Postdoctoral position

Lattice-Boltzmann Methods for flows with complex thermodynamics

Motivations

Unsteady simulation of turbulent flows has become a very valuable tool for both fundamental and applied research, but also for design and optimization in real systems engineering. Therefore, the development of improved physical and numerical models that are able to handle the full complexity of real systems is among the main research topic in Computational Fluid Dynamics (CFD). It should be emphasized that the system complexity originates in the coupling between very different scales (very small and very large ones) and the coupling between physical mechanisms of different nature. The exponential growth of computing power has enabled, in the recent past, to predict the dynamics of complex turbulent flows (in which complexity stems from geometry and multiphysic couplings), but mostly for simplified systems. A main objective is still to develop new methods that will allow to handle the total complexity of full scale real systems, and to diffuse these methods thanks to simulation tools that are available for both academic and industrial CFD communities.

This research project aims at developing new physical models and numerical methods for the unsteady simulation of flows based on Lattice Boltzmann Methods (LBM). LBM appeared, under its modern formulation, in the early 1990s. This approach has now reached a maturity level which is sufficient to consider it as a potential alternative to Navier-Stokes-based CFD tools. From the theoretical standpoint, LBM is a method to solve the Boltzmann equation, and therefore to describe flow dynamics at a finer level than continuum mechanics, considering velocity density distribution functions instead of usual macroscopic quantities (velocity, pressure, ...) From a practical standpoint, LBM-based simulation tools have proved to be more efficient than classical Navier-Stokes based solvers for subsonic aerodynamics and aeroacoustics. This is illustrated by the fact that PowerFlow, which is a commercial CFD tool based on LBM, is the worldwide leader for ground transport applications (for aerodynamics, aeroacoustics and heat transfer).

Despite their success and their huge potential, LBM methods have received a little attention compared to classical CFD approaches based on Navier-Stokes equations. Therefore, there are many fundamental and practical open questions in the LBM theory, along with a very important industrial demand. The present project is built in this context. **It aims at extending the range of application of LBM method to micrometeorology for realistic urban flow simulations.**

Research program

The aim of the project is to develop and efficient LBM scheme for fully compressible perfect gas (without shock) subjected to buoyancy forces and coupling with apotential humidity equation. While the most popular LBM schemes deals with weakly compressible athermal flows, the extension to fully compressible flows for the perfect gas equation of state is a non-trivial issue, which is still an open research topic. Such an extension is usually obtained using either the Double Distribution Function approach (in which the energy equation is solved within the LBM framework introducing an ad hoc set of distribution functions) or the hybrid approach (in which the energy equatuon is solved using a classical finite difference/finite volume scheme). The aim of the project is to further extend the physical model to account for the coupling with a humidity equation. Accounting for humidity raise new issues, since it is nonlinearly coupled to the energy equation. Therefore, the full method must be revisited to ensure physical consistency and numerical efficiency. Both DDF and hybrid approaches will be considered and compared.

The first step will consist in the derivation of a method for 2D flow, that will be extended to 3D flows in a second step. The work will be performed in close collaboration with industrial partners (Airbus, Renault) and research centres (ONERA, CERFACS).

Informations

Location: M2P2 Laboratory, Marseille, France

Duration: 12 - 24 months

Net monthly salary: 1930 euros(<3 years after PhD) or 2300 euros (>3 years after PhD)

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