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Abstracts of Papers to Appear

A Free-Lagrange Augmented Godunov Method for the Simulation of Elastic–Plastic Solids. B. P. Howell* and G. J. Ball.† *Century Dynamics Ltd., Dynamics House, Hurst Road, Horsham, West Sussex, RH12 2DT, United Kingdom; and †School of Engineering Sciences, University of Southampton, Highfield, Southampton, Hampshire, SO17 1BJ, United Kingdom.

A Lagrangian finite-volume Godunov scheme is extended to simulate two-dimensional solids in planar geometry. The scheme employs an elastic–perfectly plastic material model, implemented using the method of radial return, and either the 'stiffened' gas or Osborne equation of state to describe the material. The problem of mesh entanglement, common to conventional two-dimensional Lagrangian schemes, is avoided by utilising the free-Lagrange Method. The Lagrangian formulation enables features convecting at the local velocity, such as material interfaces, to be resolved with minimal numerical dissipation. The governing equations are split into separate subproblems and solved sequentially in time using a time-operator split procedure. Local Riemann problems are solved using a two-shock approximate Riemann solver, and piecewise-linear data reconstruction is employed using a MUSCL-based approach to improve spatial accuracy. To illustrate the effectiveness of the technique, numerical simulations are presented and compared with results from commercial fixed-connectivity Lagrangian and smooth particle hydrodynamics solvers (AUTODYN-2D). The simulations comprise the low-velocity impact of an aluminium projectile on a semiinfinite target, the collapse of a thick-walled beryllium cylinder, and the high-velocity impact of cylindrical aluminium and steel projectiles on a thin aluminium target. The analytical solution for the collapse of a thick-walled cylinder is also presented for comparison.

A Space-Time Conservation Element and Solution Element Method for Solving the Two- and Three-Dimensional Unsteady Euler Equations Using Quadrilateral and Hexahedral Meshes. Zeng-Chan Zhang,* S. T. John Yu,* and Sin-Chung Chang.† *Mechanical Engineering Department, Wayne State University, Detroit, Michigan 48202; and †NASA Glenn Research Center, Cleveland, Ohio 44135.

In this paper, we report a version of the space-time conservation element and solution element (CE/SE) method in which the 2D and 3D unsteady Euler equations are simulated using structured or unstructured quadrilateral and hexahedral meshes, respectively. In the present method, mesh values of flow variables and their spatial derivatives are treated as independent unknowns to be solved for. At each mesh point, the value of a flow variable is obtained by imposing a flux conservation condition. The spatial derivatives are evaluated using a finite-difference/weighted-average procedure. Note that the present extension retains many key advantages of the original CE/SE method which uses triangular and tetrahedral meshes, respectively, for its 2D and 3D applications. These advantages include efficient parallel computing, ease of implementing nonreflecting boundary conditions, high-fidelity resolution of shocks and waves, and a genuinely multidimensional formulation without the need to use a dimensional-splitting approach. In particular, because Riemann solvers—the cornerstones of the Godunov-type upwind schemes—are not needed to capture shocks, the computational logic of the present method is considerably simpler. To demonstrate the capability of the present method, numerical results are presented for several benchmark problems including oblique shock reflection, supersonic flow over a wedge, and a 3D detonation flow.

Coupling an Eulerian Fluid Calculation to a Lagrangian Solid Calculation with the Ghost Fluid Method. Ronald P. Fedkiw. Computer Science Department, Stanford University, Stanford, California 94305.

We propose a numerical method for modeling multimaterial flows where the domain is decomposed into separate Eulerian and Lagrangian subdomains. That is, the equations are written in Eulerian form in one subdomain and in

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Lagrangian form in the other subdomain. This is of interest, for example, when considering the effect of underwater explosions on the hull of a ship or the impact of a low speed projectile on a soft explosive target. On the one hand, high-speed fluid flows are traditionally modeled by applying shock-capturing schemes to the compressible Euler equations to avoid problems associated with tangling of a Lagrangian mesh. On the other hand, solid dynamics calculations are traditionally carried out using Lagrangian numerical methods to avoid problems associated with numerical smearing in Eulerian calculations. We use the ghost fluid method to create accurate discretizations across the Eulerian/Lagrangian interface. The numerical method is presented in both one and two spatial dimensions; three-dimensional extensions (to the interface coupling method) are straightforward.

A Performance Comparison of Tree Data Structures for N-Body Simulation. J. Waltz, G. L. Page, S. D. Milder, J. Wallin, and A. Antunes. Institute for Computational Sciences and Informatics, George Mason University, Fairfax, Virginia 22030.

We present a performance comparison of tree data structures for N-body simulation. The tree data structures examined are the balanced binary tree and the Barnes–Hut (BH) tree. Previous work has compared the performance of BH trees with that of nearest-neighbor trees and the fast multipole method, but the relative merits of BH and binary trees have not been compared systematically. In carrying out this work, a very general computational tool which permits controlled comparison of different tree algorithms was developed. The test problems of interest involve both long-range physics (e.g., gravity) and short-range physics (e.g., smoothed particle hydrodynamics). Our findings show that the Barnes–Hut tree outperforms the binary tree in both cases. However, we present a modified binary tree which is competitive with the Barnes–Hut tree for long-range physics and superior for short-range physics. Thus, if the local search time is a significant portion of the computational effort, a binary tree could offer performance advantages. This result is of particular interest since short-range searches are common in many areas of computational physics, as well as areas outside the scope of N-body simulation such as computational geometry. The possible reasons for this are outlined and suggestions for future algorithm evaluations are given.

Tests of a Simulation Method for Boltzmann-like Models with Chemical Reactions. Dorin Marinescu,* Aude Espesset,† and Cecil P. Grünfeld.‡ *Institute of Applied Mathematics, Romanian Academy, Calea 13 Septembrie, No. 13, Sector 5, P.O. Box 1-24, 70700, Bucharest, Romania; †National Institute of Applied Sciences of Toulouse, Scientific Complex of Rangueil, 31077 Toulouse cedex 4, France; and ‡Institute of Space Sciences, INFLPR, P.O. Box MG-23, Bucharest-Măgurele, Romania.

This paper reports on the numerical implementation of a convergent scheme solving a general class of nonlinear Boltzmann-like equations for reacting fluids. The scheme is tested on a model of space-homogeneous multicomponent gas with binary chemical reactions. Although the model cannot be solved exactly, it provides analytical expressions for certain low-order moments of the one-particle distribution functions. Computing these moments by applying the numerical scheme, one obtains a good agreement with the values obtained analytically. An error analysis is performed and error control considerations complete the theoretical support of the scheme developed in previous works.

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