

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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Matlab Code For Generalized Differential Quadrature Method

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