Moment Base Lattice Boltzmann Approach for Multiphysics Flow Problems

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Abstract: This paper describes a novel numerical approach for simulating multiphysics flow problems using several moments. Unsteady evolution of the moments are obtained by the lattice Boltzmann framework. Three dimensional incompressible isothermal flows can be described using lower ten moments. The Chapman-Enskog distribution functions for three dimensional lattice (for example, D3Q19) are temporary constructed from the moments. The time evolution of the moments can be obtained using the standard lattice Boltzmann method. As compared with the standard lattice Boltzmann method, the present method can save storage and inprove numerical stability. Numerical experiments indicate that the advantage is more evident for mulltiphysics flow problems.

Keywords: Lattice Boltzmann Method, Computational Fluid Dynamics, Multiphysics Flow Problem.

1 Introduction

Nowadays the lattice Boltzmann method is widely used especially for simulating incompresible isothermal flows. Simpleness of the algorithm is one of the advantage of the lattice Boltzmann method. On the other hand, the method need more storage compared with the incompressible Navier-Stokes solver, especially for three dimensional multiphysics flow problems. The incompressible isothermal Navier-Stokes solution may be obtained using the lower ten moments of the nineteen lattice Boltzmann distribution functions if we use D3Q19 lattice. For thermal flows, additional four moments are only required of the nineteen theramal lattice distribution functions. Unsteady evolution of those moments can be obtained using the simple algorithm of the standard lattice Boltzmann method. Thus the moment base lattice Boltzmann method saves storage especially for mulltiphysics flow problems.

2 Numerical Experiments

Sevelal numerical experiments have been carried out to demonstrate the advantage of the novel approach. Figure 1 shows the velocity distribution along the center lines in the standard cavity test problem at the Rynolds number of 5000. The results using 80×80 gird are compared well with Ghia's data, while the standard lattice Boltzmann method requires more than 200×200 grid

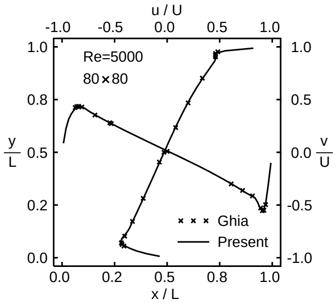

Figure 1: Velocities for cavity flow at $Re = 5000$ and a 80×80 grid.

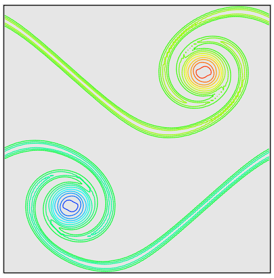

Figure 2: Vorticity from present method on a 128×128 grid.

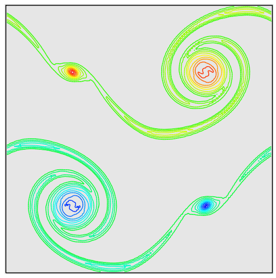

Figure 3: Vorticity from standard LBM on a 128×128 grid.

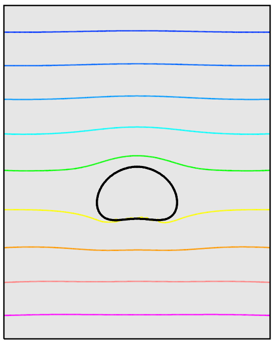

Figure 4: Pressure around a rising bubble from present method.

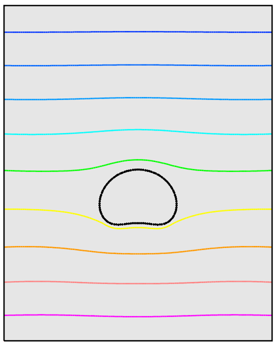

Figure 5: Pressure around a rising bubble from NS method.

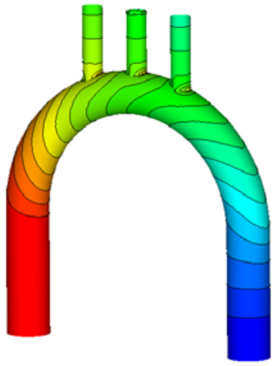

Figure 6: Surface pressure about a human aortic arch model.

at this Reynolds number. Figures 2 and 3 show the vorticity contours for the doubly periodic shear layers obtained on a 129×129 grid. Good results are obtained by the present method (Fig. 2) in contrast with the results of the standard lattice Boltzmann method (Fig. 3) in which spurious vortices are found.

Figures 4 and 5 show the pressure distribution around a rising bubble at density ratio of 833, viscosity ratio of 56. The present results (Fig. 4) are obtained with nine moments for the distribution function of fluid medium and a moment for the level set function. The results are compared well with the results of the incompressible Navier-Stokes equations (Fig. 5).

Figures 6 shows the surface pressure distribution about a human aortic arch model. Application to the biological flow problems is one of the main target of the present approach.

3 Conclusions

Numerical experiments indicate that the moment base lattice Boltzmann Method can inprove numerical stability and save storage as compared with the standard lattice Boltzmann method. The advantage is more evident for mulltiphysics flow problems. Full description of the present approach and further demonstrative numerical results will be presented in the final paper.