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Interpolative Kannan contractions are classical Kannan contractions: an alternative proof and open problems

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ABSTRACT. We present a slightly different proof from the one in [Cvetković, M. The role of concave functions in the study of interpolative contractions. *Quaest. Math.* **49** (2026), no. 1, 119–132.] of the fact that the so called interpolative Kannan contractions introduced in [Karapınar, E. Revisiting the Kannan type contractions via interpolation. *Adv. Theory Nonlinear Anal. Appl.* **2** (2018), no. 2, 85–87.] are in fact classical Kannan contractions as introduced originally in [Kannan, R. Some results on fixed points. *Bull. Calcutta Math. Soc.* **60** (1968), 71–76.] and [Kannan, R. Some results on fixed points. II. *Amer. Math. Monthly* **76** (1969), 405–408.]

1. INTRODUCTION

Banach's contraction principle is the foundation stone of metrical fixed point theory which has developed impressively in the last century starting from this fundamental result. In the case of a metric space setting, it can be stated as follows.

Theorem 1.1. *Let (X, d) be a complete metric space and $T : X \to X$ a strict contraction, i.e., a map satisfying*

$$d(Tx, Ty) \leq a\, d(x, y)\,, \quad \text{for all } x, y \in X\,, \tag{1.1}$$

where $0 \leq a < 1$ is constant. Then:
$(p1)$ T has a unique fixed point p in X (i.e., $Tp = p$);
$(p2)$ The Picard iteration $\{x_n\}_{n=0}^{\infty}$ defined by

$$x_{n+1} = Tx_n\,, \quad n = 0, 1, 2, \ldots \tag{1.2}$$

converges to p, for any $x_0 \in X$.

Remark 1.1. *A map satisfying $(p1)$ and $(p2)$ in Theorem 1.1 is said to be* a Picard operator, *see* [86], [87], [88] *and* [89], *for more details.*

Theorem 1.1 is a simple but versatile tool in establishing existence and uniqueness theorems for operator equations and plays a very important role in nonlinear analysis. This fact motivated researchers to try to extend and generalize it in such a way that its area of applications should be enlarged as much as possible.

Most of these generalizations considered only continuous mappings, like in the original case of the contraction mapping in Theorem 1.1. It was natural to ask whether there exist or not alternative contractive conditions that ensure the conclusions of Theorem 1.1 but which do not force implicitly or explicitly that T is continuous.

This question was answered in the affirmative by Kannan in 1968 [52], who proved a fixed point theorem which extends Theorem 1.1 to mappings that need not be continuous. Kannan considered instead of (1.1) the following condition:

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there exists $b \in (0, \frac{1}{2})$ such that

$$d(Tx, Ty) \leq b[d(x, Tx) + d(y, Ty)], \quad \text{for all } x, y \in X\,. \tag{1.3}$$

The original Kannan's fixed point theorem can be stated briefly as follows.

Theorem 1.2. *Let (X, d) be a complete metric space and $T : X \to X$ be a Kannan contraction mapping, that is, a mapping satisfying* (1.3). *Then T is a Picard operator.*

In a recent paper Karapinar ([54], Definition 2.1) introduced the concept of *interpolative Kannan type contraction*:

Definition 1.1. [54] *Assume (X, d) be a metric space. A self-mapping $T : X \to X$ is an interpolative Kannan type contraction if there exist a constant $\lambda \in [0, 1)$ and $\alpha \in (0, 1)$ such that*

$$d(Tx, Ty) \leq \lambda \left[d(Tx, x)\right]^{\alpha} \cdot \left[d(Ty, y)\right]^{1-\alpha} \tag{1.4}$$

where $x, y \in X$ and $x \neq Tx$.

In the same paper ([54], Theorem 2.2.), the following fixed point result has been established.

Theorem 1.3. *Let (X, d) be a complete metric spaces and $T : X \to X$ be an interpolative Kannan type contraction. Then T has a unique fixed point in X.*

Starting from this new type of contractive condition, a very impressive literature has developed, see references [1]-[51], [54]-[85], [90]-[120] at Bibliography.

Going back to the original paper [54] we note the fact that no examples are provided to show the existence of an interpolative Kannan type contraction which is not a classical Kannan contraction, so a natural question is whether such an example really exists.

Cvetković [18] has recently shown that in fact interpolative Kannan type contractions are nothing else but classical Kannan contractions.

In this note we give an alternative proof of this fact and raise the important open question whether the statement of Theorem 2.4 extends for the other types of contractions as well.

2. Interpolative Kannan type contractions are Kannan contractions

We start this section by noting that the condition $x \neq Tx$ in Definition 1.1 is incomplete. Indeed, due to the symmetry of the distance d, by changing x and y in (1.4), we are led immediately to the conclusion that $y \neq Ty$.

In our considerations here, we do not ask explicitly that $x \neq Tx$ and $y \neq Ty$ in the contraction condition (1.4). Our main aim is to prove the following simple and important result.

Theorem 2.4. *Let (X, d) be a metric space and $T : X \to X$ be an interpolative Kannan type contraction. Then T is a Kannan contraction mapping.*

Proof. In a metric space the distance is symmetric and hence $d(Tx, Ty) = d(Ty, Tx)$.

By (1.4), one obtains by changing x and y:

$$d(Tx, Ty) \leq \lambda \left[d(Ty, y)\right]^{\alpha} \cdot \left[d(Tx, x)\right]^{1-\alpha}.$$

Just sum it side by side to (1.4) to obtain

$$2d(Tx, Ty) \leq \lambda \left(\left[d(Ty, y)\right]^{\alpha} \cdot \left[d(Tx, x)\right]^{1-\alpha} + \left[d(Tx, x)\right]^{\alpha} \cdot \left[d(Ty, y)\right]^{1-\alpha} \right). \tag{2.5}$$

Now, using the inequality

$$a^{\alpha} b^{1-\alpha} + a^{1-\alpha} b^{\alpha} \leq a + b \Leftrightarrow (a^{\alpha} - b^{\alpha})(a^{1-\alpha} - b^{1-\alpha}) \geq 0,$$

valid for any $a, b \geq 0$ and $\alpha \in (0,1)$, from (2.5) we obtain exactly the desired Kannan contraction condition

$$d(Tx, Ty) \leq \lambda/2[d(Tx, x) + d(Ty, y)] \tag{2.6}$$

which is exactly the original Kannan condition with $b = \dfrac{\lambda}{2} < \dfrac{1}{2}$. □

Remark 2.2. *(i) By Theorem 2.4 it follows now that Theorem 1.3 is a consequence of Kannan fixed point theorem (Theorem 1.2).*

(ii) Another proof of Theorem 1.3, similar to that in Cvetković [18] *is the following one.*

From (1.4), one obtains by changing x and y:

$$d(Ty, Tx) \leq \lambda \left[d(Ty, y)\right]^{\alpha} \cdot \left[d(Tx, x)\right]^{1-\alpha}.$$

Just multiply the above inequality side by side with (1.4) to obtain

$$d(Tx, Ty)^2 \leq \lambda^2 d(Tx, x) \cdot d(Ty, y).$$

By extracting the square root (all quantities are nonnegative real numbers), we get

$$d(Tx, Ty) \leq \lambda \sqrt{d(Tx, x) \cdot d(Ty, y)}.$$

Using now the mean inequality $\sqrt{ab} \leq \dfrac{a+b}{2}$, valid for any $a, b \geq 0$, we deduce that

$$d(Tx, Ty) \leq \lambda/2[d(Tx, x) + d(Ty, y)] \tag{2.7}$$

which is exactly the original Kannan condition with $b = \dfrac{\lambda}{2} < \dfrac{1}{2}$.

Remark 2.3. *We note that the conditions $x \neq Tx$ and $y \neq Ty$, which are assumed in the definition of interpolative contractions and which appear in Theorems 11 and 12 in Cvetković* [18], *can be replaced by the simpler condition "T is not the identity mapping".*

3. Conclusions and open problems

As mentioned before and illustrated by the list of References, there are many papers dealing with interpolative type contractions.

Therefore, it will be of interest to determine whether the statement of Theorem 2.4 extends for the other types of interpolative contractions as well.

This will answer the very important question whether interpolative type contractions are genuine extensions of the usual type contractions to which are attached.

As a general rule, when a presumed generalized type of contractive condition is introduced, it has to be compared to the existing related contractive condition (s) in order to prove that the proposed concept is a genuine extension / generalization.

We challenge the readers to seek for an answer to the above question for as many as possible classes of interpolative type contractions introduced or studied in the papers from the list of References.

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