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SOME PROGRESS IN LATTICE BOLTZMANN METHOD. PART I. NONUNIFORM MESH GRIDS. Xiaoyi He, Li-Shi Luo, and Micah Dembo. *Los Alamos National Laboratory, Los Alamos, New Mexico 87545.*

A new lattice Boltzmann algorithm is proposed to simulate the Navier–Stokes equation on arbitrary nonuniform mesh grids. The new algorithm retains the advantages of the lattice Boltzmann method: parallel of algorithm, ease of programming, and ability to incorporate microscopic interactions. A simulation of flow in a two-dimensional symmetric channel with sudden expansion is carried out using the new algorithm on a nonuniform mesh. The results of the simulation are in excellent agreement with previous experimental and numerical results.

VORTICITY GENERATION ON A FLAT SURFACE IN 3D FLOWS. C. M. Casciola,* R. Piva,* and P. Bassanini.† **Dipartimento di Meccanica e Aeronautica, Universitá di Roma La Sapienza via Eudossiana 18, 00184 Rome, Italy; and †Dipartimento di Matematica Castelnuovo, Universitá di Roma La Sapienza P.le A. Moro 5, 00185 Rome, Italy.*

Vortex methods, based on the splitting into Euler and Stokes operators, have been successfully adopted in numerical solutions of three-dimensional Navier–Stokes equations in free-space. Here we deal with their application to flows bounded by solid walls, discussing in particular the boundary conditions for vorticity and their approximation. In two dimensions this has been accomplished by introducing a vortex sheet at the wall, determined by the local slip-velocity, as an approximation of the vorticity source. For three-dimensional flows, we analyze in the context of the Stokes substep the integral equation for the vorticity source and its connection with the creation algorithm adopted in vortex methods. The present analysis leads to a formulation which shows the connection between the exact vorticity source at the wall and the discrete vorticity creation operator adopted in the Chorin–Marsden formula. In particular, the slip velocity at the wall is identified as an approximate solution of the integral equation for the vorticity source and the corresponding error estimate is also discussed. Besides showing the consistency of this approximation, we indicate a numerical procedure which provides a wall-generation of solenoidal vorticity. This is a crucial issue for an accurate application of vortex methods to three-dimensional flows.

COMPACT HIGH-ORDER ACCURATE NONLINEAR SCHEMES. Xiaogang Deng* and Hiroshi Maekawa.† **Institute of Fluid Mechanics, Beijing University of Aeronautics and Astronautics, Beijing 100083, People's Republic of China; and †Department of Mechanical and Control Engineering, University of Electro-Communications, Tokyo 182, Japan.*

We develop here compact high-order accurate nonlinear schemes for discontinuities capturing. Such schemes achieve high-order spatial accuracy by the cell-centered compact schemes. Compact adaptive interpolations of variables at cell edges are designed which automatically "jump" to local ones as discontinuities being encountered. This is the key to make the overall compact schemes capture discontinuities in a nonoscillatory manner. The analysis shows that the basic principle to design a compact interpolation of variables at the cell edges is to prevent it from crossing the discontinuous data, such that the accuracy analysis based on Taylor series expanding is valid over all grid points. A high-order Runge–Kutta method is employed for the time integration. The conservative property, as well as the boundary schemes, is discussed. We also extend the schemes to a system of conservation laws. The extensions to multidimensional problems are straightforward. Some typical one-dimensional numerical examples, including the shock tube problem, strong shock waves with complex wave interactions, and "shock/turbulence" interaction, are presented.

FIRST- AND SECOND-ORDER AERODYNAMIC SENSITIVITY DERIVATIVES VIA AUTOMATIC DIFFERENTIATION WITH INCREMENTAL ITERATIVE METHODS. Laura L. Sherman,* Arthur C. Taylor III,* Larry L. Green,† Perry A. Newman,† Gene W. Hou,‡ and Vamschi Mohan Korivi.‡ **Department of Mechanical Engineering, Old Dominion University, Norfolk, Virginia 23529-0247; †Multidisciplinary Design Optimization Branch, NASA Langley Research Center, Hampton, Virginia 23665-5525; and ‡Department of Mechanical Engineering, Old Dominion University, Norfolk, Virginia 23529-0247.*

The straightforward automatic-differentiation and the hand-differentiated incremental iterative methods are interwoven to produce a hybrid scheme that captures some of the strengths of each strategy. With this compromise, discrete aerodynamic sensitivity derivatives are calculated with the efficient incremental iterative solution algorithm of the original flow code. Moreover, the principal advantage of automatic differentiation is retained (i.e., all complicated source code for the derivative calculations is constructed quickly with accuracy). The basic equations for second-order sensitivity derivatives are presented, which results in a comparison of four different methods. Each of these four schemes for second-order derivatives requires that large systems are solved first for the first-order derivatives and, in all but one method, for the first-order adjoint variables. Of these latter three schemes, two require no solutions of large systems thereafter. For the other two for which additional systems are solved, the equations and solution procedures are analogous to those for the first-order derivatives. From a practical viewpoint, implementation of the second-order methods is feasible only with software tools such as automatic differentiation, because of the extreme complexity and large number of terms. First- and second-order sensitivities are calculated accurately for two airfoil problems, including a turbulent-flow example. In each of these two sample problems, three dependent variables (coefficients of lift, drag, and pitching-moment) and six independent variables (three geometric-shape and three flow-condition design variables) are considered. Several different procedures are tested, and results are compared on the basis of accuracy, computational time, and computer memory. For first-order derivatives, the hybrid incremental iterative scheme obtained with automatic differentiation is competitive with the best hand-differentiated method. Furthermore, it is at least two to four times faster than central finite differences, without an overwhelming penalty in computer memory.

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On Postshock Oscillations Due to Shock Capturing Schemes in Unsteady Flows. Mohit Arora* and Philip L. Roe.† **Department of Aerospace Engineering and Scientific Computing, W. M. Keck Foundation Lab for CFD, The University of Michigan, Ann Arbor, Michigan 48109-2118; and †Department of Aerospace Engineering, W. M. Keck Foundation Laboratory for CFD, The University of Michigan, Ann Arbor, Michigan, Michigan 48109-2118.*

In this paper, the issue of postshock oscillations generated by shock-capturing schemes is investigated. Although these oscillations are frequently small enough to be ignored, there are contexts such as shock–noise interaction where they might prove very intrusive. Numerical experiments on simple nonlinear 2×2 systems of conservation laws are found to refute some earlier conjectures on their behavior. The trajectories in phase space of a computed state passing through a captured shock suggest the underlying mechanism that creates these oscillations. The results reveal a flaw in the way that the concept of monotonicity is extended from scalar conservation laws to systems; schemes satisfying this formal condition fail to prevent oscillations from being generated, even for monotone initial data. This indicates that satisfactory design criteria do not exist at the present time that would ensure captured shocks that are both narrow and free from oscillations.