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Lattice Boltzmann Method for Fluid Flow

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Abstract

We present an overview of the lattice Boltzmann method (LBM), a parallel and efficient algorithm for simulating single-phase and multiphase fluid flows and for incorporating additional physical complexities. The LBM is especially useful for modeling complicated boundary conditions and multiphase interfaces. Recent extensions of this method are described, including simulations of fluid turbulence, suspension flows, and reaction diffusion systems.

Lattice Boltzmann method (LBM) is a methodology based on the microscopic particle models and mesoscopic kinetic equations. According to Kadanoff (1986), it has been found that macroscopic behavior of a fluid system is generally not very sensitive to the underlying microscopic particle behavior if only collective macroscopic flow behavior is of interest. The fundamental idea behind the LBM is to construct simplified kinetic models that incorporate only the essential physics of microscopic or mesoscopic processes so that the macroscopic averaged properties obey the desired macroscopic equations. This subsequently avoids the use of the full Boltzmann equation, and one also avoids following each particle as in molecular dynamics simulations.

LBM is based on a particle representation, the principal focus remains in the averaged macroscopic behavior. The kinetic nature of the LBM introduces three important features that distinguish this methodology from other numerical methods. Firstly, the convection operator of the LBM in the velocity phase is linear. The inherent simple convection when combined with the collision operator allows the recovery of the nonlinear macroscopic advection through multiscale expansions. Secondly, the incompressible Navier–Stokes equations can be obtained in the nearly incompressible limit of the LBM. The pressure is calculated directly from the equation of state in contrast to satisfying Poisson's equation with velocity strains acting as sources. Thirdly, the LBM utilizes the minimum set of velocities in the phase space. Because only one or two speeds and a few moving directions are required, the transformation relating the microscopic distribution function and macroscopic quantities is greatly simplified and consists of simple arithmetic calculations.

Keywords: Lattice Boltzmann method • Mesoscopic approach • Fluid flow simulation

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