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.

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–Stockes 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

$$u(x,0) = f(x), \qquad 0 \le x \le 1,$$

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

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]

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

with the initial condition

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

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]

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

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

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Matlab Code For Generalized Differential Quadrature Method

Brian D. Hahn

Matlab Code For Generalized Differential Quadrature Method:

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 *Laminated Composite Doubly-Curved Shell Structures* Francesco Tornabene,Michele Bacciocchi,Nicholas Fantuzzi,Erasmo Viola,2016-05-17 The title Laminated Composite Doubly Curved Shell Structures Differential and Integral Quadrature Strong Form Finite Elements illustrates the theme treated and the prospective followed during the composition of the present work The aim of this manuscript is to analyze the static and dynamic behavior of thick and moderately thick composite shells through the application of the Differential Quadrature DQ method The book is divided into two volumes wherein the principal higher order structural theories are illustrated in detail and the mechanical behavior of doubly curved structures are presented by several static and dynamic numerical applications In particular the first volume is mainly theoretical whereas the second one is mainly related to the numerical DQ technique and its applications in the structural field The numerical results reported in the present volume are compared to the one available in the literature but also to the ones obtained through several codes based on the Finite Element Method FEM Furthermore an advanced version of the DQ method termed Strong Formulation Finite Element Method SFEM is presented The SFEM solves the differential equations inside each element in the strong form and implements the mapping technique typical of the FEM **Advanced Composite Materials and Structures** Mohamed Thariq Hameed Sultan,Vishesh Ranjan Kar,Subrata Kumar Panda,Kandaswamy Jayakrishna,2022-08-31 This book bridges the gap between theoretical concepts and their implementations especially for the high performance structures components related to advanced composite materials This work focuses on the prediction of various structural responses such as deformations natural frequencies etc of advanced composites under complex environments and or loading conditions In

addition it discusses micro mechanical material modeling of various advanced composite materials that involve different structures ranging from basic to advanced such as beams flat and curved panels shells skewed corrugated and other materials as well as various solution techniques via analytical semi analytical and numerical approaches This book Covers micro mechanical material modeling of advanced composite materials Describes constitutive models of different composite materials and kinematic models of different structural configuration Discusses pertinent analytical semi analytical and numerical techniques Focusses on structural responses relating to deformations natural frequencies and critical loads under complex environments Presents actual demonstrations of theoretical concepts as applied to real examples using Ansys APDL scripts This book is aimed at researchers professionals and graduate students in mechanical engineering material science material engineering structural engineering aerospace engineering and composite materials   <u>Seismic Inversion</u> Gerard T. Schuster,2017-07-01 This book describes the theory and practice of inverting seismic data for the subsurface rock properties of the earth The primary application is for inverting reflection and or transmission data from engineering or exploration surveys but the methods described also can be used for earthquake studies Seismic Inversion will be of benefit to scientists and advanced students in engineering earth sciences and physics It is desirable that the reader has some familiarity with certain aspects of numerical computation such as finite difference solutions to partial differential equations numerical linear algebra and the basic physics of wave propagation For those not familiar with the terminology and methods of seismic exploration a brief introduction is provided To truly understand the nuances of seismic inversion we have to actively practice what we preach or teach Therefore computational labs are provided for most of the chapters and some field data labs are given as well   <u>Solving Transcendental Equations</u> 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 indispensible 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 viscoelastic

functions applications of viscoelasticity for experimental tests and incremental form of viscoelastic relations for numerical modeling The book also includes supplementary codes that users can duplicate and use in their own work Takes an applied approach to material viscoelasticity explaining complicated viscoelastic equations and principles Presents examples of those equations and principles being applied to common problems in realworld settings Covers constitutive viscoelastic functions including relaxation modulus and creep compliance Outlines the construction of a master curve of viscoelastic material considering time temperature superposition Couples the correspondence principle with common viscoelastic experiments such as threepoint bending beam axial and torsional bar and dynamic shear rheometer Provides supplementary codes

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