mu \in (0, 1))$.

Next, we allege that $\{r_n\}$ is a Cauchy sequence. Assume that

$$P = \left\{r_k \in \{r_n\} : r_k = s_k = hr_{k-1}\right\},$$
$$Q = \left\{r_k \in \{r_n\} : r_k \neq hr_{k-1}\right\}.$$

Clearly, if $r_k \in Q$, then r_{k-1} and r_{k+1} pertain to P. Furthermore, due to (3.2), we can not hold two consecutive nomials of $\{r_n\} \subseteq Q$ (yet we can hold two consecutive nomials of $\{r_n\} \subseteq P$). Next, we attach 3 possibities.

Case 1. r_n, $r_{n+1} \in P$. Then, we get $s_n = hr_{n-1} = r_n$, $s_{n+1} = hr_n = r_{n+1}$. Thus

$$d\,(r_n, r_{n+1}) = d\,(hr_{n-1}, hr_n) = d\,(s_n, s_{n+1})\,.$$

As $\{r_n\} \subset C$, $\forall n \in \mathbb{N}$, from (3.3) $(r_n, r_{n-1}) \in E\,(G_C)$, and thus by G_C-modified Reich contraction condition (3.1), we obtain that

$$\begin{aligned}
d\,(r_n, r_{n+1}) &= d\,(hr_{n-1}, hr_n) \\
&\leq \eta d\,(r_n, r_{n-1}) + \vartheta d\,(r_n, hr_n) + \theta d\,(r_{n-1}, hr_{n-1}) \\
&\quad + R \min\left\{d\,(r_{n-1}, r_n,)\,, d\,(hr_n, r_n)\,, d\,(hr_{n-1}, r_{n-1},)\,, d\,(hr_{n-1}, r_n)\,, d\,(hr_n, r_{n-1})\right\} \\
&\leq \eta d\,(r_n, r_{n-1}) + \vartheta d\,(r_n, r_{n+1}) + \theta d\,(r_{n-1}, r_n) \\
&\quad + R \min\left\{\begin{array}{c} d\,(r_n, r_{n-1})\,, d\,(r_n, r_{n+1})\,, \\ d\,(r_{n-1}, r_n)\,, d\,(r_n, r_n)\,, d\,(r_{n+1}, r_{n-1}) \end{array}\right\} \\
&\leq \eta d\,(r_n, r_{n-1}) + \vartheta d\,(r_n, r_{n+1}) + \theta d\,(r_{n-1}, r_n)\,,
\end{aligned}$$

$$d(r_n, r_{n+1}) \leq \kappa d(r_{n-1}, r_n) \tag{3.4}$$

where $\kappa = \frac{\eta+\theta}{1-\vartheta} < 1$.

Case 2. $r_{n+1} \in Q$, $r_n \in P$. Then, we have $s_n = r_n = hr_{n-1}$, $r_{n+1} \neq s_{n+1} = hr_n$. We get

$$\begin{aligned} d(r_{n+1}, r_n) &\leq d(r_{n+1}, r_n) + d(s_{n+1}, r_{n+1}) \\ &= d(s_{n+1}, r_n) \\ &= d(s_{n+1}, s_n). \end{aligned}$$

Next, using an analogue argumentum to Case 1, $(r_n, r_{n-1}) \in E(G_C)$ and so by (3.1), we attain

$$\begin{aligned} d(s_n, s_{n+1}) &= d(hr_{n-1}, hr_n) \\ &\leq \eta d(r_{n-1}, r_n) + \vartheta d(r_{n-1}, hr_{n-1}) + \theta d(r_n, hr_n) \\ &\quad + R\min\{d(r_{n-1}, r_n), d(r_{n-1}, hr_{n-1}), d(r_n, hr_n), d(r_{n-1}, hr_n), d(r_n, hr_{n-1})\} \\ &= \eta d(r_{n-1}, r_n) + \vartheta d(r_{n-1}, hr_{n-1}) + \theta d(s_n, s_{n+1}) \\ &\quad + R\min\left\{ \begin{array}{c} d(r_{n-1}, r_n), d(r_{n-1}, r_n), \\ d(s_n, s_{n+1}), d(r_{n-1}, r_{n+1}), d(r_n, r_n) \end{array} \right\} \\ &= \eta d(r_{n-1}, r_n) + \vartheta d(r_{n-1}, hr_{n-1}) + \theta d(s_n, s_{n+1}) \end{aligned}$$

which yields

$$\xi d(r_{n-1}, r_n) \geq d(s_n, s_{n+1}).$$

where $\xi = \frac{\eta+\vartheta}{1-\theta} < 1$ and so,

$$d(r_{n+1}, r_n) < d(s_{n+1}, s_n) \leq \xi d(r_{n-1}, r_n). \tag{3.5}$$

Case 3. $r_{n+1} \in P$, $r_n \in Q$. Then, we have $r_{n-1} \in P$, $s_n \neq r_n$, $s_{n+1} = r_{n+1}$, $s_{n-1} = r_{n-1}$, $s_n = hr_{n-1}$ and

$$d(r_{n-1}, r_n) + d(r_n, hr_{n-1}) = d(r_{n-1}, hr_{n-1}).$$

From the *property* (M), we have

$$d(r_n, r_{n+1}) = d(r_n, hr_n) \leq d(r_{n-1}, hr_{n-1}) = d(hr_{n-2}, hr_{n-1}).$$

Therefore,

$$d(r_n, r_{n+1}) \leq d(hr_{n-2}, hr_{n-1}).$$

As $\{s_n\} \subseteq C$, $\forall n \in \mathbb{N}$, from (3.3) $(r_{n-2}, r_{n-1}) \in E(G_C)$, and thus by (3.1), we obtain that

$$\begin{aligned} d(hr_{n-2}, hr_{n-1}) &\leq \eta d(r_{n-2}, r_{n-1}) + \vartheta d(r_{n-2}, hr_{n-2}) + \theta d(r_{n-1}, hr_{n-1}) \\ &\quad + R\min\left\{ \begin{array}{c} d(r_{n-2}, r_{n-1}), d(r_{n-2}, hr_{n-2}), \\ d(r_{n-1}, hr_{n-1}), d(r_{n-2}, hr_{n-1}), d(r_{n-1}, hr_{n-2}) \end{array} \right\} \\ &= \eta d(r_{n-2}, r_{n-1}) + \vartheta d(r_{n-2}, r_{n-1}) + \theta d(r_{n-1}, r_n) \\ &\quad + R\min\left\{ \begin{array}{c} d(r_{n-2}, r_{n-1}), d(r_{n-2}, r_{n-1}), \\ d(r_{n-1}, r_n), d(r_{n-2}, r_n), d(r_{n-1}, r_{n-1}) \end{array} \right\}, \end{aligned}$$

and thus,

$$d(hr_{n-2}, hr_{n-1}) = d(r_{n-1}, hr_{n-1}) \leq (\eta + \vartheta) d(r_{n-2}, r_{n-1}) + \theta d(r_{n-1}, hr_{n-1}),$$

which yields

$$d(r_{n-1}, hr_{n-1}) \leq \frac{\eta+\vartheta}{1-\theta} d(r_{n-2}, r_{n-1}),\ n \geq 2.$$

Hence,

$$\xi d\left(r_{n-2},r_{n-1}\right)\geq d\left(r_{n},r_{n+1}\right). \tag{3.6}$$

Now, by combining (3.4), (3.5) and (3.6), it follows that

$$d\left(r_{n},r_{n+1}\right)\leq\begin{cases}\varrho d\left(r_{n},r_{n-1}\right)\\ \varrho d\left(r_{n-2},r_{n-1}\right)\end{cases}$$

where

$$\varrho=\max\left\{\frac{\eta+\theta}{1-\vartheta},\frac{\eta+\vartheta}{1-\theta}\right\}=\max\left\{\kappa,\xi\right\}.$$

Following [4] from inductive, it concludes that for $n\geq 2$

$$d\left(r_{n},r_{n+1}\right)\leq\varrho^{[n/2]}\sigma, \tag{3.7}$$

where

$$\sigma=\max\left\{d\left(r_{1},r_{0}\right),d\left(r_{1},r_{2}\right)\right\}. \tag{3.8}$$

Here, $[n/2]$ stand for the largest $\mathbb{Z}$ not surpassing $n/2$.

Next, for $N<n<m$;

$$d\left(r_{n},r_{m}\right)\leq\sum_{j=N}^{\infty}d\left(r_{j},r_{j-1}\right)\leq 2\frac{\varrho^{[n/2]}}{1-\varrho}\sigma.$$

This implies that $\{r_n\}$ is Cauchy sequence.

As $\{r_n\}\subset C$, $\forall n\in\mathbb{N}$ and C is closed, $\{r_n\}$ converges to $r_*\in C$, that is,

$$r_n\to r_* \text{ as } n\to\infty.$$

From the *property* (L) and (3.1), we get

$$d\left(hr_{k_n},hr_*\right)\leq\eta d\left(r_{k_n},r_*\right)+\vartheta d\left(r_{k_n},hr_{k_n}\right)+\theta d\left(r_*,hr_*\right). \tag{3.9}$$

Hence, owing to (3.7) and (3.9)

$$\begin{aligned}
d\left(r_*,hr_*\right) &\leq d\left(r_*,r_{k_n+1}\right)+d\left(r_{k_n+1},hr_*\right)\\
&= d\left(r_*,r_{k_n+1}\right)+d\left(hr_{k_n},hr_*\right)\\
&= d\left(r_*,r_{k_n+1}\right)+\eta d\left(r_{k_n},r_*\right)+\vartheta d\left(r_{k_n},hr_{k_n}\right)+\theta d\left(r_*,hr_*\right)\\
&\quad +R\min\left\{\begin{array}{c} d\left(r_{k_n},r_*\right),d\left(r_{k_n},hr_{k_n}\right),\\ d\left(r_*,hr_*\right),d\left(r_{k_n},hr_*\right),d\left(r_*,hr_{k_n}\right)\end{array}\right\}\\
&= d\left(r_*,r_{k_n+1}\right)+\eta d\left(r_{k_n},r_*\right)+\vartheta d\left(r_{k_n},hr_{k_n}\right)+\theta d\left(r_*,hr_*\right),
\end{aligned}$$

$$\begin{aligned}
d\left(r_*,hr_*\right) &\leq \frac{1}{1-\theta}d\left(r_*,r_{k_n+1}\right)+\frac{\eta}{1-\theta}d\left(r_{k_n},r_*\right)+\frac{\vartheta}{1-\theta}d\left(r_{k_n},hr_{k_n}\right)\\
&\leq \frac{1}{1-\theta}d\left(r_*,r_{k_n+1}\right)+\nu d\left(r_{k_n},r_*\right)+\varrho d\left(r_{k_n},r_{k_n+1}\right)\\
&\leq \frac{1}{1-\theta}d\left(r_*,r_{k_n+1}\right)\\
&\quad +\nu\left[d\left(r_{k_n},r_*\right)+\varrho^{[k_n/2]}\max\left\{d\left(r_{k_0},r_{k_1}\right),d\left(r_{k_1},r_{k_2}\right)\right\}\right].
\end{aligned} \tag{3.10}$$

Taking the limit as $n\to\infty$, then $d\left(r_*,hr_*\right)=0$ and hence $r_*=fr_*$.

To display that r_* is a unique fixed point of h, given that r_*, s_* are two fixed point of h. In that case, we get

$$\begin{aligned} d(r_*, s_*) &= d(hr_*, hs_*) \\ &\leq \eta d(r_*, s_*) + \vartheta d(r_*, hr_*) + \theta d(s_*, hs_*) \\ &\quad + R\min\{d(r_*, s_*), d(r_*, hr_*), d(s_* hs_*), d(r_*, hs_*), d(s_*, hr_*)\} \\ &= \eta d(r_*, s_*), \end{aligned}$$

and so

$$d(r_*, s_*) = 0 \text{ in view of } (1-\eta) < 1.$$

It follows that $r_* = s_*$. □

Example 3.2. Let $X = [0,1] \cup \{2,3\}$ be endued with the usual norm and let $C = \{0,1,2,3\}$. Define the operator $h : C \to X$ hereinbelow

$$hr = \begin{cases} 0, & \text{if } r \in \{0,1\}, \\ \frac{1}{5}, & \text{if } r \in \{2,3\}. \end{cases}$$

Let G be defined by

$$E(G) = \{(r,r) : r \in [0,1]\} \cup \left\{(0,1), (0,2), (2,3), (2,2), \left(2, \frac{1}{5}\right), (3,3)\right\}.$$

Then G is weakly connected graph such that the *property* (L) acquires and h is G_C-modified Reich contraction on C. It is also simple to overhaul that h is well defined on X via G_C. Actually, G_C own the set of vertices $E(G_C) = \{(3,3), (0,0), (2,3), (0,1), (2,2), (0,2), (1,1)\}$. Due to (2.3), the edges $(0,2), (2,2), (2,3), (3,3)$ have to be endured and for the remaining edges we obtain

$$(h0, h0) = (h0, h1) = (h1, h1) = (0,0) \in E(G_C).$$

Furthermore $C \supset h(\partial C)$ is provided, due to $\partial C = \{0,1\}$, thus $h(\partial C) = \{0\} \subset C$. Eventually, because we again hold $C_h = \{0\} \neq \emptyset$, whole assumption in Theorem 3.1 are ensured, 0 is single fixed point of h.

Remark 3.3. (i) For $R = 0$ in Theorem 3.1 , then it is easly proved G_C- Reich contractions with property (M) on BS including a graph.

(ii) Taking $\eta = 0$ and $\vartheta = \theta$ in Theorem 3.1 we obtain Kannan type contractions by Balog and Berinde Theorem 2.1 in [2] for a non-self map.

(iii) If $\vartheta = 0$ and $\theta = 0$ in Theorem 3.1, then it can be simply showed Theorem 3.1 in [4].

Like in [4, 2], we can replace the property (L) of (X, d, G) by favorable terms.

Theorem 3.4. *Let (X, d, G) be BS via a weakly connected and simple directed G. Let $C \neq \emptyset$ be a closed of X, $h : C \to X$ be G_C-modified Reich contraction on C. If $C_h := \{r \in \partial C : (r, hr) \in E(G)\} \neq \emptyset$, h is orbitally $G-$continuous and h satisfies $C \supset h(\partial C)$, then h has a fixed point in C.*

Proof. With respect to argument of Theorem 3.1, we have that $\{r_n\}$ defined by $r_n = h^n r_0$ for all n converges to r_*. Since $\left(h^n r_0, h^{n+1} r_0\right) \in E(G)$, $\forall n \in \mathbb{N}$, h is orbitally $G-$continuous, we obtain

$$r_* = \lim_{n\to\infty} h(h^n r_0) = hr_*.$$

That is, $r_* = hr_*$. Assume that s_* is another fixed point of h. Using an analogue technique as in Theorem 3.1, we get $r_* = s_*$. □

Remark 3.5. (i) For $R = 0$ in Theorem 3.4 , then it is easly proved G_C- Reich contractions on BS including a graph.

(ii) Taking $\eta = 0$ and $\vartheta = \theta$ in Theorem 3.4, we obtain Kannan type contractions by Balog and Berinde Theorem 2.2 in [2] for a non-self map.

(iii) If $\vartheta = 0$ and $\theta = 0$ in Theorem 3.4, then it can be simply showed Theorem 3.2 in [4].

In the instant writing, non-self G_C- modified Reich contractions on BS via G have been defined. Our deductions conduce a more general approximation to such a non-self contractions engendered by [4],[2].

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