Title: **Coupling of finite volume method and thermal lattice Boltzmann method and its application to natural convection**

Authors: **Luan, H.B., Xu, H., Chen, L. ,Feng, Y.L., He Y.L. & Tao, W.Q.**

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Review by: Mario Forcinito

Lattice Boltzmann method (LBM) has been gaining acceptance in the field of computational fluid dynamics (CFD), particularly over the last 10 years. Evolved from Lattice Gas Automata methods[1] they are based on modeling the underlying molecular movement and collisions between molecules by using (real valued) particle distribution functions for each lattice direction and a collision operator that describe in a very simple way the rate of change in the distribution due to the interaction between distributions. These distributions represent the fluid at a meso-scale and they are smooth enough to be usable in numerical simulations. It is surprising that such a simple model converges, with second order accuracy, to the Navier-Stokes equations for low speed regimes (flow velocity small with respect to the speed of sound). Reference [2] has a very succinct and clear description of how this can be proven using the Chapman-Enskog expansion.

From the computational point of view LBM has some advantages over the standard finite element and finite volume method because the computations are comparatively simple and can be parallelized very easily. However the range of flow regimes and additional physics that can be handle by LBM is limited therefore researchers have been looking for ways to combine LBM with other computational methods.

Luan et al. have been working on a coupled, Finite Volume method (FVM) and LBM method and in this paper they present the results of its application to the natural convection problem. To illustrate the basic idea and the capabilities of their CFVLBM approach, the authors selected the natural convection in a square cavity as example. The cavity is meshed using three regions, one in which the LBM is used, one in which the FVM is used and one in which the transition between the two is computed.

In this approach, computations proceed as follows:

- *Step 1. With some assumed initial boundary conditions at the division line between the regions, the FVM simulation in the left region is performed.*
- *Step 2. After a temporary solution is obtained, the information at the division line is transformed into the density-velocity distribution function and the temperature distribution function.*
- *Step 3. The LBM simulation is carried out in the right region.*
- *Step 4. The temporary solution of LBM at the division line is transported into the macro variables and the FVM simulation is repeated.*
- *Step 5. Such computation is repeated until the results are within an allowed tolerance.*

It is worth noting that the authors solved the problem of the temperature reconstruction by using a Double Density Function (DDF) approach, which uses two independent lattice equations for the LBM model. This is seemingly a first in the literature.

In this work, the natural convection in a square cavity was used to validate the feasibility and reliability of the proposed CFVLBM scheme. The residual curve shows that the coupled model is more stable than pure LBM.The authors concluded that the CFVLBM is reliable and accurate Rayleigh number $Ra = 10^6$.

References:

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