Introduction to Lattice Boltzmann Methods: GLY-5835

Syllabus

Course Level: Graduate 5835
Location: PC-323 Time: MWF 12:00 – 12:50 or by arrangement

Course Description

Introduction to the theory, implementation, and application of Lattice Boltzmann models. Emphasis on single and multiphase models and their applications in Engineering and Earth and Environmental Sciences. Review of basic fluid dynamics. Boundary conditions. Single phase flow simulation. Non-ideal gasses, liquid-vapor phase separation, Laplace law, and single component multiphase models. Homogeneous and heterogeneous cavitation. Wetting and interactions with solid surfaces. Body forces and gravity. Buoyancy and capillary rise. Oil-water-like systems and multicomponent, multiphase models. Metastability. Solute and energy transport simulation. Porous media.

Prerequisites: Graduate standing and permission of the instructor.

Instructor:	Dr. Michael Sukop
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Office:	PC-346A
Lab:	PC-323
Office/Lab Hours:	M, W 3 to 4 pm, walk-in, and by arrangement

Objectives

The objective of this course is to provide introductions to the theory, implementation, and application Lattice Boltzmann models of fluid dynamics. Students will develop and modify computer codes to implement Lattice Boltzmann models. Students will investigate a specific application, prepare a scientific paper on it, and present the results in a scientific meeting format.

Outline

1. Introduction

2. Review of Basic Fluid Mechanics

3. Basic Matlab skills

4. Basic Boltzmann Gas Concepts

5. Lattice Gas Models

6. Lattice Boltzmann Models (LBM)
    a. Fundamental LBM Equations
        i. Collision
        ii. Streaming
    b. Boundary Conditions
        i. Periodic boundaries
        ii. Von Neumann (flux) boundaries
        iii. Dirichlet (pressure) boundaries
        iv. Bounceback boundaries

7. Single-component, single phase LBM (SCSP LBM)
    a. Poiseuille Flow
        i. Velocity boundaries
        ii. Pressure boundaries
        iii. Gravity
    b. Flows in More Complex Geometries
    c. Unsteady Flows at Higher Reynolds Numbers

8. Single-component, multiphase LBM (SCMP LBM)
    a. Non-ideal Equation of State
    b. Interparticle forces
    c. Phase (Liquid-Vapor) Separation and Interface Minimization
        i. The Laplace equation
        ii. Drops and bubbles
    d. Cavitation
        i. Homogeneous nucleation
        ii. Heterogeneous nucleation
    e. SCMP LBM with Surfaces
        i. Particle-Surface forces
        ii. Adsorption/Capillary condensation
        iii. Hysteretic wetting/drying of pores
    f. Buoyancy and Gravity
        i. Bubbles
        ii. Capillary rise

9. Multicomponent Multiphase LBM (MCMP LBM)
    a. Interparticle Forces
    b. Phase (Fluid-Fluid) Separation
    c. Metastable States
    d. MCMP LBM with Surfaces
    e. Solute/Heat Transport

10. LBM for macroscopic porous media

Assignment Dates

Assignments will be due weekly.

Performance Measures/Grading and Attendance Standards

Attendance: Up to 3 pre-arranged absences and emergency absences acceptable. Otherwise, full attendance is expected.

Homework: Homework assignments will be given weekly and will generally consist of short reports on specific simulations, though reading of key papers will also be required. These assignments will account for 1/2 of your grade. English, units, significant figures, quality of graphics, accuracy and quality of analysis and overall appearance of your submissions will all be considered in grading the assignments.

Examinations: Mid-term and final examinations will account for 1/8 of your grade each. These will focus on your conceptual understanding of the LBM and associated physics but will include some quantitative aspects.

Application Project: A more in-depth look at a particular application. Preparation of report in scientific journal manuscript format. Two weeks will be allotted at the end of the semester for Project development (i.e., there will be no homework assignments). Your 'protopaper' will account for 1/8 of your grade.

Presentations: In-class presentation of Application Project. You will be expected to produce and deliver a scientific meeting-quality presentation of 15-minute duration at the end of the semester for 1/8 of your grade.

Text

Sukop, M.C. and D.T. Thorne, Jr., 2006. Lattice Boltzmann Modeling: An introduction for geoscientists and engineers. Springer, Heidelberg, Berlin, New York 172 p.

Bibliography

Chen, S. and G.D. Doolen, Lattice Boltzmann method for fluid flows, *Annu. Rev. Fluid Mech.*, 30, 329-364, 1998.

Rothman, D.H. and S. Zaleski, *Lattice-gas cellular automata*, Cambridge University Press, Cambridge, 1997.

Shan, X. and H. Chen, Simulation of nonideal gases and liquid-gas phase transitions by the lattice Boltzmann equation, *Phys. Rev. E*, 49, 2941-2948, 1994.

Succi, S., *The lattice Boltzmann equation for fluid dynamics and beyond*, Clarendon Press, Oxford, 2001.

Wolf-Gladrow, D.A., *Lattice-gas cellular automata and lattice Boltzmann models: an introduction*, Springer, Lecture notes in mathematics, Berlin, 2000.

Zou, Q. and X. He, On pressure and velocity boundary conditions for the lattice Boltzmann BGK model, *Phys. Fluids*, 9, 1591-1598, 1997