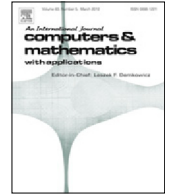




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A new fourth-order compact scheme for the Navier–Stokes equations in irregular domains

D. Fishelov*

Afeka - Tel-Aviv Academic College of Engineering, 38 Mivtza Kadesh St., Tel-Aviv 69107, Israel
 School of Mathematical Sciences, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, Israel

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ABSTRACT

We present a high-order finite difference scheme for Navier–Stokes equations in irregular domains. The scheme is an extension of a fourth-order scheme for Navier–Stokes equations in streamfunction formulation on a rectangular domain (Ben-Artzi et al., 2010). The discretization offered here contains two types of interior points. The first is regular interior points, where all eight neighboring points of a grid point are inside the domain and not too close to the boundary. The second is interior points where at least one of the closest eight neighbors is outside the computational domain or too close to the boundary. In the second case we design discrete operators which approximate spatial derivatives of the streamfunction on irregular meshes, using discretizations of pure derivatives in the x , y and along the diagonals of the element.

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1. Introduction

In this paper we are interested in high-order discretizations of the Navier–Stokes equations. The Navier–Stokes equations play a central role in modeling fluid flows. Here we focus on incompressible flows. It is well-known that this system may be represented in pure streamfunction formulation as follows (see [1,2]).

$$\begin{cases} \partial_t \Delta \psi + \nabla^\perp \psi \cdot \nabla \Delta \psi - \nu \Delta^2 \psi = f(x, y, t), \\ \psi(x, y, t) = \psi_0(x, y). \end{cases} \quad (1.1)$$

Recall that $\nabla^\perp \psi = (-\partial_y \psi, \partial_x \psi)$ is the velocity vector. The no-slip boundary condition associated with this formulation is

$$\psi = \frac{\partial \psi}{\partial n} = 0, \quad (x, y) \in \partial \Omega, \quad t > 0 \quad (1.2)$$

and the initial condition is

$$\psi(x, y, 0) = \psi_0(x, y), \quad (x, y) \in \Omega. \quad (1.3)$$

In this paper we extend the fourth-order scheme [3] to irregular domains. The strategy used here is to present the biharmonic operator $\partial_x^4 + 2\partial_x^2 \partial_y^2 + \partial_y^4$ as a combination of pure fourth-order derivatives in the x , y and the diagonal directions $\eta = (x + y)/\sqrt{2}$, $\xi = (y - x)/\sqrt{2}$. Then, the pure fourth-order derivatives may be approximated via a compact scheme

* Correspondence to: Afeka - Tel-Aviv Academic College of Engineering, 38 Mivtza Kadesh St., Tel-Aviv 69107, Israel.
 E-mail address: fishelov@gmail.com.

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