

REVIEW

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Landmarks and new frontiers of computational fluid dynamics

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Abstract

A narrative of landmarks in computational fluid dynamics (CFD) is presented to highlight the cornerstone achievements, illuminating accomplishments starting from the very beginning of the coherent development until the most recent progress will be elucidated over the span over more than six decades. Meanwhile, the cutting-edge scientific innovations will also be discussed for their lasting impacts to fluid dynamics and the physics-based modeling and simulation discipline. To traverse such a vast domain over time by a single presentation, numerous and excellent contributions to CFD will be unavoidably overlooked. Nevertheless it is my ardent hope that the present discussion will be able to reaffirm excellence in research and to identify new frontiers for scientific research. Especially, the challenges to future innovations will also be delineated to recommend for potential and fertile research areas for the modeling and simulation science.

Keywords: Computational fluid dynamics, Numerical algorithms, Turbulence, Interdisciplinary computational fluid dynamics

1 Introduction

In order to discuss the physics-based modeling and simulation discipline, the underlying principles must be explicitly stipulated to define its limitations. The traditional computational fluid dynamics (CFD) technique is mostly applying in the continuum gas domain which is limited to the negligible Knudsen number; $N_{\text{Kn}} = \lambda/l < < 1.0$. In this physical domain, the mean-free-path of particle collisions is negligible in comparison with the characteristic length of the flowfield considered. In the continuum regime, the compressible Navier-Stokes equations become the governing equation for describing fluid dynamics in the macroscopic scale, and the nonlinear partial differential equations system is the incompletely parabolic type. Even though the incompressible Navier-Stokes was known to us as far back as 1827, only more recently the system of equations was derived in integral form via the control-volume formulation to become the basis for the finite-volume approach. Nevertheless, the necessary initial values, boundary conditions, and their placement and implementation are mandatory to achieve a unique numerical simulation.

Numerical algorithms are inseparable parts of CFD research, also are the most demanding and creative efforts of this discipline, because they dictate the computational accuracy that provides the required physical fidelity to any computational simulations. In the gist, the numerical algorithm and the computational procedure research is a tool

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will become the standard reference for CFD for the next 20 years *Analysis of Coastal Upwelling and the Production of a Biomass* John T. Howe, 1979 Computational Fluid Dynamics Paul D. Bates, Stuart N. Lane, Robert I. Ferguson, 2005-08-05

Uniquely outlines CFD theory in a manner relevant to environmental applications This book addresses the basic topics in CFD modelling in a thematic manner to provided the necessary theoretical background as well as providing global cases studies showing how CFD models can be used in practice demonstrating how good practice can be achieved with reference to both established and new applications First book to apply CFD to the environmental sciences Written at a level suitable for non mathematicians **Continuum Mechanics of Single-Substance Bodies** A. Cemal Eringen, 2013-10-22 Continuum Physics Volume II Continuum Mechanics of Single Substance Bodies discusses the continuum mechanics of bodies constituted by a single substance providing a thorough and precise presentation of exact theories that have evolved during the past years This book consists of three parts basic principles constitutive equations for simple materials and methods of solution Part I of this publication is devoted to a discussion of basic principles irrespective of material geometry and constitution that are valid for all kinds of substances including composites The geometrical notions kinematics balance laws and thermodynamics of continua are also deliberated Part II focuses on materials consisting of a single substance followed by a general theory of constitutive equations and special types of bodies The thermoelastic solids thermoviscous fluids and memory dependent materials are likewise considered Part III is devoted to a discussion of a variety of nonlinear and linear problems as well as nonlinear deformations of elastic solids viscometric fluids singular surfaces and waves and complex function technique This volume is a good source for researchers and students conducting work on the continuum mechanics of single substance bodies *Applied Mechanics Reviews* , 1966 **Galactic Dynamics** James Binney, Scott Tremaine, 2011-10-30 Since it was first published in 1987 Galactic Dynamics has become the most widely used advanced textbook on the structure and dynamics of galaxies and one of the most cited references in astrophysics Now in this extensively revised and updated edition James Binney and Scott Tremaine describe the dramatic recent advances in this subject making Galactic Dynamics the most authoritative introduction to galactic astrophysics available to advanced undergraduate students graduate students and researchers Every part of the book has been thoroughly overhauled and many sections have been completely rewritten Many new topics are covered including N body simulation methods black holes in stellar systems linear stability and response theory and galaxy formation in the cosmological context Binney and Tremaine two of the world s leading astrophysicists use the tools of theoretical physics to describe how galaxies and other stellar systems work succinctly and lucidly explaining theoretical principles and their applications to observational phenomena They provide readers with an understanding of stellar dynamics at the level needed to reach the frontiers of the subject This new edition of the classic text is the definitive introduction to the field A complete revision and update of one of the most cited references in astrophysics Provides a comprehensive description of the dynamical structure and evolution of galaxies and

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