



JMAACS

Journal of Mathematical Analysis, Algebra and Computational Science

An International, Peer-Reviewed, Open Access Journal

Website: <https://jmaacs.com>

editor@jmaacs.com

— Email:

ISSN: XXXX-XXXX

e-ISSN:

XXXX-XXXX

Sample Article Title for JMAACS Template

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Received: 12 January 2026 — Revised: 20 February 2026 — Accepted: 18 March 2026

DOI: [10.12345/jmaacs.2026.0001](https://doi.org/10.12345/jmaacs.2026.0001)

Abstract

This is a sample abstract for the Journal of Mathematical Analysis, Algebra and Computational Science (JMAACS). Authors are requested to prepare their manuscripts according to the guidelines provided in this template. The abstract should be informative and self-contained, summarising the purpose, methods, results, and conclusions of the work. It should not exceed 250 words and should not contain references, footnotes, or non-standard abbreviations.

Keywords: sample keyword; another keyword; JMAACS; mathematics; computer science

MSC(2020): 00A06, 00A07, 68Q01

1 Introduction

This is a sample section to demonstrate the appearance of text in the JMAACS L^AT_EX template. The journal accepts original research articles, survey papers, and short communications in the

fields of pure and applied mathematics and computational science.

Mathematics is the language of science, and computation is the driving force of modern discovery. Let $\mathbb{R}$ be the set of real numbers and $\mathbb{N}$ the set of natural numbers. Throughout this paper we assume that all metric spaces are complete unless stated otherwise.

The rest of this paper is organised as follows. Section 2 recalls basic definitions. Section 3 presents the main results. Section 4 gives illustrative examples, and Section 5 concludes the paper.

2 Preliminaries

In this section, we provide some basic definitions and results that will be used throughout the paper.

Definition 2.1. Let X be a nonempty set. A function $f : X \rightarrow X$ is said to be a *contraction* if there exists $k \in (0, 1)$ such that

$$d(f(x), f(y)) \leq k d(x, y), \quad \forall x, y \in X,$$

where d is a metric on X .

Theorem 2.2 (Banach Fixed Point Theorem). *Let (X, d) be a complete metric space and $f : X \rightarrow X$ be a contraction. Then f has a unique fixed point in X .*

Proof. This is a sample proof. Authors can use the provided theorem environments for consistency. The full classical proof proceeds by constructing the Picard iteration $x_{n+1} = f(x_n)$ and showing it is Cauchy. $\square$

Example 2.3. Consider $f(x) = \frac{x}{2}$ on $X = \mathbb{R}$ with the usual metric. Then f is a contraction with $k = \frac{1}{2}$ and has a unique fixed point $x = 0$.

Lemma 2.4. *Under the hypotheses of Theorem 2.2, the sequence $(x_n)_{n \geq 0}$ defined by $x_{n+1} = f(x_n)$ satisfies*

$$d(x_m, x_n) \leq \frac{k^n}{1-k} d(x_0, x_1) \quad \text{for all } m > n \geq 0.$$

Proof. By the triangle inequality and the contraction condition,

$$\begin{aligned} d(x_m, x_n) &\leq \sum_{i=n}^{m-1} d(x_{i+1}, x_i) \leq \sum_{i=n}^{m-1} k^i d(x_1, x_0) \\ &\leq \frac{k^n}{1-k} d(x_1, x_0). \end{aligned} \quad \square$$

3 Main Results

3.1 Generalised Contraction Principle

We now present an extension of the Banach theorem to the setting of b -metric spaces [1].

Definition 3.1. A b -metric space (X, d, s) is a set X equipped with a function $d : X \times X \rightarrow [0, \infty)$ and a constant $s \geq 1$ such that for all $x, y, z \in X$:

- (i) $d(x, y) = 0$ if and only if $x = y$;
- (ii) $d(x, y) = d(y, x)$;
- (iii) $d(x, z) \leq s[d(x, y) + d(y, z)]$.

Theorem 3.2. Let (X, d, s) be a complete b -metric space and let $f : X \rightarrow X$ satisfy

$$d(f(x), f(y)) \leq \lambda d(x, y)$$

for all $x, y \in X$, where $\lambda \in (0, \frac{1}{s})$. Then f has a unique fixed point $x^* \in X$, and the Picard iterates $x_n = f^n(x_0)$ converge to x^* for every $x_0 \in X$.

Proof. The proof follows the classical pattern. One verifies that (x_n) is Cauchy in (X, d, s) using Lemma 2.4 adapted to the b -metric setting, and completeness then gives existence. Uniqueness follows directly from the contraction condition. $\square$

Corollary 3.3. Every contraction on a complete metric space (i.e., $s = 1$) satisfies the hypotheses of Theorem 3.2.

3.2 Error Estimates

The following proposition provides a priori and a posteriori error bounds for the fixed-point iteration.

Proposition 3.4. Under the hypotheses of Theorem 3.2, the following estimates hold for all $n \geq 1$:

$$d(x_n, x^*) \leq \frac{(s\lambda)^n}{1 - s\lambda} d(x_0, x_1) \quad (\text{a priori}), \quad (1)$$

$$d(x_n, x^*) \leq \frac{s\lambda}{1 - s\lambda} d(x_{n-1}, x_n) \quad (\text{a posteriori}). \quad (2)$$

4 Illustrative Examples

Example 4.1. Let $X = [0, 1]$ with the b -metric $d(x, y) = |x - y|^2$ (so $s = 2$). Define $f(x) = x/3$. Then

$$d(f(x), f(y)) = \left| \frac{x - y}{3} \right|^2 = \frac{1}{9} |x - y|^2 = \frac{1}{9} d(x, y),$$

so f is a contraction with $\lambda = 1/9 < 1/s = 1/2$. Theorem 3.2 guarantees the unique fixed point $x^* = 0$.

Remark 4.2. The condition $\lambda < 1/s$ is sharp: if $s > 1$ and $\lambda \in [1/s, 1)$, a contraction-type mapping need not possess a fixed point in a complete b -metric space [2].

The results in Table 1 compare the convergence speed for various values of λ and s .

Table 1. Convergence comparison: number of iterations to reach $d(x_n, x^*) < 10^{-6}$ starting from $d(x_0, x^*) = 1$.

s	λ	$s\lambda$	Iterations
1	0.5	0.50	20
2	0.4	0.80	61
2	0.3	0.60	31
3	0.3	0.90	131

5 Conclusion

In this paper we have reviewed the Banach contraction principle and its extension to b -metric spaces. The main result (Theorem 3.2) generalises the classical theorem, and the error estimates (1)–(2) provide practical convergence bounds for numerical applications.

Future work will consider weakly contractive mappings and applications to integral equations arising in mathematical physics.

Acknowledgements

The authors thank the editorial board of JMAACS for their support. The first author was partially supported by [Funding Agency, Grant No. 000].

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