Vol 8. No.2_ June 2022

TẠP CHÍ KHOA HỌC ĐẠI HỌC TÂN TRÀO

ISSN: 2354 - 1431 http://tckh.daihoctantrao.edu.vn/

TẠP CHI KHOA HỌC ĐẠI HỌC TAN TRAO

ISSN: 2354 - 1431

http://tckh.daihoctantrao.edu.vn/

MỘT MỞ RỘNG CỦA PHƯƠNG PHÁP THÁC TRIỂN THEO THAM SỐ

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Ngô Thanh Bình^{1,∗}
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Dịa chỉ Email: ntbinhspktnd@gmail.com $\begin{array}{lll} \hline \textbf{1} & \textbf{1}$ G PHÁP THÁC TRIỂN THEO :
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Tóm tắt:
Trong bài báo này, chúng tôi đề xuất một mở r

**MỘT MỞ RỘNG CỦA PHƯƠNG PHÁP THÁC TH\n GLÅI HÊ PHUONG TRÌNH PHI TUYÊN
** $Ng\hat{o}$ **Thanh Bình^{1,*}
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DOI: https://do** MỘT MỞ RỘNG CỦA PHƯƠNG PHÁI

GIẢI HỆ PHƯƠNG TRÌNH P]

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DOI: https://doi.org/10.51453/2354-1431/2022/763

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DOI: https://doi.org/10.51453/2354-1431/2022/763
 Thông tin bài viết
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DOI: https://doi.org/10.51453/2354-1431/2022/763
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Dịa chỉ Email: ntbinhspktnd@gmail.com
DOI: https://doi.org/10.51453/2354-1431/2022
Thông tin bài viết
Ngày nhận bài: 20/03/2022
Ngày sửa bài: 20/04/2022
Ngày duyệt đăng: 01/06/2022
Từ kh Địa chỉ Email: ntbinhspktnd@gmail.com DOI: https://doi.org/10.51453/2354-1431/2022/763

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Fia chi Email: ntbinhspktnd@gmail.com

DOI: https://doi.org/10.51453/2354-1431/2022/763

 Tromg tin bài viết

Phống tin bài viết

Pháp thác triển theo tham số giải

Ngày nhận bài: 20/03/2022

Pháp thác triển theo tha phương trình phi tuyến có nhiễu, Giải xấp trình bày thông qua một ví dụ.

Tôm tất:

Ngày nhận bài: 20/03/2022

Ngày sửa bài: 20/04/2022

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cứu. Chúng tôi cũng inh, Việt Nam
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AN EXTENSION OF PARAMETER CONTINUATION METHOD FOR

SOLVING PERTURBED SYSTEMS OF NONLINEAR EQUATIONS TAP CHI KHOA HỌC ĐẠI HỌC TAN TRAO

ISSN: 2354 - 1431

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NON EXTENSION OF PARAMETER CONTINUATION METHOD FOR

SOLVING PERTURBED SYSTEMS OF NONLINEAR EQUATIONS

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am Dinh Univer 1 Nam Dinh University of Technology Education, Vietnam

2 Name Dinh University of Technology Education, Vietnam

2 Ngo Thanh Binh^{1,*}

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2 Dinh University of Technol

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SOLVING PERTURBED SYSTEMS OF NONLIT

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DOI: https://doi.org/10.51453/2 AN EXTENSION OF PARAMET

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DOI: https://doi.org/10.51453/2354-1431/2022/763

Article info Email address: ntbinhspktnd@gmail.com DOI: https://doi.org/10.51453/2354-1431/2022/763

Received:20/3/2022 Revised: 20/4/2022
Accepted: 01/6/2022

Keywords:

Article info

Received:20/3/2022

Revised: 20/4/2022

Accepted: 01/6/2022

Accepted: 01/6/2022
 Keywords: be in

Parameter continuation method, Per- The v

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proximate solution. Accepted: 01/6/2022
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 1 Introduction

Solving systems of nonlinear equations is of gree

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Revised: 20/4/2022

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Ition, Vietnam
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In this paper, we propose an extension of parameter con-

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The this paper, we propose an extension of parameter con-

tinuation method for solving perturbed systems of nonlinear

equations. The existence and uniqueness of the solution will

be investigated. We also dis For the existence and the existence and the solution of parameter continuation method for solving perturbed systems of nonlinear equations. The existence and uniqueness of the solution will be investigated. We also discuss For the interest of the method. Vien
an abstract:

In this paper, we propose an extension of parameter con-

tinuation method for solving perturbed systems of nonlinear

equations. The existence and uniqueness of the solut The valid of the propose an extension of parameter continuation method for solving perturbed systems of nonlinear equations. The existence and uniqueness of the solution will be investigated. We also discuss error analysis example. systems of nonlinear equations. This work can be viewed as says the solution will gated. We also discuss error analysis of the method.
It was applicability of the method is verified by an applicability of the method is ver is. The existence and uniqueness of the solution will
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wed as an extension of the result in [4].

The remainder of this paper is structured

be investigated. We also discuss error an
 stranter continuation method, Per- The validity and applicability of the met
 bed systems of nonlinear equations, Ap-example.
 Introduction

Solving systems of nonlinear equ $\begin{minipage}[t]{0.9\textwidth} \begin{tabular}{p{0.8cm}} \textit{Parameter} \textit{continuation} & \textit{method,} & \textit{Per-} & \textit{The validity and applicability of the met}\textit{turbed systems of nonlinear equations,} \textit{Ap}-& \textit{example.} \end{tabular} \end{minipage} \begin{minipage}[t]{0.9\textwidth} \begin{tabular}{p{0.8cm}} \textit{inemation of the reactions} & \textit{inemation of the recondition} \end{tabular} \end{minipage} \begin{minipage}[t]{0.9\textwidth} \begin{tabular}{p{0.8cm}} \textit{inemation of the recondition} &$ turbed systems of nonlinear equations, Ap-

proximate solution.
 1 Introduction

Solving systems of nonlinear equations is of great

The remainder of the

importance, because these systems frequently arise lows. In Secti mate solution.
 11 Introduction

Systems of nonlinear equations

viewed as an extension of the r

Solving systems of nonlinear equations is of great

The remainder of this paper

importance, because these systems frequen **Cult 1**
 Cult to get their current solution
 Cult to get solution spaces these systems frequently arise

in many branches of computational mathematics. In Section 2, we recall

in many branches of computational mathem 1 **Introduction**
systems of nonlinear equation
viewed as an extension of the
Solving systems of nonlinear equations is of great The remainder of this pape
importance, because these systems frequently arise lows. In Section 1 **Introduction** systems of nonlinear equations is of great viewed as an extension of this parameter. Solving systems of nonlinear equations is of great The remainder of this parameter solutional mathematics. The section 2 **EXECUTE 11 INTOGUCTION**

Solving systems of nonlinear equations is of great

in many branches of computational mathematics.

In Section 2, we recal

in many branches of computational mathematics.

Systems of nonlinear equ Solving systems of nonlinear equations is of great The remainder of this paper is
portance, because these systems frequently arise lows. In Section 2, we recall som
many branches of computational mathematics. initions and Solving systems of nonlinear equations is of great

importance, because these systems frequently arise lows. In Section 2, we recall s

in many branches of computational mathematics.

Systems of nonlinear equations are us mportance, because these systems requently arise

in many branches of computational mathematics, in itions and known results before

Systems of nonlinear equations are usually diffi-

results in Section 3. Section 4 di

c In many branches of computational mathematics. Through and movies contract to get their exact solutions. So many differed in Section 3. Section 4 cult to get their exact solutions. So many differed in Section 3. Section 4

by systems of nonlinear equations are usually differ-
cult to get their exact solutions. So many differ-
entiterative methods have been proposed to obtain
approximate solutions of the systems of nonlinear
equations, which iterative methods have been proposed to obtain
iterative methods have been proposed to obtain
proximate solutions of the systems of nonlinear
ations, which were presented in [1, 6, 8, 13].
Parameter continuation method (P Example in a solution of the systems of nonlinear

equations, which were presented in [1,6,8,13].

Parameter continuation method (PCM) [7, 10, Consider the operator e

11, 14–17] is a powerful technique for solving operat **EXECUTE 21.** Preferentially be the system of $[1, 6, 8, 13]$.

Parameter continuation method (PCM) [7, 10, Consider the operator equation 11, 14–17] is a powerful technique for solving operator equations of various kinds Parameter continuation method (PCM) [7, 10, Consider the operator equations of various kinds. In recent years, the PCM has been successfully applied to solve many nonlinear equations [3, 12, 18]. In previous paper, we stu

lity and applicability of the method is verified by an
 Example 2018

Systems of nonlinear equations. This work can be

viewed as an extension of the result in [4].

The remainder of this paper is structured as fol-

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ions and known results before introducing main

ults in Section 3. Section 4 draws some conclu-

ns from the paper.
 Pre

$$
x + A(x) + B(x) = f,\tag{1}
$$

results in Section 3. Section 4 draws some conclusions from the paper.

2 **Preliminaries**

Consider the operator equation
 $x + A(x) + B(x) = f$, (1)

where A, B are nonlinear operators from the Ba-

nach space X into itself and **2 Preliminaries**

Consider the operator equation
 $x + A(x) + B(x) = f$, (1)

where *A*, *B* are nonlinear operators from the Ba-

mach space *X* into itself and *f* is a given function

in *X*. **2 Preliminaries**

Consider the operator equation
 $x + A(x) + B(x) = f$, (1)

where A, B are nonlinear operators from the Ba-

nach space X into itself and f is a given function

in X.
 Definition 2.1. (see [7]) The mapping A, Consider the operator equation
 $x + A(x) + B(x) = f$, (1)

where A, B are nonlinear operators from the Ba-

nach space X into itself and f is a given function

in X.
 Definition 2.1. (see [7]) The mapping A, which

operates in

Ngo Thanh Binh/Vol 8. No.2_Jun
if for any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ the *where*
following inequality holds $q_A =$
 $||x_1 - x_2 + \varepsilon [A(x_1) - A(x_2)]|| \ge ||x_1 - x_2||$. (2) $\frac{\text{for } A}{B, n}$

$$
||x_1 - x_2 + \varepsilon [A(x_1) - A(x_2)]|| \ge ||x_1 - x_2||. (2)
$$

Ngo Thanh Binh/Vol 8. No.2_ June 2022|p.163-167

if for any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ the *where N* is the smallest natura

following inequality holds
 $q_A = \frac{L}{N} < 1, L$ is Lipschitz coefficially
 $||x_1 - x$ *Ngo Thanh Binh/*Vol 8. No.2_ June 2022|p.163-167

if for any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ the where N is the smallest natural

following inequality holds
 $q_A = \frac{L}{N} < 1$, L is Lipschitz coeffici
 $||x_1 - x_2 + \vare$ *Ngo Thanh Binh/Vol*
if for any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ t
following inequality holds
 $||x_1 - x_2 + \varepsilon [A(x_1) - A(x_2)]|| \ge ||x_1 - x_2||$.
Remark 2.2. (see [7]) If X is Hilbert space th
the condition of monotony (2) i or any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ the where N is the smallest

wing inequality holds
 $q_A = \frac{L}{N} < 1$, L is Lipsch:
 $x_1 - x_2 + \varepsilon [A(x_1) - A(x_2)] \le ||x_1 - x_2||$. (2) tor A, q_B is a contraction
 mark 2.2. (see [if for any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ the *where* N is the smallest natur
following inequality holds
 $q_A = \frac{L}{N} < 1, L$ is Lipschitz coe,
 $||x_1 - x_2 + \varepsilon [A(x_1) - A(x_2)]|| \ge ||x_1 - x_2||$. (2) \qquad tor A, q_B is a con

$$
\langle A(x_1) - A(x_2), x_1 - x_2 \rangle \ge 0, \ \forall x_1, x_2 \in X,
$$

 $||x_1 - x_2 + \varepsilon [A(x_1) - A(x_2)]|| \ge ||x_1 - x_2||$. (2) $B, n = 1, 2,$
 Remark 2.2. (see [7]) If X is Hilbert space then

the condition of monotony (2) is equivalent to the Next, we introduce the following

classical condition
 \langle **Remark 2.2.** (see [7]) If X is Hilbert space then
the condition of monotony (2) is equivalent to the
classical condition
 $\langle A(x_1) - A(x_2), x_1 - x_2 \rangle \ge 0, \forall x_1, x_2 \in X,$
where $\langle \cdot, \cdot \rangle$ is an inner product in the Hilbert spa **a** contraction of monotony (2) is equivalent to the $(A(x_1) - A(x_2), x_1 - x_2) \ge 0$, $\forall x_1, x_2 \in X$, **Theorem 2.5.** (see $\forall x_1, x_2 \in X$, **Theorem 2.5.** (see $\forall x_1, x_2 \in X$, **Theorem 2.5.** (see $\forall x_1, x_2 \in X$, **Theorem 2.5.** (s and the solution for any element f exception of the proof of the classical condition
 $\langle A(x_1) - A(x_2), x_1 - x_2 \rangle \ge 0, \forall x_1, x_2 \in X,$

Theorem 2.5. (see [4]) Assume

where $\langle \cdot, \cdot \rangle$ is an inner product in the Hilbert space
 Find a paper in the Hilbert space
 $f(x, y)$ is an inner product in the Hilbert space
 $f(x, y)$ is an inner product in the Hilbert space
 $f(x, y)$ is a differentiable mappin
 $f(x, y)$ is $f(x, y)$ and $f(x, y)$ and $f(x, y)$ is $f(x$

Lipschitz-continuous and monotone operator, B is The *subgroup*
$$
[a, b]
$$
 has a *unitary in* $[a, b]$ $$

$$
x_{i+1} = -\varepsilon_0 A(x_i) + x_j^{(1)}, \, i = 0, 1, \dots,
$$
 (4a)

$$
x_{j+1}^{(1)} = -\varepsilon_0 A G_1^{-1}(x_j^{(1)}) + x_l^{(2)}, \, j = 0, 1, \dots, \quad (4b)
$$

$$
x_{p+1}^{(N)} = -BG_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, \dots,
$$

$$
x_0^{(N)} = f,\t\t(4d)
$$

 $\begin{aligned}\n &\text{equa} \, (x_j^{(1)}) + x_j^{(1)}, \, i = 0, 1, \ldots, \\
 &\text{equa} \, (4a) \\
 &\text{equa} \, (4c) \\
 &\text{where} \, (4d) \\
 &\text{equa} \, (4e) \\
 &\text{where} \, (4e) \\
 &\text$ where $x^{(1)} = x + \varepsilon_0 A(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$ (and in processes and $x + F$
 $= -\varepsilon_0 A(x_i) + x_j^{(1)}, i = 0, 1, ...,$ (4a)
 $= -\varepsilon_0 A G_1^{-1}(x_j^{(1)}) + x_l^{(2)}, j = 0, 1, ...,$ (4b)
 \therefore
 $= -BG_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, ...,$ wector, $b = (b_1, b_2)$
 $= c_0 C_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, ...,$ wec $\varepsilon_0 A G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x)$ • $B G_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, \ldots,$
 $x_0^{(N)} = f,$ (4d

¹⁾ = $x + \varepsilon_0 A(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$

that the number of steps in each iteration

of iteration processes (4a)–(4d) is the $\begin{array}{ll} x_{i+1}=-\varepsilon_0A(x_i)+x_j^{(1)},\ i=0,1,\ldots, & \text{(4a)}\\ x_{j+1}^{(1)}=-\varepsilon_0AG_1^{-1}(x_j^{(1)})+x_l^{(2)},\ j=0,1,\ldots, & \text{(4b)}\\ \quad \ \, \ldots, & \text{(4c)}\\ x_{p+1}^{(N)}=-BG_1^{-1}\cdots G_N^{-1}(x_p^{(N)})+f, p=0,1,\ldots, & \text{vector, } b=(b_1,b_2,\ldots, b_n)^T\\ x_0^{(N)}=f, & \text{(4d)}\\ \quad \ \, \text{where }x^{(1)}$ $\begin{array}{llll} x_{j+1}^{(1)}=-\varepsilon_0 AG_1^{-1}(x_j^{(1)})+x_t^{(2)}, \, j=0,1,\ldots, & \mbox{(4b)} & x+F(x)+\Phi(x)\\ \ldots, & \mbox{(4c)} & \mbox{where}\ x=(x_1,x_2,\ldots,x_n)^T & \mbox{vector,}\ b=(b_1,b_2,\ldots,b_n)^T & \mbox{vector,}\ b=(b_1,b_2,\ldots,b_n)^T & \mbox{vector,}\ F(x)=(f_1(x),f_2(x),\\ x_0^{(N)}=f, & \mbox{(4d)} & (\varphi_1(x),\varphi_2(x),\ldots,\varphi_n(x))^T & \$ $x_{p+1} = -\varepsilon_0 \Lambda \sigma_1^{-1} \dots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, \dots,$
 $x_0^{(N)} = f,$ (4d) where $x = (x_1, x_2, \dots, x_n)^T \in$
 $x_0^{(N)} = f,$ (4d) $(x_0, x_0^{(N)}) = f,$ (4d) $(x_1, x_2^{(N)}, \dots, x_n^{(N)}) = f,$

where $x^{(1)} = x + \varepsilon_0 A(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$ nonli $x_{p+1}^{(N)} = -BG_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, \ldots,$ vector, $b = (b_1, b_2, \ldots, b_n)^T$
 $x_0^{(N)} = f,$ (4d) vector, $F(x) = (f_1(x), f_2(x),$

where $x^{(1)} = x + \varepsilon_0 A(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$ nonlinear mappings.
 $\varepsilon_0 A G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{$ $x_{p+1}^{(N)} = -BG_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, \ldots,$
 $x_0^{(N)} = f,$ (4d) $(\varphi_1(x), \varphi_2(x), \ldots, \varphi_n(x))^T$

where $x^{(1)} = x + \varepsilon_0 A(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$ nonlinear mappings.
 $\varepsilon_0 A G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$.

Ass theorem. where $x^{(1)} = x + \varepsilon_0 A(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + \text{nonlinear mappings.}$
 $\varepsilon_0 A G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2.$

Assume that the number of steps in each iteration

scheme of iteration processes (4a)-(4d) is the same

and equal $\begin{aligned}\n\text{Hence,} \ E_0 A G_1^{-1} \cdots G_k^{-1}(x) &\equiv G_{k+1}(x), \ k=1,2,\ldots,N-2. \\
\text{Assume that the number of steps in each iteration} \end{aligned}$ $\begin{aligned}\n\text{Hence,} \ E_0 A G_1^{-1} \cdots G_k^{-1}(x) &\equiv G_{k+1}(x), \ k=1,2,\ldots,N-2. \\
\text{Setermine the number of steps in each iteration} \end{aligned}$ $\begin{aligned}\n\text{Hence,} \ E_0 A G_1^{-1} \cdots G_k^{-1}(x) &\equiv G_{k+1}(x), \ k=1,2,\ldots,N-2. \\$ **Example 1.1** Theorem **3.1.** Suppose that

Assume that the number of steps in each iteration

scheme of iteration processes (4a)–(4d) is the same

and equals n. Let x_n be approximate solutions of (i) F is a differenti

to the equation 1. Note that x_n depends on N . Hence

the equation 1. Note that x_n depends on N . Hence

the equation 1. Note that x_n depends on N . Hence

theorem.

(ii) $\left| \frac{\partial f_i}{\partial x_i} \right| \leq \alpha$, $i = \overline{1, n}$,
 heorem **2.4.** (see [5]) Let the assumption

Theorem 2.3 are satisfied. Then the sequence

pproximate solutions {x(n, N)}, n = 1, 2,...

tructed by iteration processes (4a)-(4d) conve

o the exact solution $x \in X$ of the e

$$
||x(n,N)-x|| \le \frac{1}{1-q_B} \left[\frac{q_A^{n+1}}{1-q_A} \frac{1-q_B^{n+1}}{1-q_B} \frac{e^{q_A N} - 1}{e^{q_A} - 1} - \frac{e^{q_A N} - 1}{1-q_B} \frac{e^{q_A N} - 1}{e^{q_A} - 1} \right]
$$

Then the perturbed system of
 (7) has a unique solution for a

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if for any elements $x_1, x_2 \in X$ and any $\varepsilon > 0$ the *where N* is the smallest nat

following inequality holds $q_A = \frac{L}{N} < 1$, *L* is *Lipschitz* ϵ
 $||x_1 - x_2 + \varepsilon [$ tor A, q_B is a contraction coefficient of the operator $B, n = 1, 2, \ldots$ 2_ June 2022|p.163-167
where N is the smallest natural number such that
 $q_A = \frac{L}{N} < 1, L$ is Lipschitz coefficient of the opera-
tor A, q_B is a contraction coefficient of the operator $q_A = \frac{L}{N} < 1, L$ is Lipschitz coefficient of t $2022|p.163-167$

is the smallest natural number such that
 $< 1, L$ is Lipschitz coefficient of the opera-
 $\frac{1}{2}, \ldots$ 2_June 2022|p.163-167
where N is the smallest natural number such that
 $q_A = \frac{L}{N} < 1, L$ is Lipschitz coefficient of the operator
 A, q_B is a contraction coefficient of the operator
 $B, n = 1, 2,$ 2_ June 2022|p.163-167

where N is the smallest natural number such that
 $q_A = \frac{L}{N} < 1$, L is Lipschitz coefficient of the operator
 A , q_B is a contraction coefficient of the operator
 B , $n = 1, 2, ...$

Next, we int 2_ June 2022|p.163-167

where N is the smallest natural number such that
 $q_A = \frac{L}{N} < 1$, L is Lipschitz coefficient of the operator
 A, q_B is a contraction coefficient of the operator
 $B, n = 1, 2, ...$

Next, we introduce 2_ June 2022|p.163-167

where N is the smallest natural number such that
 $q_A = \frac{L}{N} < 1$, L is Lipschitz coefficient of the operator
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Next, we int where N is the smallest natural number such that
 $q_A = \frac{L}{N} < 1$, L is Lipschitz coefficient of the operator
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Next, we introduce the following tec where *I*v is the smallest natural number such $q_A = \frac{L}{N} < 1$, *L* is *Lipschitz coefficient of the oper* B , $n = 1, 2, ...$

Next, we introduce the following technical v

known theorem for the proof of the main resul
 Th

tor A, q_B is a contraction coefficient of the operator
 $B, n = 1, 2,$

Next, we introduce the following technical well-

known theorem for the proof of the main result.
 Theorem 2.5. (see [4]) Assume that, $F : \mathbb{R}^n$ *B*, $n = 1, 2, \ldots$

Next, we introduce the following technical well-

known theorem for the proof of the main result.
 Theorem 2.5. (see [4]) Assume that, $F : \mathbb{R}^n \to$
 \mathbb{R}^n is a differentiable mapping and satis for the proof of the main result.
 heorem 2.5. (see [4]) Assume that, $F : \mathbb{R}^n \to$

ⁿ is a differentiable mapping and satisfies the fol-

wing conditions:
 $\frac{\partial f_i}{\partial x_i} \geq \alpha$, $i = \overline{1, n}$,
 $\Big| \frac{\partial f_i}{\partial x_j} \Big| \leq \$ that, $F : \mathbb{R}^n \to$

satisfies the fol-
 x , $y \in \mathbb{R}^n$. (6)
 $\forall x, y \in \mathbb{R}^n$. (6)
 $\therefore 1)\beta = 0$ then F
 $1)\beta > 0$ then F

\n- i)
$$
\frac{\partial f_i}{\partial x_i} \geq \alpha, \ i = \overline{1, n},
$$
\n- ii) $\left| \frac{\partial f_i}{\partial x_j} \right| \leq \beta, i \neq j, \ i, j = \overline{1, n}.$
\n- Then, the following inequality holds
\n

$$
\langle F(x) - F(y), x - y \rangle \geq [\alpha - (n-1)\beta] \|x - y\|^2,
$$

$$
\forall x, y \in \mathbb{R}^n. \quad (6)
$$

 \mathbb{R}^n is a differentiable mapping and satisfies the fol-
lowing conditions:
(i) $\frac{\partial f_i}{\partial x_i} \geq \alpha$, $i = \overline{1, n}$,
(ii) $\left| \frac{\partial f_i}{\partial x_j} \right| \leq \beta, i \neq j$, $i, j = \overline{1, n}$.
Then, the following inequality holds
 $\langle F(x) - F(y),$ *lowing conditions:*

(i) $\frac{\partial f_i}{\partial x_i} \ge \alpha$, $i = \overline{1, n}$,

(ii) $\left| \frac{\partial f_i}{\partial x_j} \right| \le \beta$, $i \neq j$, $i, j = \overline{1, n}$.
 Then, the following inequality holds
 $\langle F(x) - F(y), x - y \rangle \ge [\alpha - (n - 1)\beta] ||x - y||^2$,
 $\forall x, y \in \mathbb{R}^n$. (6)
 (i) $\frac{\partial f_i}{\partial x_i} \ge \alpha$, $i = \overline{1, n}$,

(ii) $\left| \frac{\partial f_i}{\partial x_j} \right| \le \beta, i \neq j$, $i, j = \overline{1, n}$.

Then, the following inequality holds
 $\langle F(x) - F(y), x - y \rangle \ge [\alpha - (n-1)\beta] ||x - y||^2$,
 $\forall x, y \in \mathbb{R}^n$. (6)
 Remark 2.6. (see [4]) If $\langle F(x) - F(y), x - y \rangle \geq [\alpha - (n-1)\beta] ||x - y||^2,$
 $\forall x, y \in \mathbb{R}^n$. (6)
 Remark 2.6. (see [4]) If $\alpha - (n-1)\beta = 0$ then *F*

is monotone mapping. If $\alpha - (n-1)\beta > 0$ then *F*

is strongly monotone mapping.
 3 Main results

In thi Fig. (a) $\mathbf{I}(\mathbf{g})$, $\mathbf{w}(\mathbf{g}) = \mathbf{g}(\mathbf{g})$ of $\mathbf{g}(\mathbf{g}) = \mathbf{g}(\mathbf{g})$.
 $\forall x, y \in \mathbb{R}^n$. (6)
 In this section, we propose an extension of the
 Main results

In this section, we propose an extension of vx, $y \in \mathbb{R}$. (b)

Remark 2.6. (see [4]) If $\alpha - (n-1)\beta = 0$ then F

is monotone mapping. If $\alpha - (n-1)\beta > 0$ then F

is strongly monotone mapping.
 3 Main results

In this section, we propose an extension of the

PCM fo **Remark 2.6.** (see [4]) If $\alpha - (n-1)\beta = 0$ then F
is monotone mapping. If $\alpha - (n-1)\beta > 0$ then F
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3 Main results
In this section, we propose an extension of the
PCM for solving perturbed sys

 \overline{N} , $p = 0, 1, \ldots$ (3) **3 Main results**
 \overline{N} , $p = 0, 1, \ldots$ (3) **3 Main results**

and be understood as
 \overline{P} . In this section, we propose PCM for solving perturbed
 \overline{P} , \overline{P} , \overline{P} , \overline{P} ,

$$
x + F(x) + \Phi(x) = b,\t(7)
$$

(4c) where $x = (x_1, x_2, \ldots, x_n)^T \in \mathbb{R}^n$ is unknown $e_{\mathbf{0}}A(x_i) + x_j^{(1)}, i, j, \ldots, p = 0, 1, \ldots$ (b) 3 Main results
olic notation (3) should be understood as
ing iteration processes, which consist of
reform solving perturbed symptoms in several variables
 $-\varepsilon_0 A(x_i) + x_j^{(1)}, i =$ vector, $F(x) = (f_1(x), f_2(x), \dots, f_n(x))^T, \Phi(x) = (\varphi_1(x), \varphi_2(x), \dots, \varphi_n(x))^T$ and $F, \Phi : \mathbb{R}^n \to \mathbb{R}^n$ are nonlinear mappings. **3 Main results**

In this section, we propose an extension of the

PCM for solving perturbed system of nonlinear

equations in several variables
 $x + F(x) + \Phi(x) = b,$ (7)

where $x = (x_1, x_2, ..., x_n)^T \in \mathbb{R}^n$ is unknown

vector, an extension of the

ystem of nonlinear

= b, (7)

∈ \mathbb{R}^n is unknown

∈ \mathbb{R}^n is a given

∴ $f_n(x)$ ^T, $\Phi(x)$ = **3 Main results**

In this section, we propose an extension of the

PCM for solving perturbed system of nonlinear

equations in several variables
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where $x = (x_1, x_2, ..., x_n)^T \in \mathbb{R}^n$ is unknown

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F, $\Phi : \mathbb{R}^n \to \mathbb{R}^n$ are In this section, we propose an extension of the

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equations in several variables
 $x + F(x) + \Phi(x) = b,$ (7)

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vector, $b = (b_1, b_2, ..., b_n)^T$ on of the

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 $\Rightarrow \mathbb{R}^n$ are In this section, we propose an extension of the

PCM for solving perturbed system of nonlinear

equations in several variables
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PCM for solving perturbed system of nonlinear

equations in several variables
 $x + F(x) + \Phi(x) = b,$ (7)

where $x = (x_1, x_2, ..., x_n)^T \in \mathbb{R}^n$ is unknown

vector, $b = (b_1, b_2, ..., b_n)^T$ equations in several variables
 $x + F(x) + \Phi(x) = b,$ (7)

where $x = (x_1, x_2, ..., x_n)^T \in \mathbb{R}^n$ is unknown

vector, $b = (b_1, b_2, ..., b_n)^T \in \mathbb{R}^n$ is a given

vector, $F(x) = (f_1(x), f_2(x), ..., f_n(x))^T, \Phi(x) =$
 $(\varphi_1(x), \varphi_2(x), ..., \varphi_n(x))^T$ and $F, \$ $x + F(x) + \Phi(x) = b,$ (

where $x = (x_1, x_2, ..., x_n)^T \in \mathbb{R}^n$ is unknow

vector, $b = (b_1, b_2, ..., b_n)^T \in \mathbb{R}^n$ is a give

vector, $F(x) = (f_1(x), f_2(x), ..., f_n(x))^T, \Phi(x)$
 $(\varphi_1(x), \varphi_2(x), ..., \varphi_n(x))^T$ and $F, \Phi : \mathbb{R}^n \to \mathbb{R}^n$ a

nonlinear ma here $x = (x_1, x_2, ..., x_n)^T \in \mathbb{R}^n$ is unknown

ector, $b = (b_1, b_2, ..., b_n)^T \in \mathbb{R}^n$ is a given

ector, $F(x) = (f_1(x), f_2(x), ..., f_n(x))^T, \Phi(x) =$
 $p_1(x), \varphi_2(x), ..., \varphi_n(x))^T$ and $F, \Phi : \mathbb{R}^n \to \mathbb{R}^n$ are

bend and $F, \Phi : \mathbb{R}^n \to \mathbb{R}$ ector, $b = (b_1, b_2, ..., b_n)^T \in \mathbb{R}^n$ is a given

ector, $F(x) = (f_1(x), f_2(x), ..., f_n(x))^T, \Phi(x) =$
 $\varphi_1(x), \varphi_2(x), ..., \varphi_n(x))^T$ and $F, \Phi : \mathbb{R}^n \to \mathbb{R}^n$ are

onlinear mappings.
 Theorem 3.1. Suppose that the following condi-

ions $(\alpha, \beta, \ldots, \varphi_n(x))^T$ and $F, \Phi : \mathbb{R}^n \to \mathbb{R}^n$ are
 a mappings.
 a 3.1. Suppose that the following condi-

satisfied

a differentiable mapping;
 $\geq \alpha, i = \overline{1, n};$
 $|\leq \beta, i \neq j, i, j = \overline{1, n};$
 $(n-1)\beta \geq 0;$
 $\partial f_i(x$

-
-

(iii)
$$
\left| \frac{\partial f_i}{\partial x_j} \right| \leq \beta, i \neq j, i, j = \overline{1, n};
$$

(iv) $\alpha - (n-1)\beta > 0$;

(v) ⁿ j=1 [|] ∂fi(x1,x2,...,xn) ∂x^j | ≤ L, [∀]^x [∈] ^R n , [∀]ⁱ ⁼ ¹, n; (vi) There is a positive real number q < ¹ such Φ(x) [−] Φ(y) [≤] ^q ^x [−] ^y, [∀]x, y [∈] ^R . Then the perturbed system of nonlinear equations (7) has a unique solution for any ^b [∈] ^Rⁿ.

that

$$
\|\Phi(x) - \Phi(y)\| \le \overline{q} \|x - y\|, \ \forall x, y \in \mathbb{R}^n.
$$

Ngo Thanh Binh/Vol 8. No.2_ June 2022 $|p.163-167$
Proof. From the assumptions (i)-(iv), by Theo- where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G$
rem 2.5 and Remark 2.6 we have F is monotone $\varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x)$
mapping. Let *Ngo Thanh Binh/Vol 8.* No.2_ June 2022|p.163-167
Proof. From the assumptions (i)-(iv), by Theo- where $x^{(1)} = x + \varepsilon_0 F(x) =$
rem 2.5 and Remark 2.6 we have F is monotone $\varepsilon_0 F G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+}$
mapping. Let $F'(x)$ *Ngo Thanh Binh/Vol 8.*
 Proof. From the assumptions (i)-(iv), by Theo

rem 2.5 and Remark 2.6 we have F is monotone

mapping. Let $F'(x) \equiv A = (a_{ij})$, where $a_{ij} = \frac{\partial f_i(x_1, x_2, ..., x_n)}{\partial x_j}$. The assumption (v) is equivalent *Ngo Thanh Binh/*Vol 8. No.2_ June 2022|p.163-167
 \therefore assumptions (i)-(iv), by Theo-

where $x^{(1)} = x + \varepsilon_0 F(x)$

mark 2.6 we have F is monotone
 $\varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_k$
 $\qquad'(x) \equiv A = (a_{ij})$, where $a_{ij} =$

Assume tha $\frac{\partial f_i(x_1, x_2, \ldots, x_n)}{\partial x_j}$. The assumption Ngo Thanh Binh/Vol 8. No.2_ June 2022|p.163-167

the assumptions (i)-(iv), by Theo-

where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x)$

Remark 2.6 we have F is monotone
 $\varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k :$
 $F'(x) \equiv A = (a_{ij})$, where $a_{ij} =$
 $\sum_{i=1}^{n} |a_{ij}| \leq L$. For any $h = (h)$ $j=1$ *Ngo Thanh Binh/*Vol 8. No.2_ June 2022|p.163-167
 of. From the assumptions (i)-(iv), by Theo-

where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x)$

2.5 and Remark 2.6 we have *F* is monotone
 $\varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k$

pping. L have

$$
\frac{\partial f_i(x_1, x_2, ..., x_n)}{\partial x_j}
$$
\nThe assumption (v) is equivalent to \overline{f} at the $\overline{f$

$$
||A(h)||_{\infty} = \max_{1 \le i \le n} \sum_{j=1}^{n} |a_{ij}h_j| \le \max_{1 \le i \le n} \sum_{j=1}^{n} |a_{ij}|||h||_{\infty}
$$

 $\le L||h||_{\infty}$.
 $\le L||h||_{\infty}$.
 $\le L||h||_{\infty}$.

 $|a_{ij}h_j| \leq \max_{j=1}^n |a_{ij}|||h||_{\infty}$.
 Theorem 3.3
 $= \sum_{j=1}^n |a_{ij}|||h||_{\infty}$.
 $|a_{ij}h_j| \leq \max_{1 \leq i \leq n} \sum_{j=1}^n |a_{ij}|||h||_{\infty}$ eration process
 $|a_{ij}h_j| \leq \sum_{1 \leq i \leq n} \sum_{j=1}^n |a_{ij}||h||_{\infty}$.
 $\leq L||h||_{\infty}$.
 \therefore *j*=1 *j*=1 *j*=1 *i* $\sum_{j=1}^{n} |a_{ij}||h||_{\infty}$. **Theorem 3.3.** Let the *solutions* { $x(n, N)$ }, *n* = 1

It follows that
 $||A(h)||_{\infty} = \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}h_j| \leq \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}||h||_{\infty}$ *eration processe* $\text{H follows that} \quad \begin{aligned} \n\|A(h)\|_{\infty} &= \sum_{j=1}^{n} |a_{ij}|||h\|_{\infty}. \quad \text{Theorem 3.3.}\n\end{aligned}$ It follows that
 $\|A(h)\|_{\infty} = \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}h_j| \leq \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}|||h\|_{\infty}. \quad \text{function process} \in \mathbb{R}$
 $\text{Hence } \|A\|_{\infty} \leq L <$ It follows that
 $\|A(h)\|_{\infty} = \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}h_j| \leq \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}||h||_{\infty}$
 $\|A(h)\|_{\infty} = \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}h_j| \leq \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}||h||_{\infty}$
 $\text{Hence } \|A\|_{\infty} \leq L < +\infty \text{ then } F \$ It follows that
 $\|A(h)\|_{\infty} = \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}h_j| \leq \max_{1 \leq i \leq n} \sum_{j=1}^{n} |a_{ij}|||h\|_{\infty}$
 $\leq L ||h||_{\infty}$.
 $\leq L ||h||_{\infty}$.

Hence $||A||_{\infty} \leq L < +\infty$ then F is Lipschitz-
 $\leq L ||h||_{\infty}$.
 $\leq L ||h||_{\infty}$.
 Find $\|A\|_{\infty} \leq \frac{1}{1 \leq i \leq n} \sum_{j=1}^{\lfloor \alpha_{ij} \rfloor} \sum_{j=1}$ Figure $\|A\|_{\infty} \leq L \times +\infty$ then F is Lipschitz

continuous mapping with Lipschitz coefficient

equal to L. It follows from the assumption (vi) that
 Φ is a contraction mapping with contraction coef-

ficient equal t Allow $\leq L < +\infty$ then *F* is Lipschitz-
continuous mapping with Lipschitz coefficient $\|x(n,N)-x\| \leq$
equal to *L*. It follows from the assumption (vi) that
 Φ is a contraction mapping with contraction coef-
ficient equ Hence $||A||_{\infty} \leq L < +\infty$ then *F* is Lipschitz
continuous mapping with Lipschitz coefficient $||x(n, N) - x|| \leq \frac{1}{1 - \overline{q}} \left[\frac{q^{n+1}}{1 - \overline{q}} \right]$
equal to *L*. It follows from the assumption (vi) that $+ \overline{q}^{n+1}$ ||
 $\$

continuous mapping with Lipschitz coefficient \mathbb{R}^n equal to *L*. It follows from the assumption (vi) that Φ is a contraction mapping with contraction coefficient equal to $\overline{q} < 1$.

Consequently, all condition equal to *L*. It follows from the assumption (vi) that Φ is a contraction mapping with contraction coef-
ficient equal to $\overline{q} < 1$.
Consequently, all conditions of Theorem 2.4 are sat. $q = \frac{L}{N} < 1$, *L* is *Lipsch* Φ is a contraction mapping with contraction coef-
ficient equal to $\overline{q} < 1$.
Consequently, all conditions of Theorem 2.4 are sat-
isfied. By Theorem 2.4, the perturbed system of $q = \frac{L}{N} < 1$, L is Lipschitz coef ficient equal to $\overline{q} < 1$.

Consequently, all conditions of Theorem 2.4 are sat-

is fied. By Theorem 2.4, the perturbed system of F and \overline{q} is a contraction coefficie

is fied. By Theorem 2.4, the perturbed sys Consequently, all conditions of Theorem 2.4 are sat-

isfied. By Theorem 2.4, the perturbed system of F and \overline{q} is a contraction coefficie

nonlinear equations (7) has a unique solution for Φ .

any $b \in \mathbb{R}^n$ isfied. By Theorem 2.4, the perturbed system of F and q is a contraction coef,
nonlinear equations (7) has a unique solution for Φ .
any $b \in \mathbb{R}^n$. This completes the proof. \Box
Remark 3.2. In the perturbed sys nonlinear equations (7) has a unique solution for

any $b \in \mathbb{R}^n$. This completes the proof. \Box
 Remark 3.2. In the perturbed system of nonlin-

ear equations (7), we can consider the monotone

and Lipschitz-contin any $b \in \mathbb{R}^n$. This completes the proof. \square
 Remark 3.2. In the perturbed system of nonlinear equations (7), we can consider the monotone

ear equations (7), we can consider the monotonear equations

and Lipschitz **Remark 3.2.** In the perturbed system of nonlin-

ear equations (7), we can consider the monotone

and Lipschitz-continuous mapping F as the main

tubation mapping or vice versa. This result is the

extend of the known re ear equations (7), we can consider the monotone

and Lipschitz-continuous mapping F as the main **Example 3.1.** Consider t

mapping while the contractive operator Φ as a per-

tubation mapping or vice versa. This result and Lipschitz-continuous mapping F as the main

mapping while the contractive operator Φ as a per-

tubation mapping or vice versa. This result is the

extend of the known result on the application of the

method of co mapping while the contractive operator Φ as a per-

tubation mapping or vice versa. This result is the

extend of the known result on the application of the

method of contractive mapping for solving system

of nonline tubation mapping or vice versa. This result is the
extend of the known result on the application of the
method of contractive mapping for solving system
of nonlinear equations and result in [4] about PCM
for solving syste extend of the known result on the application of the

method of contractive mapping for solving system

of nonlinear equations and result in [4] about PCM

for solving system of nonlinear equations. Indeed,

we write this method of contractive mapping for solving system

of nonlinear equations and result in [4] about PCM

for solving system of nonlinear equations. Indeed,

we write this system as the form

we consider the two following spe of nonlinear equations and result in [4] about PCM
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we consider the two following special cases. When
 $F \equiv 0$ the equation (7) has form $x + \$ for solving system of nonlinear equations. Indeed, we write this system as the

we consider the two following special cases. When
 $F \equiv 0$ the equation (7) has form $x + \Phi(x) = b$ with
 Φ is a contraction mapping. When Φ

processes mapping. When $\Phi \equiv 0$ the equa-
 $x + F(x) = b$ with F is monotone (f₁(*x*) the summary of the equal of the equation of the expression of the approximate so-

respectively, the approximate so-

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respectively, is a contraction mapping. When $\Phi \equiv 0$ the equa-

on (7) has form $x + F(x) = b$ with F is monotone

(f₁(x₁, x₂), f₂(x₁, x₂))⁷

dd Lipschitz - continuous mapping.

y substituting F, Φ , b for A, B, f in iterat $\mathbf{H}^{-1}(t)$ has form $x + F(x) = 0$ which F is monotone

L Lipschitz - continuous mapping.

substituting F , Φ, b for A , B , f in iteration pro-

ses (4a)-(4d), respectively, the approximate so-

ions of the per (x) = 0 with *F* is monotone (y₁(x₁, x₂)

ous mapping.

for *A*, *B*, *f* in iteration pro-

tively, the approximate so-
 $f_2(x_1, x_2)$

d system of nonlinear equa-

by the following iteration and $\Phi(x)$:

It is eas

$$
x_{i+1} = -\varepsilon_0 F(x_i) + x_j^{(1)}, \, i = 0, 1, \dots,
$$
 (8a)

$$
x_{j+1}^{(1)} = -\varepsilon_0 FG_1^{-1}(x_j^{(1)}) + x_l^{(2)}, \ j = 0, 1, \dots, \quad \text{(8b)} \quad\n\begin{aligned}\n&\alpha - (n-1)\beta = \frac{1}{3} - (2 - \frac{1}{3}) \\
&\xi = \frac{2}{3}, \\
&\xi = \frac{1}{3} \frac{\partial f_i(x_1, x_2)}{\partial x_j} \leq L = \frac{5}{3},\n\end{aligned}
$$

$$
x_{i+1} = -\varepsilon_0 F(x_i) + x_j^{(1)}, \quad i = 0, 1, \ldots, \qquad \text{(8a)} \quad \text{and } \left| \frac{\partial f_i}{\partial x_j} \right|
$$
\n
$$
x_{j+1}^{(1)} = -\varepsilon_0 F G_1^{-1}(x_j^{(1)}) + x_l^{(2)}, \quad j = 0, 1, \ldots, \qquad \text{(8b)} \quad \frac{\alpha - (n-1)}{\alpha - (n-1)}
$$
\n
$$
\ldots, \qquad \text{(8c)} \quad \sum_{j=1}^{\infty} \left| \frac{\partial f_i(x_j, x_j)}{\partial x_j} \right|
$$
\n
$$
x_{p+1}^{(N)} = -\Phi G_1^{-1} \cdots G_N^{-1}(x_p^{(N)}) + f, p = 0, 1, \ldots, \qquad \text{For all } x = x_0^{(N)} = b,
$$
\n
$$
\text{(8d)}
$$
\n66|

where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$ 2022|p.163-167

(1) = $x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$
 $\cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, ..., N-2.$

me that, the numbers of steps in each iter-

heme of iteration processes (8a)–(8d) is the $\varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2.$

 $|a_{ij}| \max_{1 \leq j \leq n} |h_j|$ rem. denote $x(n, N) \equiv x_n$. We have the following theorem. 2_ June 2022|p.163-167
where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = \varepsilon_0 F G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots$
Assume that, the numbers of steps in ea
ation scheme of iteration processes (8a)-(8c
same and equals *n*. Let x_n $(0.022|p.163-167)$

⁽¹⁾ = $x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$
 $\cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$

are that, the numbers of steps in each iteration processes (8a)-(8d) is the

dequals *n*. Let x_n be approximate so June 2022|p.163-167

ere $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + F G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2.$

Assume that, the numbers of steps in each iter-

on scheme of iteration processes (8a)–(8d) is the

ne and equa 2_June 2022|p.163-167
where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + \varepsilon_0 F G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2.$
Assume that, the numbers of steps in each iter-
ation scheme of iteration processes (8a)–(8d) is the
sa 2_ June 2022|p.163-167
where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + \varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$.
Assume that, the numbers of steps in each iter-
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where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + \varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$.
Assume that, the numbers of steps in each iter-
ation scheme of iteration processes (8a)–(8d) is the
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where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} +$
 $\varepsilon_0 FG_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$.
Assume that, the numbers of steps in each iter-
ation scheme of iteration processes (8a)-(8d) is the
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where $x^{(1)} = x + \varepsilon_0 F(x) \equiv G_1(x), x^{(k+1)} = x^{(k)} + \varepsilon_0 F G_1^{-1} \cdots G_k^{-1}(x) \equiv G_{k+1}(x), k = 1, 2, \ldots, N-2$.

Assume that, the numbers of steps in each iter-

ation scheme of iteration processes (8a)-(8d) is t Assume that, the numbers of steps in each iter-

assume that, the numbers of steps in each iter-

assume and equals *n*. Let x_n be approximate solu-

tions of the perturbed system of nonlinear equa-

tions (7). Note tha solution scheme of iteration processes $(8a)–(8d)$ is the
same and equals *n*. Let x_n be approximate solu-
tions of the perturbed system of nonlinear equa-
tions (7). Note that x_n depends on *N*, hence we
denote $x(n, N$

Theorem 3.3. Let the assumptions of Theorem 3.1 be satisfied. Then the sequence of approximate $|a_{ij}| ||h||_{\infty}$ solution $x \in \mathbb{R}^n$ of the perturbed system linear equations (7). Moreover, the following esti-
mates hold example and equals n. Let x_n be approximate solu-
tions of the perturbed system of nonlinear equa-
tions (7). Note that x_n depends on N, hence we
denote $x(n, N) \equiv x_n$. We have the following theo-
rem.
Theorem 3.3. Let in Every 20 approximate solution
the system of nonlinear equa-
aat x_n depends on N , hence we
 x_n . We have the following theo-
Let the assumptions of Theorem
then the sequence of approximate
 $\}, n = 1, 2, ...$ constructed dions (7). Note that x_n depends on N , hence we
denote $x(n, N) \equiv x_n$. We have the following theo-
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Theorem 3.3. Let the assumptions of Theorem
3.1 be satisfied. Then the sequence of approximate
solutions $\{x(n, N)\}$ denote $x(n, N) \equiv x_n$. We have the following t
rem.
Theorem 3.3. Let the assumptions of The
3.1 be satisfied. Then the sequence of approxi
solutions $\{x(n, N)\}$, $n = 1, 2, ...$ constructed l
eration processes (8a)-(8d) converg Theorem 3.3. Let the assumptions of Theorem 3.3. Let the assumptions of Theorem .

clutions $\{x(n, N)\}, n = 1, 2, \ldots$ constructed b

ration processes (8a)-(8d) converges to the e

clution $x \in \mathbb{R}^n$ of the perturbed system en the sequence of approximate
 $n = 1, 2, ...$ constructed by it-

(a)-(8d) converges to the exact
 f the perturbed system of non-
 $Moreover, the following esti-
\nMoreover, the following esti-
\n
$$
\frac{1}{-\overline{q}} \left[\frac{q^{n+1}}{1-q} \frac{1-\overline{q}^{n+1}}{1-\overline{q}} \frac{e^{qN}-1}{
$$$ solutions $\{x(n, N)\}, n = 1, 2, \ldots$ constructed by it-
eration processes $(8a)$ - $(8d)$ converges to the exact
solution $x \in \mathbb{R}^n$ of the perturbed system of non-
linear equations (7). Moreover, the following esti-
mates ho *n* processes (8a)-(8d) converges to the exact
 n $x \in \mathbb{R}^n$ of the perturbed system of non-

equations (7). Moreover, the following esti-

hold
 $(N) - x \leq \frac{1}{1 - \overline{q}} \left[\frac{q^{n+1}}{1 - q} \frac{1 - \overline{q}^{n+1}}{1 - \overline{q}} \frac{e^{qN$

$$
||x(n, N) - x|| \le \frac{1}{1 - \overline{q}} \left[\frac{q^{n+1}}{1 - q} \frac{1 - \overline{q}^{n+1}}{1 - \overline{q}} \frac{e^{qN} - 1}{e^q - 1} + \overline{q}^{n+1} \right] ||b||, n = 1, 2, ..., \quad (9)
$$

 $q\!=\!\frac{L}{N} < 1, L$ is Lipschitz coefficient of t solution $x \in \mathbb{R}^n$ of the perturbed system of non-
linear equations (7). Moreover, the following esti-
mates hold
 $||x(n, N) - x|| \le \frac{1}{1 - \overline{q}} \left[\frac{q^{n+1}}{1 - q} \frac{1 - \overline{q}^{n+1}}{1 - \overline{q}} \frac{e^{qN} - 1}{e^q - 1} + \overline{q}^{n+1} \right] ||b$ Φ. $||x(n, N) - x|| \le \frac{1}{1 - \overline{q}} \left[\frac{q^{n+1}}{1 - q} \frac{1 - \overline{q}^{n+1}}{1 - \overline{q}} \frac{e^{qN} - 1}{e^q - 1} + \overline{q}^{n+1} \right] ||b||, n = 1, 2, \ldots, (9)$
where *N* is the smallest natural number such that
 $q = \frac{L}{N} < 1, L$ is Lipschitz coefficient of the $||x(n, N) - x|| \le \frac{1}{1 - \overline{q}} \left[\frac{q}{1 - q} - \frac{1 - q}{1 - \overline{q}} - \frac{e^{z}}{\overline{q}^2 - 1} + \frac{1}{\overline{q}^2 + 1} \right] ||b||, n = 1, 2, \ldots, (9)$

where *N* is the smallest natural number such that
 $q = \frac{L}{N} < 1, L$ is Lipschitz coefficient of the oper where N is the smallest natural number such the $q = \frac{L}{N} < 1$, L is Lipschitz coefficient of the operato F and \overline{q} is a contraction coefficient of the operato Φ .
Proof. The proof follows immediately from Theorem

$$
q = \frac{1}{N} \times 1
$$
, *E* is *in* position coefficient of the operator
\n*F* and \overline{q} is a contraction coefficient of the operator
\n Φ .
\n*Proof.* The proof follows immediately from Theorem 2.4 by setting $A = F, B = \Phi$ and $f = b$. \Box
\n**Example 3.1.** Consider the following system of
\nnonlinear equations
\n
$$
\begin{cases}\n\frac{4}{3}x_1 + ln(e^{x_1} + 1) + \frac{1}{3}x_2 + \frac{2}{3}sinx_2 = 1 \\
-\frac{1}{3}x_1 + \frac{3}{4}cosx_1 + \frac{4}{3}x_2 + arctan x_2 = \frac{1}{2}\n\end{cases}
$$
\nWe write this system as the form
\n $x + F(x) + \Phi(x) = b$,
\nwhere $x = (x_1, x_2)^T$, $b = (1 - ln(2), -\frac{1}{4})^T$, $F(x) =$
\n $(f_1(x_1, x_2), f_2(x_1, x_2))^T$ with
\n $f_1(x_1, x_2) = \frac{1}{3}x_1 + ln(e^{x_1} + 1) + \frac{1}{3}x_2 - ln(2)$,

$$
x + F(x) + \Phi(x) = b,
$$

 $(\frac{1}{4})^T$, $F(x) =$ $= 1$
 $= \frac{1}{2}$
 $, F(x) =$
 $ln(2),$

$$
\begin{cases}\n3 & 3 \\
-3x_1 + \frac{3}{4}\cos x_1 + \frac{4}{3}x_2 + \arctan x_2 = \frac{1}{2}\n\end{cases}
$$
\nWe write this system as the form\n
$$
x + F(x) + \Phi(x) = b,
$$
\nwhere $x = (x_1, x_2)^T$, $b = (1 - \ln(2), -\frac{1}{4})^T$, $F(x) = (f_1(x_1, x_2), f_2(x_1, x_2))^T$ with\n
$$
f_1(x_1, x_2) = \frac{1}{3}x_1 + \ln(e^{x_1} + 1) + \frac{1}{3}x_2 - \ln(2),
$$
\n
$$
f_2(x_1, x_2) = -\frac{1}{3}x_1 + \frac{1}{3}x_2 + \arctan x_2,
$$
\nand $\Phi(x) = (\frac{2}{3}\sin x_2, \frac{3}{4}\cos x_1 - 3/4)^T$.
\nIt is easy to verify that $\frac{\partial f_i}{\partial x_i} \ge \alpha = \frac{1}{3}$, $i = 1, 2, 3$ \nand $\left|\frac{\partial f_i}{\partial x_j}\right| = \beta = \frac{1}{3}$, $i \neq j$, $i, j = 1, 2$, so that\n
$$
\alpha - (n-1)\beta = \frac{1}{3} - (2-1)\frac{1}{3} = 0
$$
. Moreover, we have

 $\frac{2}{3}sinx_2, \frac{3}{4}cosx_1 - 3/4)^T$. and $\Phi(x) = (\frac{2}{3}sin x_2, \frac{3}{4}cos x_1 - 3/4)^T$.

bying.
 $f_1(x_1, x_2), f_2(x_1, x_2)$ with
 $f_3(f)$ in iteration pro-
 $f_1(x_1, x_2) = \frac{1}{3}x_1 + ln(e^{x_1} -$
 $f_2(x_1, x_2) = -\frac{1}{3}x_1 + \frac{1}{3}x_2 +$
 $f_3(x_1, x_2) = -\frac{1}{3}x_1 + \frac{1}{3}x_2 +$
 $f_4(x_1, x_2) = -\frac{1}{3}x_1 + \frac{1}{3}x_2 +$
 $f_$)–(4d), respectively, the approximate so-

the perturbed system of nonlinear equa-

can be found by the following iteration and $\Phi(x) = (\frac{2}{3}sinx_2, \frac{3}{4}cosx_1 - \frac{1}{3}x_2 + a_2 - \frac{1}{3}cosx_1 - \frac{1}{3}cosx_2 - \frac{1}{3}cosx_1 - \frac{1}{3}cosx_2 \frac{1}{3}$, $i = 1, 2, 3$ j^T , $F(x) =$
 $\frac{1}{2} - \ln(2)$,

,

,

,
 $i = 1, 2, 3$

, 2, so that

er, we have and $\left|\frac{\partial f_i}{\partial x_j}\right| = \beta = \frac{1}{3}, i \neq j, \quad i, j = 1, 2$, so t where $x = (x_1, x_2)^T$, $b = (1 - ln(2), -\frac{1}{4})^T$, $F(x) = (f_1(x_1, x_2), f_2(x_1, x_2))^T$ with
 $f_1(x_1, x_2) = \frac{1}{3}x_1 + ln(e^{x_1} + 1) + \frac{1}{3}x_2 - ln(2)$,
 $f_2(x_1, x_2) = -\frac{1}{3}x_1 + \frac{1}{3}x_2 + arctan x_2$,

and $\Phi(x) = (\frac{2}{3}sin x_2, \frac{3}{4}cos x_1 - 3/4$ $\frac{1}{3} - (2 - 1)\frac{1}{3} = 0$. Moreover, we ha $\begin{aligned}\n\frac{\partial f_i}{\partial x^2} + 1) + \frac{1}{3}x_2 - \ln(2), \\
x_2 + \arctan x_2, \\
x_1 - 3/4)^T. \\
\frac{\partial f_i}{\partial x_i} &\ge \alpha = \frac{1}{3}, i = 1, 2, 3 \\
\vdots, i, \quad i, j = 1, 2, \text{ so that} \\
\frac{1}{3} = 0. \text{ Moreover, we have} \\
x &= (x_1, x_2) \in \mathbb{R}^2, i = 1, 2. \\
y_1, y_2) &= \mathbb{R}^2 \text{ we have}\n\end{aligned}$ $\sum_{j=1}^{\infty} |\frac{\partial f_i(x_1,x_2)}{\partial x_j}| \leq L = \frac{5}{3}, \forall x = (x_1, x_2) \in \mathbb{R}^2, i = 1, 2.$ $\frac{2}{3}sinx_2, \frac{3}{4}cosx_1 - 3/4$ ^T.

verify that $\frac{\partial f_i}{\partial x_i} \ge \alpha = \frac{1}{3}, i = 1, 2, 3$
 $\beta = \frac{1}{3}, i \ne j, \quad i, j = 1, 2$, so that
 $= \frac{1}{3} - (2 - 1)\frac{1}{3} = 0$. Moreover, we have
 $| \le L = \frac{5}{3}, \forall x = (x_1, x_2) \in \mathbb{R}^2, i = 1, 2$.
 $f_1(x_1, x_2) = \frac{1}{3}x_1 + ln(e^{x_1} + 1) + \frac{1}{3}x_2 - ln(2),$
 $f_2(x_1, x_2) = -\frac{1}{3}x_1 + \frac{1}{3}x_2 + arctan x_2,$

and $\Phi(x) = (\frac{2}{3}sin x_2, \frac{3}{4}cos x_1 - 3/4)^T$.

It is easy to verify that $\frac{\partial f_i}{\partial x_i} \ge \alpha = \frac{1}{3}, i = 1, 2, 3$

and $\left|\frac{\partial f_i$ 3

$$
\|\Phi(x) - \Phi(y)\| \le \frac{3}{4} \|x - y\|.
$$

Ngo Thanh Binh/Vol 8. No.2_ June 2022|p.163-167
Therefore, the conditions of Theorem 3.1 are satis-
fied. Then the given system has a unique solution. *tension method for an equ*
By applying the iteration processes $(8a$ *Ngo Thanh Binh/Vol 8.* No.2_ June 2022|p.163-167
Therefore, the conditions of Theorem 3.1 are satis-
fied. Then the given system has a unique solution.
By applying the iteration processes $(8a)$ – $(8d)$ and $kind with a Lipschitz$ -
the *Ngo Thanh Binh/Vol 8. No.2_ June 2022* |p.163-167

Therefore, the conditions of Theorem 3.1 are satis-

[7] Gaponenko, Y. L. (1986). *T*

fied. Then the given system has a unique solution.

By applying the iteration proc *Ngo Thanh Binh/*Vol 8. No.2_ June 2022|p.163-167

Therefore, the conditions of Theorem 3.1 are satis-

fied. Then the given system has a unique solution.

By applying the iteration processes $(8a)$ – $(8d)$ and

the error *Ngo Thanh Binh/Vol 8.* No.2_ June 2022|p.163-167

Therefore, the conditions of Theorem 3.1 are satis-

fied. Then the given system has a unique solution.

By applying the iteration processes (8a)–(8d) and

the error esti *Ngo Thanh Binh/Vol 8.* No.2_ June 2022|p.163-167

Therefore, the conditions of Theorem 3.1 are satis-

Fied. Then the given system has a unique solution.

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Example 3.1 are satis-

Example 3.1 are satis-

Example 3.1 are satis-
 $\begin{array}{ll}\n & [7] \text{ Gaponen} \\
 \text{ration processes (8a)–(8d) and } & \text{kind with} \\
 & \text{tension } r \\
 \text{ratio processes (8a)–(8d) and } & \text{kind with} \\
 & \text{tension } r \\
 \text{of this system and cor-} & \text{to:} \\
 & \text{tonic } \text{ope} \\
 \text{$ Therefore, the conditions of Theorem 3.1 are satis-

ied. Then the given system has a unique solution.

By applying the iteration processes (8a)–(8d) and

tension method for

he error estimations (9) with $N = 2$, for some 20 (0.2035249334, −0.07148567278) 5.025545612 × 10⁻¹ [-1] $\frac{1}{2}$ (By applying the iteration processes (8a)-(8d) and $\frac{1}{2}$ kind with a Lipsc
the error estimations (9) with $N = 2$, for some *n* tonic operator, C
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external solutions. Error ming, Appl. Math. 7: 47

20(0.2035255893, -0.07148406388) 1.19371495

30(0.2035249334, -0.07148567987) 1.928279061 × 10⁻¹ [9] Leray, J., Schauder, J.

50(0.2035249230, -0.07148567278) 5.0255456 20 (0.203525893, -0.07148406388) 1.19371495

30 (0.2035249334, -0.07148567987) 1.928279061 × 10⁻¹ [9] Leray, J., Schauder, J. (2010)

50 (0.2035249230, -0.07148567278) 5.025545612 × 10⁻³ *(autions fonctionnelles, A*
 the proposed of the proposed method

is also provided. Finally, a numerical example is

given to illustrate the effectiveness of the result.

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4 Conclusions

In this paper, we have presented an **is also provided.** Finally, a numerical example is given to illustrate the effectiveness of the result.

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 4 Conclusions (10) Ninh, K. V. (1999). Approximate the P 91: 49–78.

In this paper, we have presented an extension of the equation of a section of the PCM for solving perturbed systems of nonlinear equations. We first establish the sufficient conditions for the existence and un Fig. 2011). A methom ions for the existence and uniqueness of the solu-

ion. Then, error analysis of the proposed method

also provided. Finally, a numerical example is

ion to illustrate the effectiveness of the result.

- Then, error analysis of the proposed method

so provided. Finally, a numerical example is

to illustrate the effectiveness of the result.
 $[12]$ Ninh, K. V., Binh, N. T.
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 $[12]$ Ninh, K. V., Binh, N. T.
 R so provided. Finally, a numerical example is $\begin{array}{lll}\n & at \sigma r\!\!& at \sigma r\$ 106. **EXERENCES** [12] Ninh, K. V., Binh
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 ing and Paramei

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 ear equations, **REFERENCES** *Intion of Volterra-Fredholm*
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 erative methods for solving a system of nonl pring and Parameters (1) Aslam Noor, M., Waseem, M. (2009). *Some it* J. Appl. Comparative methods for solving a system of nonlin-
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