Large Scale Lattice-Boltzmann Simulations: Computational Methods and Applications

Kandhai, B.D.

Citation for published version (APA):

General rights
It is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), other than for strictly personal, individual use, unless the work is under an open content license (like Creative Commons).

Disclaimer/Complaints regulations
If you believe that digital publication of certain material infringes any of your rights or (privacy) interests, please let the Library know, stating your reasons. In case of a legitimate complaint, the Library will make the material inaccessible and/or remove it from the website. Please Ask the Library: https://uba.uva.nl/en/contact, or a letter to: Library of the University of Amsterdam, Secretariat, Singel 425, 1012 WP Amsterdam, The Netherlands. You will be contacted as soon as possible.
## Contents

I  Introduction                                           1

1  Computer simulations in fluid dynamics            3
   1.1 Fluid dynamics ........................................ 3
   1.2 Computational fluid dynamics                   5
   1.3 Lattice Gas hydrodynamics                      7
   1.4 Research motivation and outline                10

2  Theoretical background                             13
   2.1 Lattice-Boltzmann models                      13
   2.2 The general Lattice Boltzmann equation        14
   2.3 The Lattice-BGK model                         18
      2.3.1 Single time relaxation approximation     18
      2.3.2 The first-order distribution function    19
      2.3.3 Lattice symmetries                       19
   2.4 The Navier-Stokes equations                    20
   2.5 Regularly used LBGK models                    21
   2.6 Taxonomy of LGA and LBM                       22

II  Computational Methods                              27

3  Boundary Conditions and checkerboard effects in Lattice-BGK models  29
   3.1 Introduction ........................................ 29
   3.2 The bounce-back boundary condition             30
   3.3 Comparison between body force and pressure boundaries  35
   3.4 Checkerboard effect in the $D_3Q_{14}$ and $D_3Q_{15}$ models  38
   3.5 Conclusions ........................................ 43

4  Iterative Momentum Relaxation for Fast Lattice-Boltzmann Simulations  45
   4.1 Introduction ........................................ 45
   4.2 The Iterative Momentum Relaxation (IMR) technique 46
   4.3 Simulation results .................................. 47
   4.4 Conclusions ........................................ 50
A.4 Nested grids ......................................................... 125
  A.4.1 Algorithm ................................................. 125
  A.4.2 Grid coupling ........................................... 126
A.5 Preliminary results ........................................... 127
A.6 Conclusion and Future Work ................................. 130

Bibliography ......................................................... 131

Summary ....................................................................... 141

Samenvatting ............................................................. 145

Nawoord .................................................................... 149

Publications ............................................................... 153

Part I
Introduction
Contents

VI. Conclusion and Recommendations on Numerical Simulation at the Short Time Scale... 133
VII. Conclusion and Recommendations on Numerical Simulation at the Long Time Scale... 134
VIII. Summary and Future Directions

Validation and Applications

6 Lattice-Boltzmann and Finite-Element Simulations of Fluid Flow in a Hybrid Mixer

7.1 Introduction

7.2 The Effect of Particle Loading

7.3 The Effect of Particle Shape

7.4 Numerical Challenges

7.5 Conclusion

8 Conclusion and Discussion

A Finite-Difference Lattice-Boltzmann Method on Nested Grids

A.1 Introduction

A.2 Background

A.3 Numerical Discretization of the Boltzmann Equation