

Application of the Generalized Differential Quadrature Method in Solving Burgers' Equations

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Abstract The aim of this paper is to obtain numerical solutions of the one-dimensional, two-dimensional and coupled Burgers' equations through the generalized differential quadrature method (GDQM). The polynomial-based differential quadrature (PDQ) method is employed and the obtained system of ordinary differential equations is solved via the total variation diminishing Runge-Kutta (TVD-RK) method. The numerical solutions are satisfactorily coincident with the exact solutions. The method can compete against the methods applied in the literature.

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Key words: generalized differential quadrature method (GDQM), total variation diminishing Runge-Kutta (TVD-RK) method, Burgers' equations

1 Introduction

Exact and numerical solutions of the nonlinear partial differential equations and systems of nonlinear partial differential equations play an important role in the physical sciences as well as in the engineering fields, see e.g. Refs. [1–5] and their bibliographies.

Burgers' equation is one of the very few nonlinear partial differential equations that can be solved exactly using the Hopf-Cole transformation. Nevertheless, numerical methods for solving such equations have practical significance and drawn the attention of many scientists.

Burgers' equation was formulated by Bateman in 1915,^[6] and later treated by Burgers.^[7] This equation is also called the nonlinear advection-diffusion equation, and can be regarded as a qualitative approximation of the Navier-Stokes equations. It retains the nonlinear aspects of the governing equation in many practical transport problems such as aggregation interface growth, the formation of large-scale structures in the adhesion model for cosmology, turbulence transport, shock wave theory, wave processes in thermo-elastic medium, transport and dispersion of pollutants in rivers and sediment transport.

One-dimensional Burgers' equation is as follows^[8]

$$\frac{\partial u}{\partial t} + \alpha u \frac{\partial u}{\partial x} - \nu \frac{\partial^2 u}{\partial x^2} = 0, \quad 0 < x < 1, \quad t > 0, \quad (1)$$

with the initial condition

$$u(x, 0) = f(x), \quad 0 \leq x \leq 1,$$

where $\nu = 1/\text{Re}$ in which Re is the Reynolds' number. Some exact/numerical solutions of the one-dimensional Burgers' equation are obtained by an explicit Backlund

transformation,^[9] tanh-coth method,^[10] differential transformation method,^[11] variational iteration method,^[12] homotopy analysis method,^[13] modified local Crank-Nicolson method,^[14] element-free characteristic Galerkin method,^[15] least-squares quadratic B-spline finite element method,^[16] a sixth-order compact finite difference scheme,^[17] cubic B-spline quasi-interpolation method,^[18] finite element method,^[19] reproducing kernel method^[20] and so on.

Two-dimensional Burgers' equation is as follows^[14]

$$\begin{aligned} \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} - \nu \frac{\partial^2 u}{\partial x^2} + \nu \frac{\partial^2 u}{\partial y^2} = 0, \\ 0 < x, \quad y < 1, \quad t > 0, \end{aligned} \quad (2)$$

with the initial condition

$$u(x, y, 0) = f(x, y), \quad 0 \leq x, \quad y \leq 1.$$

Some exact/numerical solutions of two-dimensional Burgers' equation reported in the literature are: modified local Crank-Nicolson method,^[14] Adomian decomposition method,^[21] generalized (G'/G)-expansion method,^[22] lattice Boltzmann method,^[23] Eulerian-Lagrangian method,^[24] artificial boundary method^[25] and etc.

The coupled Burgers' equation which we consider is as follows^[26–27]

$$\begin{aligned} \frac{\partial u}{\partial t} - \frac{\partial^2 u}{\partial x^2} + \eta u \frac{\partial u}{\partial x} + \alpha \frac{\partial(uv)}{\partial x} = 0, \\ 0 < x < 1, \quad t > 0, \\ \frac{\partial v}{\partial t} - \frac{\partial^2 v}{\partial x^2} + \eta v \frac{\partial v}{\partial x} + \beta \frac{\partial(uv)}{\partial x} = 0, \\ 0 < x < 1, \quad t > 0, \end{aligned} \quad (3)$$

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Innovative Approaches in Computational Structural Engineering George C. Tsiatas, Vagelis Plevris, 2020-04-22 Nowadays numerical computation has become one of the most vigorous tools for scientists researchers and professional engineers following the enormous progress made during the last decades in computing technology in terms of both computer hardware and software development Although this has led to tremendous achievements in computer based structural engineering the increasing necessity of solving complex problems in engineering requires the development of new ideas and innovative methods for providing accurate numerical solutions in affordable computing times This collection aims at providing a forum for the presentation and discussion of state of the art innovative developments concepts methodologies and approaches in scientific computation applied to structural engineering It involves a wide coverage of timely issues on computational structural engineering with a broad range of both research and advanced practical applications This Research Topic encompasses but is not restricted to the following scientific areas modeling in structural engineering finite element methods boundary element methods static and dynamic analysis of structures structural stability structural mechanics meshless methods smart structures and systems fire engineering blast engineering structural reliability structural health monitoring and control optimization and composite materials with application to engineering structures

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Solving Transcendental Equations John P. Boyd, 2014-09-23 Transcendental equations arise in every branch of science and engineering While most of these equations are easy to solve some are not and that is where this book serves as the mathematical equivalent of a skydiver s reserve parachute not always needed but indispensable when it is The author s goal is to teach the art of finding the root of a single algebraic equation or a pair of such equations

Applications of Viscoelasticity Pouria Hajikarimi, Fereidoon Moghadas Nejad, 2021-04-27 Applications of Viscoelasticity Bituminous Materials Characterization and Modeling starts with an introduction to the theory of viscoelasticity emphasizing its importance to various applications in material characterization and modeling It next looks at constitutive viscoelastic functions outlines basic equations for different loading conditions and introduces the Boltzmann superposition principle relaxation modulus and creep compliance Mechanical models including integer order and fractional order are studied next featuring real experimentation data alongside the benefits and drawbacks of using each model in various real world scenarios The book then covers the correspondence principle followed by time temperature superposition featuring a simple procedure to construct a real master curve and challenges that might be encountered The concluding chapters cover the Hopkins and Hamming Park and Kim and General Power law methods for interconversion of constitutive

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International Aerospace Abstracts, 1995 Numerical Methods for Chemical Engineers with MATLAB Applications A. Constantinides, Navid Mostoufi, 1999 Master numerical methods using MATLAB today s leading software for problem solving This complete guide to numerical methods in chemical engineering is the first to take full advantage of MATLAB s powerful calculation environment Every chapter contains several examples using general MATLAB functions that implement the method and can also be applied to many other problems in the same category The authors begin by introducing the solution of nonlinear equations using several standard approaches including methods of successive substitution and linear interpolation the Wegstein method the Newton Raphson method the Eigenvalue method and synthetic division algorithms With these fundamentals in hand they move on to simultaneous linear algebraic equations covering matrix and vector operations Cramer s rule Gauss methods the Jacobi method and the characteristic value problem Additional coverage includes Finite difference methods and interpolation of equally and unequally spaced points Numerical differentiation and integration including differentiation by backward forward and central finite differences Newton Cotes formulas and the Gauss Quadrature Two detailed chapters on ordinary and partial differential equations Linear and nonlinear regression

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