Accepted Manuscript

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PII: S1658-3655(17)30063-8
DOI: http://dx.doi.org/doi:10.1016/j.jtusci.2017.05.002
Reference: JTUSCI 386

To appear in:

Received date: 15-4-2017
Revised date: 22-4-2017
Accepted date: 22-5-2017

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Boubaker polynomials collocation approach for solving systems of nonlinear Volterra-Fredholm integral equations

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Abstract

Numerical schemes have been developed for solutions of systems of nonlinear mixed Volterra-Fredholm integral equations of the second kind based on the First Boubaker polynomials (FBPs). The classical operational matrices are derived. The unknown has been approximated by FBPs and the Newton-Cotes points were applied as the collocations points. Error estimate and convergence analysis of the proposed method have been proved. Some numerical experiments are considered. The results are compared with relevant studies in order to test the reliability, validity and effectiveness of the proposed approach.

Keywords: First Boubaker polynomials; Best approximation; Operational matrix; Systems of Volterra-Fredholm integral equations; Collocation methods

AMS subject Classification:65R20; 45G15; 45B99; 45D99

1. Introduction

A number of problems in physics, engineering, biology, applied mathematics and various branches of science and analytical disciplines are described by the system of integral equations. The present paper principally focusses on the general systems of nonlinear mixed Volterra-Fredholm integral equations (SNV-FEIs) of the second kind as shown below:

$$\mathbf{y}(x) = \mathbf{f}(x) + \int_0^x \mathbf{K}_1(x,\, t,\, \mathbf{y}(t))\, dt + \int_0^1 \mathbf{K}_2(x,\, t,\, \mathbf{y}(t))\, dt, \quad x \in I = [0,\, 1], \tag{1}$$

where

$$\begin{aligned}
&\mathbf{y}(x) = [y_1(x),\, y_2(x),\, \ldots,\, y_M(x)]^T, \quad \mathbf{f}(x) = [f_1(x),\, f_2(x),\, \ldots,\, f_M(x)]^T,\\
&\mathbf{K}_l(x,\, t,\, y(t)) = \begin{bmatrix} K_1^{(l)}(x,\, t,\, \mathbf{y}(t)) & K_2^{(l)}(x,\, t,\, \mathbf{y}(t)) & \ldots & K_M^{(l)}(x,\, t,\, \mathbf{y}(t)) \end{bmatrix}^T,\\
&K_{j_1}^{(1)}(x,\, t,\, \mathbf{y}(t)) = \sum_{j_2=1}^{m_{j_1}^{(1)}} \kappa_{j_1 j_2}^{(1)}(x,\, t)\, \varphi_{j_1 j_2}^{(1)}(t,\, y_1(t),\, \ldots,\, y_M(t)),\\
&K_{j_1}^{(2)}(x,\, t,\, \mathbf{y}(t)) = \sum_{j_3=1}^{m_{j_1}^{(2)}} \kappa_{j_1 j_3}^{(2)}(x,\, t)\, \varphi_{j_1 j_3}^{(2)}(t,\, y_1(t),\, \ldots,\, y_M(t)),\\
&l = 1, 2, \quad M \geq 1, \quad j_1 = 1\,(1)\, M, \quad m_{j_1}^{(l)} \in \mathbb{N},
\end{aligned}$$

in which $f_{j_1}(x) \in L^2(I)$, $\kappa_{j_1 j_2}^{(1)}(x,\, t)$, $\kappa_{j_1 j_3}^{(2)}(x,\, t) \in L^2(I \times I)$, $\varphi_{j_1 j_2}^{(1)}$, $\varphi_{j_1 j_3}^{(2)}$ are known continuous functions in all variables and $\mathbf{y}(x)$ is the unknown vector function to be determined. Moreover; $\varphi_{j_1 j_2}^{(1)}$, $\varphi_{j_1 j_3}^{(2)}$ are nonlinear with respect to M unknown real functions $y_1(x),\, \ldots,\, y_M(x)$.

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