Lattice Boltzmann Method And Its Applications In Engineering Advances In Computational Fluid Dynamics

The history of the Lattice Boltzmann Method and its application to fluid mechanics are investigated here. Detailed formulations are provided to form a basis for the Lattice Boltzmann Method and its many variations. These variations are designed to overcome shortcomings in the standard single relaxation time Lattice Boltzmann model. Presented here are: a model that utilizes the non-equilibrium parts of the stress tensor, the Regularized Lattice Boltzmann model; a model that converts over to momentum space, the Multi-Relaxation Time Lattice Boltzmann model; and a model that corrects itself using the entropy equation, the entropic Lattice Boltzmann model. Extensions for the Lattice Boltzmann method are derived that include: external forces, multiphase flows, and thermal flows. Various types of boundary conditions are modeled using different approaches. A detailed explanation on extracting common macroscopic flow properties in physical units is provided. These extracted properties can be used to check temporal and spatial convergence. A two dimensional, nine velocity model and a three dimensional, fifteen velocity model are used to provide examples of a number of the approaches mentioned. A two dimensional and three dimensional lid-driven cavity flow is used to illustrate these methods.

Transport phenomena in biological flow and soft matter is very important in understanding human disease and health. The interaction between cells and blood plasma is important because it not only shows complex mechanical behavior but also advance our knowledge in medical research. This dissertation presents modeling work in drug carrier delivery in blood suspensions and early detection of circulating tumor cells. Methodologically, the Lattice Boltzmann method was employed as Navier-Stokes fluid solver due to its competence in modeling single phase and multiphase flow, handling complex geometries, and the capacity in parallel computing. A significant part of the work was devoted to the theory, algorithm, boundary conditions, and code implementations. The cells were implemented using a coarse grained molecular dynamics model because of its capacity in modeling solid nonlinear large deformations. Besides the suspending fluid and cells, nanoparticles (drug carriers) were also introduced into the system. The coupling fluid and solid was based on the Immersed Boundary Method which removes the burden of expensive mesh updating in traditional Arbitrary Lagrangian Eulerian approach.

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.

The Lattice Boltzmann Methods and Their Applications to Fluid Flows

Introduction to the Lattice Boltzmann Method, An: A Numerical Method for Complex Boundary and Moving Boundary Flows

Lattice-Gas Cellular Automata and Lattice Boltzmann Models

Lattice Boltzmann Method

Thermal Multiphase Fluid Dynamics

Certain forms of the Boltzmann equation, have emerged, which relinquish most mathematical complexities of the true Boltzmann equation. This text provides a detailed survey of Lattice Boltzmann equation theory and its major applications.

Lattice Boltzmann Method introduces 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 with applications and examples, and complete computer codes accompany the coverage of single and multi-relaxation-time methods. Although the codes are written in FORTRAN, they can be easily translated to other languages, such as C++. The codes can also be extended with little effort to multi-phase and multi-physics, if the reader knows the physics of the problem. Readers with some experience of advanced mathematics and physics will find Lattice Boltzmann Method a useful and easy-to-follow text. It has been written for those who are interested in learning and applying the LBM to engineering and industrial problems and it can also serve as a textbook for advanced undergraduate or graduate students who are studying computational transport phenomena.

Lattice Boltzmann Method and Its Applications in EngineeringWorld Scientific
Introduction To The Lattice Boltzmann Method, An: A Numerical Method For Complex Boundary And Moving Boundary Flows

Simulation of the CRUD Formation Process Using the Lattice Boltzmann Method
Theory of the Lattice Boltzmann Method: Lattice Boltzmann Models for Non-ideal Gases
On the Lattice Boltzmann Method

Theory and Application of Multiphase Lattice Boltzmann Methods presents a comprehensive review of all popular multiphase Lattice Boltzmann Methods developed thus far and is aimed at researchers and practitioners within relevant Earth Science disciplines as well as Petroleum, Chemical, Mechanical and Geological Engineering. Clearly structured throughout, this book will be an invaluable reference on the current state of all popular multiphase Lattice Boltzmann Methods (LBMs). The advantages and disadvantages of each model are presented in an accessible manner to enable the reader to choose the model most suitable for the problems they are interested in. The book is targeted at graduate students and researchers who plan to investigate multiphase flows using LBMs. Throughout the text most of the popular multiphase LBMs are analyzed both theoretically and through numerical simulation. The authors present many of the mathematical derivations of the models in greater detail than is currently found in the existing literature. The approach to understanding and classifying the various models is principally based on simulation compared against analytical and observational results and discovery of undesirable terms in the derived macroscopic equations and sometimes their correction. A repository of FORTRAN codes for multiphase LBM models is also provided.
Progress in Computational Physics is an e-book series devoted to recent research trends in computational physics. It contains chapters contributed by outstanding experts of modeling of physical problems. The series focuses on interdisciplinary computational perspectives of current physical challenges, new numerical techniques for the solution of mathematical wave equations and describes certain real-world applications. With the help of powerful computers and sophisticated methods of numerical mathematics it is possible to simulate many ultramodern devices, e.g. photonic crystals structures, semiconductor nanostructures or fuel cell stacks devices, thus preventing expensive and longstanding design and optimization in the laboratories. In this book series, research manuscripts are shortened as single chapters and focus on one ho

topic per volume. Engineers, physicists, meteorologists, etc. and applied mathematicians can benefit from the series content. Readers will get a deep and active insight into state-of-the art modeling and simulation techniques of ultra-modern devices and problems. The third volume - Novel Trends in Lattice Boltzmann Methods - Reactive Flow, Physicochemical Transport and Fluid-Structure Interaction - contains 10 chapters devoted to mathematical analysis of different issues related to the lattice Boltzmann methods, advanced numerical techniques for physico-chemical flows, fluid structure interaction and practical applications of these phenomena to real world problems.

This research project presents an overview of the Lattice Boltzmann Method (LBM), an alternative numerical approach to conventional CFD. LBM has increased in popularity among the scientific community in recent years, due to its promising abilities. Namely, it claims to achieve the same level of accuracy as that of traditional CFD, while offering new benefits such as easy parallelization and the possibility of implementing complex and multiscale flows. Unlike conventional CFD which focuses on the numerical solution of the Navier Stokes Equations, the Lattice Boltzmann Method focuses on microscopic particle interactions to represent the macroscopic behaviour of the fluid. The aim of this project is to appraise the ability of the Lattice Boltzmann Method to accurately simulate incompressible flows and to analyse its accuracy performance and stability. This report presents the theoretical basis of this novel method, as well as a verification of its convergence results through some examples. These examples are implemented through an open-source code (Palabos). This project not only focuses on matching the LBM solutions with analytical or existing solutions, but it also focuses on studying the effect that the parameters of the model have on the results provided, on stability and on computational cost. The results and their analysis show that LBM is an accurate method for representing incompressible flows. The report also describes how to implement the Lattice Boltzmann Method and suggests some ways to continue the work further.

The Lattice Boltzmann Method for Complex Flows

Theory and Applications of the Lattice Boltzmann Method

Accelerated Lattice Boltzmann Model for Colloidal Suspensions

The Lattice Boltzmann Method

Lattice Boltzmann Method and Its Applications in Soft Matter

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

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.

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.

Special Issue

Progress in Computational Physics Volume 3: Novel Trends in Lattice-Boltzmann Methods

For Fluid Dynamics and Beyond

Lattice Boltzmann Modeling

Applications of the Lattice Boltzmann Method to Model Fluid Flow in Microchannels

This book begins by introducing the reader to Lattice Boltzmann Method (LBM), covering the fundamental principles of the method, while also outlining the potential problems involved. It provides a detailed description to build the thermal multiphase LBM (TMLBM) which includes the effects of interfacial tension and its dependence on temperature by a hybrid scheme. It also describes how a nearest-neighbor molecular interaction force is introduced into LB equation to model the adhesive forces between the fluid and solid surface. Some example simulations, e.g., two-phase Rayleigh-Benard convection, vibration-induced thermal convection in a two-layer fluid system, micron-scale fluid droplet on a heterogeneous surface, are included. The method has a remarkable ability to simulate a rich of behaviors, including single- and multiphase with or without thermal problem, phase separation, buoyancy, and the interactions with solid surfaces. This book may be used as a reference for science and engineers, and a textbook for graduates in engineering sciences such as materials, mechanical, biomedical engineering.

This thesis presents the extension of the lattice Boltzmann equation (LBE) to several well-known flows. First, the flow over a cylinder is studied using the LBE and the numerical predictions are shown to compare well with those obtained using a stylised finite volume method. A clear and formal perturbation analysis of the generalised LBE is also presented. A LBE for axisymmetric flows is developed, the precise form of which is derived through a Chapman-Enskog analysis so that the additional axisymmetric contributions to the Navier-Stokes equation are furnished when written in the cylindrical polar coordinate system. Stokes' flow over a sphere is studied and excellent agreement is found between the numerical and analytical predictions. A lattice Boltzmann model for immiscible binary fluids with variable viscosities and density ratio is developed. In the macroscopic limit this model is shown to recover the Navier-Stokes equations for two phase flow. A theoretical expression for surface tension is determined. The validity of this analysis is confirmed by comparing numerical and theoretical predictions of surface tension as a function of density. A number of numerical simulations are presented and shown to be in good agreement with analytical results. Finally, an axisymmetric multiphase lattice Boltzmann model has been proposed. This model is easy to implement and some test cases have been performed to demonstrate its capabilities. A review of the extension of the lattice Boltzmann equation to viscoelasticity is also presented.

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.

Fundamentals and Engineering Applications with Computer Codes

Application of Lattice Boltzmann Method

An Introduction

Lattice Boltzmann Methods for Shallow Water Flows

Simplified And Highly Stable Lattice Boltzmann Method: Theory And Applications

Programming has become a significant part of connecting theoretical development and scientific application computation. Fluid dynamics provide an important asset in experimentation and theoretical analysis. Analysis and Applications of Lattice Boltzmann Simulations provides emerging research on the efficient and standard implementations of simulation methods on current and upcoming parallel architectures. While highlighting topics such as hardware accelerators, numerical analysis, and sparse geometries, this publication explores the techniques of specific simulators as well as the multiple extensions and various uses. This book is a vital resource for engineers, professionals, researchers, academics, and students seeking current research on computational fluid dynamics, high-performance computing, and numerical and flow simulations.

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.

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.

The Finite-difference Lattice Boltzmann Method and Its Application in Computational Aero-acoustics

Lattice Boltzmann And Gas Kinetic Flux Solvers: Theory And Applications

The Lattice Boltzmann Equation: For Complex States of Flowing Matter

The Lattice Boltzmann Method for Fluid Flows,

Implementation and Applications

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.

This book constitutes the thoroughly refereed post-conference proceedings of the Second International Conference on High Performance Computing and Applications, HPCA 2009, held in Shangahi, China, in August 2009. The 71 revised papers presented together with 10 invited presentations were carefully selected from 324 submissions. The papers cover topics such as numerical algorithms and solutions; high performance and grid computing; novel approaches to high performance computing; massive data storage and processsing; and hardware acceleration.

Flowing matter is all around us, from daily-life vital processes (breathing, blood circulation), to industrial, environmental, biological, and medical sciences. Complex states of flowing matter are equally present in fundamental physical processes, far remote from our direct senses, such as quantum-relativistic matter under ultra-high temperature conditions (quark-gluon plasmas). Capturing the complexities of such states of matter stands as one of the most prominent challenges of modern science, with multiple ramifications to physics, biology, mathematics, and computer science. As a result, mathematical and computational techniques capable of providing a quantitative account of the way that such complex states of flowing matter behave in space and time are becoming increasingly important. This book provides a unique description of a major technique, the Lattice Boltzmann method to accomplish this task. The Lattice Boltzmann method has gained a prominent role as an efficient computational tool for the numerical simulation of a wide variety of complex states of flowing matter across a broad range of scales; from fully-developed turbulence, to multiphase micro-flows, all the way down to nano-biofluidics and lately, even quantum-relativistic sub-nuclear fluids. After providing a self-contained introduction to the kinetic theory of fluids and a thorough account of its transcription to the lattice framework, this text provides a survey of the major developments which have led to the impressive growth of the Lattice Boltzmann across most walks of fluid dynamics and its interfaces with allied disciplines. Included are recent developments of Lattice Boltzmann methods for non-ideal fluids, micro- and nanofluidic flows with suspended bodies of assorted nature and extensions to strong non-equilibrium flows beyond the realm of continuum fluid mechanics. In the final part, it presents the extension of the Lattice Boltzmann method to quantum and relativistic matter, in an attempt to match the major surge of interest spurred by recent developments in the area of strongly interacting holographic fluids, such as electron flows in graphene.

A Coupled Bonded Particle and Lattice Boltzmann Method with Its Application to Geomechanics

Analysis and Applications of Lattice Boltzmann Simulations

Theory and Application

An Introduction for Geoscientists and Engineers

Second International Conference, HPCA 2009, Shanghai, China, August 10-12, 2009, Revised Selected Papers

The lattice Boltzmann method (LBM) is a modern numerical technique, very efficient, flexible to simulate different flows within complex/varying geome tries. It is evolved from the lattice gas automata (LGA) in order to overcome the difficulties with the LGA. The core equation in the LBM turns out to be a special discrete form of the continuum Boltzmann equation, leading it to be self-explanatory in statistical physics. The method describes the micro scopic picture of particles movement in an extremely simplified way, and on the macroscopic level it gives a correct average description of a fluid. The av eraged particle velocities behave in time and space just as the flow velocities in a physical fluid, showing a direct link between discrete microscopic and continuum macroscopic phenomena. In contrast to the traditional computational fluid dynamics (CFD) based on a direct solution of flow equations, the lattice Boltzmann method provides an indirect way for solution of the flow equations. The method is characterized by simple calculation, parallel process and easy implementation of boundary conditions. It is these features that make the lattice Boltzmann method a very promising computational method in different areas. In recent years, it receives extensive attentions and becomes a very potential research area in computational fluid dynamics. However, most published books are limited to the lattice Boltzmann methods for the Navier-Stokes equations. On the other hand, shallow water flows exist in many practical situations such as tidal flows, waves, open channel flows and dam-break flows.

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.

We briefly review the method of the lattice Boltzmann equation (LBE). We show the three-dimensional LBE simulation results for a non-spherical particle in Couette flow and 16 particles in sedimentation in fluid. We compare the LBE simulation of the three-dimensional homogeneous isotropic turbulence flow in a periodic cubic box of the size 1283 with the pseudo-spectral simulation, and find that the two results agree well with each other but the LBE method is more dissipative than the pseudo-spectral method in small scales, as expected. Luo, Li-Shi and Qi, Dewei and Wang, Lian-Ping and Bushnell, Dennis M. (Technical Monitor) Langley Research Center NASA/CR-2002-211659, NAS 1.26:211659, ICASE-2002-19

Principles and Practice

Apprasial of Flow Simulation by the Lattice Boltzmann Method

Lattice Boltzmann Method and Its Applications in Engineering

High Performance Computing and Applications

Multiphase Lattice Boltzmann Methods

Colloids are ubiquitous in the food, medical, cosmetics, polymers, water purification, and pharmaceutical industries. The thermal, mechanical, and storage properties of colloids are highly dependent on their interface morphology and their rheological behavior. Numerical methods provide a convenient and reliable tool for the study of colloids. Accelerated Lattice Boltzmann Model for Colloidal Suspensions introduce the main building-blocks for an improved lattice Boltzmann-based numerical tool designed for the study of colloidal rheology and interface morphology. This book also covers the migrating multi-block used to simulate single component, multi-component, multiphase, and single component multiphase flows and their validation by experimental, numerical, and analytical solutions. Among other topics discussed are the hybrid lattice Boltzmann method (LBM) for surfactant-covered droplets; biological suspensions such as blood; used in conjunction with the suppression of coalescence for investigating the rheology of colloids and microvasculature blood flow. The presented LBM model provides a flexible numerical platform consisting of various modules that could be used separately or in combination for

the study of a variety of colloids and biological flow deformation problems.

This book covers the fundamental and practical application of the Lattice Boltzmann method (LBM). This method is a relatively new simulation technique for the modeling of complex fluid systems and has attracted interest from researchers in computational physics.

Computational fluid dynamics (CFD) encompasses a variety of numerical methods. Some depend on macroscopic model representatives, which are solved by finite volume, finite element or finite difference method, while others rely on a microscopic description. The lattice Boltzmann method (LBM) is considered a mesoscopic particle method, with its scale lying between macroscopic and microscopic. LBM works well when solving incompressible flow problems, but limitations arise when solving compressible flows, particularly at high Mach numbers. In the present research, this limitation will be overcome by using higher-order Taylor series expansion of the Maxwell equilibrium distribution function and Kataoka and Tsutahara (KT) models for compressible flows. The multiple relaxation times (MRT) approach associated with the collision term of the lattice Boltzmann equation (LBE) will be adopted to enhance the numerical stability of the code, while the large eddy simulation (LES) scale model will be implemented in LBM to simulate compressible jet flows at high subsonic speeds pertinent to jet noise problems. Three-dimensional simulation is performed using 19- and 15-lattice velocity with D3Q19 and D3Q15 models, respectively. In addition, compressible LBM is applied to simulate both heated and unheated jets to show the ability of the nonadiabatic fifth-order equilibrium distribution function in solving nonadiabatic compressible flows. The near-field flow physics and noise simulations are performed using a compressible lattice Boltzmann method. The results from the LMB simulation are used in the Kirchhoff surface integral approach to predict far-field jet noise. Finally, because of the ability of lattice Boltzmann in parallel computing and to improve the computation efficiency of LBM on the numerical simulations of turbulent flows, compute unified device architecture (CUDA) is used to implement LBM in the graphics processing unit (GPU), creating the hybrid code LBM-MRT-LES by utilizing the Kirchhoff integral method, a powerful tool for simulating aeroacoustics problems.

The Lattice Boltzmann Equation
Lattice Boltzmann Method for Integrating the Bloch Equation in Muscle Fibers and Microvessels
The Lattice Boltzmann Method for the Study of Volcano Aeroacoustic Source Processes
Lattice Boltzmann Method for the Simulation of Viscoelastic Fluid Flows
Applications of the Lattice Boltzmann Method to Complex and Turbulent Flows