Master Internship

Vectorial Lattice Boltzmann Method for Compressible Flows

Context

Collecting energy from concentrated solar radiation, biomass combustion/gasification, geothermal reservoirs, and wasted heat sources plays a significant role in diversifying our energy sources. Cutting-edge technologies include Organic Rankine Cycle (ORC) and supercritical CO2 (scCO2) cycle power systems. The comprehension of the fluid dynamics in the turbine under thermodynamic conditions close to the **critical point** is a formidable physical and numerical challenge.

Rooted in kinetic theory of gases, the Lattice Boltzmann (LB) method has become a robust tools in the realm of computational fluid dynamics for simulating weakly-compressible complex industrial configurations. We recently showcase the use of a hybrid LB method for simulating compressible turbulence of non-ideal gases [Vienne, 2024].

With a similar formalism as the LB method, **kinetic relaxation schemes** [Buchut, 1999 ; Aregba-Driollet, 2000] have shown promise in solving arbitrary **hyperbolic conservation laws** [Toro, 2009]. Recent advancements [Anandan, 2024] suggest that kinetic relaxations schemes could be adapted to simulate non-ideal compressible fluid dynamics.

Objectives

The aim of this internship is to develop a **prototype code** for simulating the **Euler equations** using a kinetic relaxation scheme. Depending on the candidate's experience, the development will be carried out using either Python or CUDA/OpenCL. The primary focus will be on validating the model through advection and compressible shock-tube problems. The accuracy and numerical stability of the proposed scheme will be compared with the hybrid Lattice Boltzmann (LB) method previously developed. As a future direction, an interesting extension of this work involves exploring non-classical shock-tube scenarios targeting specific thermodynamic features exhibited by some non-ideal gases.

The candidate will benefit from the expertise and support of Dr. Lucien Vienne (numerical methods, coding), Dr. Alexis Giauque (non-ideal CFD, turbomachines) and Dr. Emmanuel Lévêque (numerical methods, turbulence).

Profile

Since this internship primarily involves **numerical development**, we are looking for a final-year Master or Engineering student in applied mathematics, fluid mechanics, computer science or a related field. A strong interest in coding, numerical methods or the physical analysis of fluid dynamics will be an asset.

Location, duration, and reward

This internship is a 5-6 months position, starting in spring 2025. It will be carried out in the Fluid Mechanics and Acoustics Laboratory (LMFA) at Ecole Centrale de Lyon (ECL). The internship reward is about 600€/month. There may be an opportunity to open a **PhD position** following this internship.

How to apply

Please send CV, Application letter and Transcripts to : alexis.giauque@ec-lyon.fr ; emmanuel.leveque@ec-lyon.fr ; lucien.vienne@ec-lyon.fr

References

L. Vienne, et al. (2024), Hybrid Lattice Boltzmann Method for Turbulent Non-Ideal Compressible Fluid Dynamics, Physics of Fluids

F. Buchut (1999), Construction of BGK Models with a Family of Kinetic Entropies for a Given System of Conservation Laws, Journal of Statistical Physics

D. Aregba-Driollet, et al. (2000), Discrete kinetic schemes for multidimensional systems of conservation laws, SIAM Journal on Numerical Analysis

M. Anandan, et al. (2024), On Lattice Boltzmann Methods based on vector-kinetic models for hyperbolic partial differential equations, Computers and Fluids

E.F. Toro (2009), Riemann Solvers and Numerical Methods for Fluid Dynamics, Springer