The Lattice Boltzmann Equation For Fluid Dynamics And Beyond Numerical Mathematics And Scientific Computation By Succi Sauro 2013 Paperback

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Lattice Boltzmann Modeling for Chemical Engineering

SILAS MAHONEY

A Numerical Theory of Lattice Gas and Lattice Boltzmann Methods in the Computaton of Solutions to Nonlinear Advective-diffusive Systems John Wiley & Sons
The book introduces the fundamentals and applications of the lattice Boltzmann method (LBM) for incompressible viscous flows. It is written clearly and easy to understand for graduate students and researchers.The book is organized as follows. In Chapter 1, the SRT- and MRT-LBM schemes are derived from the discrete Boltzmann equation for lattice gases and the relation between the LBM and the Navier-Stokes equation is explained by using the asymptotic expansion (not the Chapman-Enskog expansion). Chapter 2 presents the lattice kinetic scheme (LKS) which is an extension method of the LBM and can save memory because of needlessness for storing the velocity distribution functions. In addition, an improved LKS which can stably simulate high Reynolds number flows is presented. In Chapter 3, the LBM combined with the immersed boundary method (IB-LBM) is presented. The IB-LBM is well suitable for moving boundary flows. In Chapter 4, the two-phase LBM is explained from the point of view of the difficulty in computing two-phase flows with large density ratio. Then, a two-phase LBM for large density ratios is presented. In Appendix, sample codes (available for download) are given for users.
Multiphase Lattice Boltzmann Methods World Scientific
A careful comparison of the performance of a commercially available Lattice-Boltzmann Equation solver (Power-FLOW) was made with a conventional, block-structured computational fluid-dynamics code (CFL3D) for the flow over a two-dimensional NACA-0012 airfoil. The results suggest that the version of PowerFLOW used in the investigation produced solutions with large errors in

the computed flow field; these errors are attributed to inadequate resolution of the boundary layer for reasons related to grid resolution and primitive turbulence modeling. The requirement of square grid cells in the PowerFLOW calculations limited the number of points that could be used to span the boundary layer on the wing and still keep the computation size small enough to fit on the available computers. Although not discussed in detail, disappointing results were also obtained with PowerFLOW for a cavity flow and for the flow around a generic helicopter configuration.Lockard, David P. and Luo, Li-Shi and Singer, Bart A. and Bushnell, Dennis M. (Technical Monitor)Langley Research CenterBOLTZMANN TRANSPORT EQUATION; TURBULENCE MODELS; BOUNDARY LAYERS; COMPUTER PROGRAMS; COMPUTATIONAL FLUID DYNAMICS; AIRFOILS; CAVITY FLOW; FLOW DISTRIBUTION

An Accurate Curved Boundary Treatment in the Lattice Boltzmann Method
Springer

The generalized hydrodynamics (the wave vector dependence of the transport coefficients) of a generalized lattice Boltzmann equation (LBE) is studied in detail. The generalized lattice Boltzmann equation is constructed in moment space rather than in discrete velocity space. The generalized hydrodynamics of the model is obtained by solving the dispersion equation of the linearized LBE either analytically by using perturbation technique or numerically. The proposed LBE model has a maximum number of adjustable parameters for the given set of discrete velocities. Generalized hydrodynamics characterizes dispersion, dissipation (hyper-viscosities), anisotropy, and lack of Galilean invariance of the model, and can be applied to select the values of the adjustable parameters which optimize the properties of the model. The proposed generalized hydrodynamic analysis also provides some insights into stability and proper initial conditions for LBE simulations. The stability properties of some 2D LBE models are analyzed and compared with each other in the parameter space of the mean streaming velocity and the viscous relaxation time. The procedure described in this work can be applied to analyze other LBE models. As examples, LBE models with various interpolation schemes are analyzed. Numerical results on shear flow with an initially discontinuous velocity profile (shock) with or without a constant streaming velocity are shown to demonstrate the dispersion effects in the LBE model; the results compare favorably with our theoretical analysis. We also show that whereas linear analysis of the LBE evolution operator is equivalent to Chapman-Enskog analysis in the long wave-length limit (wave vector k = 0), it can also provide results for large values of k. Such results are important for the stability and other hydrodynamic properties of the LBE method and cannot be obtained through Chapman-Enskog analysis.Lallemand, Pierre and Luo, Li-ShiLangley Research CenterBOLTZMANN TRANSPORT EQ

Evaluation of the Lattice-Boltzmann Equation Solver PowerFLOW for Aerodynamic Applications Academic Press

This book introduces readers to the lattice Boltzmann method (LBM) for solving transport phenomena – flow, heat and mass transfer – in a systematic way. Providing explanatory computer codes throughout the book, the author guides readers through many practical examples, such as: • flow in isothermal and non-isothermal lid-driven cavities; • flow over obstacles; • forced flow through a heated channel; • conjugate forced convection; and • natural convection. Diffusion and advection–diffusion equations are discussed, together with applications and examples, and complete computer codes accompany the sections on single and multi-relaxation-time methods. The codes are written in MatLab. However, the codes are written in a way that can be easily converted to other languages, such as FORTRANm Python, Julia, etc. The codes can also be extended with little effort to multi-phase and multi-physics, provided the physics of the respective problem are known. The second edition of this book adds new chapters, and includes new theory and applications. It discusses a wealth of practical examples, and explains LBM in connection with various engineering topics, especially the transport of mass, momentum, energy and molecular species. This book offers a useful and easy-to-follow guide for readers with some prior experience with advanced mathematics and physics, and will be of interest to all researchers and other readers who wish to learn how to apply LBM to engineering and industrial problems. It can also be used as a textbook for advanced undergraduate or graduate courses on computational transport phenomena

Some Recent Results on Discrete Velocity Model and Ramifications for Lattice Boltzmann Equation Springer

This book provides a comprehensive introduction to the kinetic theory for describing flow problems from molecular scale, hydrodynamic scale, to Darcy scale. The author presents various numerical algorithms to solve the same Boltzmann-like equation for different applications of different scales, in which the dominant transport mechanisms may differ. This book presents a concise introduction to the Boltzmann equation of the kinetic theory, based on which different simulation methods that were independently developed for solving problems of different fields can be naturally related to each other. Then, the advantages and disadvantages of different methods will be discussed with reference to each other. It mainly covers four advanced simulation methods based on the Boltzmann equation (i.e., direct simulation Monte Carlo method, direct simulation BGK method, discrete velocity method, and lattice Boltzmann method) and their applications with detailed results. In particular, many simulations are included to demonstrate the applications for both conventional and unconventional reservoirs. With the development of high-resolution CT and high-performance computing facilities, the study of digital rock physics is becoming increasingly important for understanding the mechanisms of enhanced oil and gas recovery. The advanced methods presented here have broad applications in petroleum engineering as well as mechanical engineering , making them of interest to researchers, professionals, and graduate students alike. At the same time, instructors can use the codes at the end of the book to help their students implement the advanced technology in solving real industrial problems.

Non-Linear Lattice GRIN Verlag

The Lattice Boltzmann Method (LBM) is a powerful technique for the computation of a wide variety of complex fluid flow problems including single and multiphase fluids in complex geometries. Historically, the Lattice Boltzmann equation for modeling hydrodynamics

originated from the lattice gas cellular automata (LGCA), which are discrete models based on particles that move on a lattice. The LBM is different from traditional computational fluid dynamics (CFD) approaches, which solve the Navier-Stokes equations numerically. The LBM models the fluid with particle distributions, and assumes that these particles perform collision and steaming processes on a discrete lattice mesh. During the last decade, the LBM has been receiving increased attention. Great improvements have occurred not only in theoretical understanding but also in algorithmic development, and the method has been used more widely in computational fluid dynamics. The LBM are explicit time-integration approaches which are based on the Lattice Boltzmann Equation (LBE). They are notoriously inefficient for steady-state simulations or time-dependent problems which have large separations in relevant time and spatial scales. To solve this problem, a time-implicit multigrid LBE scheme is developed in this work. This scheme can solve the time dependent LBE problem more efficiently by using unconditionally large time step sizes. The improved efficiency and temporal accuracy of this implicit multigrid LBE scheme are demonstrated by numerical experiments and comparisons with the original explicit LBE approach.
Computational Fluid Dynamics Springer
In,1872, Boltzmann published a paper which for the first time provided a precise mathematical basis for a discussion of the approach to equilibrium. The paper dealt with the approach to equilibrium of a dilute gas and was based on an equation - the Boltzmann equation, as we call it now - for the velocity distribution function of such ~ gas. The Boltzmann equation still forms the basis of the kinetic theory of gases and has proved fruitful not only for the classical gases Boltzmann had in mind, but als- if properly generalized - for the electron gas in a solid and the excitation gas in a superfluid. Therefore it was felt by many of us that the Boltzmann equation was of sufficient interest, even today, to warrant a meeting, in which a review of its present status would be undertaken. Since Boltzmann had spent a good part of his life in Vienna, this city seemed to be a natural setting for such a meeting. The first day was devoted to historical lectures, since it was generally felt that apart from their general interest, they would furnish a good introduction to the subsequent scientific sessions. We are very much indebted to Dr. D.
Theory of the Lattice Boltzmann Method: Lattice Boltzmann Models for Non-ideal Gases IGI Global
Lattice Boltzmann Modeling for Chemical Engineering, Volume 56 in the Advances in Chemical Engineering series, highlights new advances in the field, with this new volume presenting interesting chapters on Simulations of homogeneous and heterogeneous chemical reactions, LBM for 3D Chemical Reactors, LBM Simulations of PEM fuel cells, LBM for separation processes, LBM for two-phase flow (bio)reactors, and more. Provides the authority and expertise of leading contributors from an international board of authors Presents the latest release in the Advances in Chemical Engineering series Includes the latest information on Lattice Boltzmann Modeling for Chemical Engineering
Lattice Boltzmann Equation on a 2D Rectangular Grid Bentham Science Publishers
Nature continuously presents a huge number of complex and multi-scale

phenomena, which in many cases, involve the presence of one or more fluids flowing, merging and evolving around us. Since its appearance on the surface of Earth, Mankind has tried to exploit and tame fluids for their purposes, probably starting with Hero's machinery to open the doors of the Temple of Serapis in Alexandria to arrive to modern propulsion systems and actuators. Today we know that fluid mechanics lies at the basis of countless scientific and technical applications from the smallest physical scales (nanofluidics, bacterial motility, and diffusive flows in porous media), to the largest (from energy production in power plants to oceanography and meteorology). It is essential to deepen the understanding of fluid behaviour across scales for the progress of Mankind and for a more sustainable and efficient future. Since the very first years of the Third Millennium, the Lattice Boltzmann Method (LBM) has seen an exponential growth of applications, especially in the fields connected with the simulation of complex and soft matter flows. LBM, in fact, has shown a remarkable versatility in different fields of applications from nanoactive materials, free surface flows, and multiphase and reactive flows to the simulation of the processes inside engines and fluid machinery. LBM is based on an optimized formulation of Boltzmann's Kinetic Equation, which allows for the simulation of fluid particles, or rather quasi-particles, from a mesoscopic point of view thus allowing the inclusion of more fundamental physical interactions in respect to the standard schemes adopted with Navier-Stokes solvers, based on the continuum assumption. In this book, the authors present the most recent advances of the application of the LBM to complex flow phenomena of scientific and technical interest with particular focus on the multi-scale modeling of heterogeneous catalysis within nano-porous media and multiphase, multicomponent flows.

Viscous Flow Computations with the Lattice Boltzmann Equation Method

Springer

This book is an introduction to the theory, practice, and implementation of the Lattice Boltzmann (LB) method, a powerful computational fluid dynamics method that is steadily gaining attention due to its simplicity, scalability, extensibility, and simple handling of complex geometries. The book contains chapters on the method's background, fundamental theory, advanced extensions, and implementation. To aid beginners, the most essential paragraphs in each chapter are highlighted, and the introductory chapters on various LB topics are front-loaded with special "in a nutshell" sections that condense the chapter's most important practical results. Together, these sections can be used to quickly get up and running with the method. Exercises are integrated throughout the text, and frequently asked questions about the method are dealt with in a special section at the beginning. In the book itself and through its web page, readers can find example codes showing how the LB method can be implemented efficiently on a variety of hardware platforms, including multi-core processors, clusters, and graphics processing units. Students and scientists learning and using the LB method will appreciate the wealth of clearly presented and structured information in this volume.

The Lattice Boltzmann Equation

Morgan & Claypool Publishers

This volume focuses on progress in applying the lattice gas approach to partial differential equations that arise in simulating the flow of fluids.Lattice gas methods are new parallel, high-resolution, high-efficiency techniques for solving partial differential equations. This volume focuses on progress in applying the lattice gas approach to partial differential equations that arise in simulating the flow of fluids. It introduces the lattice Boltzmann equation, a new direction in lattice gas research that considerably reduces fluctuations.The twenty-seven contributions explore the many available software options exploiting the fact that lattice gas methods are completely parallel, which produces significant gains in speed. Following an overview of work done in the past five years and a discussion of frontiers, the chapters describe viscosity modeling and hydrodynamic mode analyses, multiphase flows and porous media, reactions and diffusion, basic relations and long-time correlations, the lattice Boltzmann equation, computer hardware, and lattice gas applications.Gary D. Doolen is Acting Director of the Center for Nonlinear Studies at Los Alamos National Laboratory.

Lattice Gas Methods Oxford University Press

This book is a printed edition of the Special Issue "Non-Linear Lattice" that was published in Entropy

Lattice Boltzmann Method and Its Applications in Engineering Oxford University Press

Lattice-gas cellular automata (LGCA) and lattice Boltzmann models (LBM) are relatively new and promising methods for the numerical solution of nonlinear partial differential equations. The book provides an introduction for graduate students and researchers. Working knowledge of calculus is required and experience in PDEs and fluid dynamics is recommended. Some peculiarities of cellular automata are outlined in Chapter 2. The properties of various LGCA and special coding techniques are discussed in Chapter 3. Concepts from statistical mechanics (Chapter 4) provide the necessary theoretical background for LGCA and LBM. The properties of lattice Boltzmann models and a method for their construction are presented in Chapter 5.

Lattice-Gas Cellular Automata and Lattice Boltzmann Models BiblioGov

This book is concerned with the methods of solving the nonlinear Boltz mann equation and of investigating its possibilities for describing some aerodynamic and physical problems. This monograph is a sequel to the book 'Numerical direct solutions of the kinetic Boltzmann equation' (in Russian) which was written with F. G. Tcheremissine and published by the Computing Center of the Russian Academy of Sciences some years ago. The main purposes of these two books are almost similar, namely, the study of nonequilibrium gas flows on the basis of direct integration of the kinetic equations. Nevertheless, there are some new aspects in the way this topic is treated in the present monograph. In particular, attention is paid to the advantages of the Boltzmann equation as a tool for considering nonequi librium, nonlinear processes. New fields of application of the Boltzmann equation are also described. Solutions of some problems are obtained with higher accuracy. Numerical procedures, such as parallel computing, are in vestigated for the first time. The structure and the contents of the present book have some com mon features with the monograph mentioned above, although there are new issues concerning the mathematical apparatus developed so that the Boltzmann equation can be applied for new physical problems. Because of this some chapters have been rewritten and checked again and some new chapters have been added.

Lattice Boltzmann Modeling of Complex Flows for Engineering Applications World Scientific

Computational fluid dynamics (CFD) has been widely applied in a wide variety of industrial applications, including aeronautics, astronautics, energy, chemical, pharmaceuticals, power and petroleum.This unique compendium documents the recent developments in CFD based on kinetic theories, introducing flux reconstruction strategies of kinetic methods for the simulation of complex incompressible and compressible flows, namely the lattice Boltzmann and the gas kinetic flux solvers (LBFS or GKFS). LBFS and GKFS combine advantages of both Navier-Stokes (N-S) solvers and kinetic solvers.Detailed derivations, evaluations and applications of LBFS and GKFS, and their advantages over conventional flux reconstruction strategies are analyzed and discussed in the volume.The must-have reference text is useful for scholars, researchers, professionals and students who are keen in CFD methods and numerical simulations.

Analysis and Applications of Lattice Boltzmann Simulations MIT Press

This unique professional volume is about the recent advances in the lattice Boltzmann method (LBM). It introduces a new methodology, namely the simplified and highly stable lattice Boltzmann method (SHSLBM), for constructing numerical schemes within the lattice Boltzmann framework. Through rigorous mathematical derivations and abundant numerical validations, the SHSLBM is found to outperform the conventional LBM in terms of memory cost, boundary treatment and numerical stability.This must-have title provides every necessary detail of the SHSLBM and sample codes for implementation. It is a useful handbook for scholars, researchers, professionals and students who are keen to learn, employ and further develop this novel numerical method.

Connection Between the Lattice Boltzmann Equation and the Beam Scheme Springer Science & Business Media

Doctoral Thesis / Dissertation from the year 2007 in the subject Mathematics - Analysis, University of Constance (Fachbereich Mathematik & Statistik), 69 entries in the bibliography, language: English, abstract: Lattice-Boltzmann algorithms represent a quite novel class of numerical schemes, which are used to solve evolutionary partial differential equations (PDEs). In contrast to other methods (FEM, FVM), lattice-Boltzmann methods rely on a mesoscopic approach. The idea consists in setting up an artificial, grid-based particle dynamics, which is chosen such that appropriate averages provide approximate solutions of a certain PDE, typically in the area of fluid dynamics. As lattice-Boltzmann schemes are closely related to finite velocity Boltzmann equations being singularly perturbed by special scalings, their consistency is not obvious. This work is concerned with the analysis of lattice-Boltzmann methods also focusing certain numeric phenomena like initial layers, multiple time scales and boundary layers. As major analytic tool, regular (Hilbert) expansions are employed to establish consistency. Exemplarily, two and three population algorithms are studied in one space dimension, mostly discretizing the advection-diffusion equation. It is shown how these model schemes can be derived from two-dimensional schemes in the case of special symmetries. The analysis of the schemes is preceded by an examination of the singular limit being characteristic of the corresponding scaled finite velocity Boltzmann equations. Convergence proofs are obtained using a Fourier series approach and alternatively a general regular expansion combined with an energy estimate. The appearance of initial layers is investigated by multiscale and irregular expansions. Among others, a hierarchy of equations is found which gives insight into the internal coupling of the initial layer and the regular part of the solution. Next, the consistency of the model algorithms is considered followed by

Time-implicit Solution of the Lattice Boltzmann Equation Springer Nature
Here is a basic introduction to Lattice Boltzmann models that emphasizes intuition and simplistic conceptualization of processes, while avoiding the complex mathematics that underlies LB models. The model is viewed from a particle perspective where collisions, streaming, and particle-particle/particle-surface interactions constitute the entire conceptual framework. Beginners and those whose interest is in model application over detailed mathematics will find this a powerful 'quick start' guide. Example simulations, exercises, and computer codes are included.

Direct Methods for Solving the Boltzmann Equation and Study of Nonequilibrium Flows MDPI
In this paper a procedure for systematic a priori derivation of the lattice Boltzmann models for non-ideal gases from the Enskog equation (the modified Boltzmann equation for dense gases) is presented. This treatment provides a unified theory of lattice Boltzmann models for non-ideal gases. The lattice Boltzmann equation is systematically obtained by discretizing the Enskog equation in phase space and time. The lattice Boltzmann model derived in this paper is thermodynamically consistent up to the order of discretization error. Existing lattice Boltzmann models for non-ideal gases are analyzed and compared in detail. Evaluation of these models are made in light of the general procedure to construct the lattice Boltzmann model for non-ideal gases presented in this work.

Lattice Boltzmann Modeling Createspace Independent Publishing Platform
We construct a multi-relaxation lattice Boltzmann model on a two-dimensional rectangular grid. The model is partly inspired by a previous work of Koelman to construct a lattice BGK model on a two-dimensional rectangular grid. The linearized dispersion equation is analyzed to obtain the constraints on the isotropy of the transport coefficients and Galilean invariance for various wave propagations in the model. The linear stability of the model is also studied. The model is numerically tested for three cases: (a) a vortex moving with a constant velocity on a mesh periodic boundary conditions; (b) Poiseuille flow with an arbitrasy inclined angle with respect to the lattice orientation: and (c) a cylinder &symmetrically placed in a channel. The numerical results of these tests are compared with either analytic solutions or the results obtained by other methods. Satisfactory results are obtained for the numerical simulations.

Bouzidi, MHamed and DHumieres, Dominique and Lallemand, Pierre and Luo, Li-Shi and Bushnell, Dennis M. (Technical Monitor) Langley Research Center NASA/CR-2002-211658, NAS 1.26:211658, ICASE-2002-18