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Abstracts of Papers to Appear in Future Issues

ON THE ALGEBRAIC MULTIGRID METHOD. Qianshun Chang,*† Yau Shu Wong,‡ and Hanqing Fu.† **Institute of Applied Mathematics, The Chinese Academy of Sciences, Beijing, 100080, China; †Laboratory of Computational Physics, Institute of Applied Physics and Computational Mathematics, Beijing, 100088, China; ‡Department of Mathematical Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2G1.*

New formulations for the algebraic multigrid (AMG) method are presented. A new interpolation operator is developed, in which the weighting could be negative. Numerical experiments demonstrate that the use of negative interpolation weights is necessary in some applications. New approaches to construct the restriction operator and the coarse-grid equations are discussed. Two new AMG methods are proposed. Theoretical study and convergence analysis of the AMG methods are presented. The main contributions of this paper are to improve the convergence rate and to extend the range of applications of an AMG method. Numerical experiments are reported for matrix computations that resulted from partial differential equations, signal processing, and queueing network problems. The success of the proposed new AMG algorithms is clearly demonstrated by applications to non-diagonally dominant matrix problems for which the standard AMG method fails to converge.

COMPUTATION OF THREE DIMENSIONAL DENDRITES WITH FINITE ELEMENTS. Alfred Schmidt. *Albert-Ludwigs-Universität Freiburg, Institut für Angewandte Mathematik, Hermann-Herder-Straße 10, D-79104 Freiburg i. Br., Germany.*

Starting from an initial seed crystal inside an undercooled liquid, the solid phase begins to grow rapidly and develops unstable growth patterns. Some growth directions are preferred because of anisotrophic parameters in the physical model. This results in the development of dendrites. The physical model includes the heat equation for both the liquid and solid phases; the Gibbs–Thomson law couples velocity and curvature of the interface and the temperature. We describe a numerical method that enables us to compute dendritic growth of crystals in two and three space dimensions. The method consists of two coupled finite element algorithms. The first one solves the heat equation; the other operates on a discretization of the free boundary and computes the evolution of this moving interface. The two methods work with totally independent grids. By using timedependent, locally refined and coarsened adaptive meshes in both methods, we are able to reach a spatial resolution necessary to compute dendritic growth in two and three space dimensions.

SENSITIVITY DERIVATIVES FOR ADVANCED CFD ALGORITHM AND VISCOUS MODELING PARAMETERS VIA AUTOMATIC DIFFERENTIATION. Lawrence L. Green, Perry A. Newman, and Kara J. Haigler. *NASA Langley Research Center, Hampton, Virginia 23681-0001, U.S.A.*

The computational technique of automatic differentiation (AD) is applied to a complicated computer program to illustrate the simplicity, efficiency, and versatility of AD with complex algorithms for use within a sensitivity analysis. Many algorithmic and physics modeling coefficients appear in computer programs that are routinely set in an hoc manner; AD can be used to enhance computer programs with derivative information suitable for guiding formal sensitivity analyses, which allows these coefficient values to be chosen in a rigorous manner to achieve particular program properties such as an improved convergence rate or improved accuracy. In this paper, AD is applied to a three-dimensional thin-layer Navier–Stokes multigrid flow solver to assess the feasibility and computational impact of obtaining exact sensitivity derivatives with respect to algorithmic and physics modeling parameters typical of those needed for sensitivity analyses. Calculations are performed for an ONERA M6 wing in transonic flow with both the Baldwin–Lomax and Johnson–King turbulence models. The wing lift, drag, and pitching moment coefficients are differentiated with respect to two different groups of input parameters. The first group consists of the second- and fourth-order damping coefficients of the computational algorithm, whereas the second group consists of two parameters in the viscous turbulent flow physics modeling. Results obtained via AD are compared for both accuracy and computational efficiency with the results obtained with divided differences (DD). The AD results are accurate, extremely simple to obtain, and show significant computational advantage over those obtained by DD for some cases.

NONLOCAL ARTIFICIAL BOUNDARY CONDITIONS FOR THE INCOMPRESSIBLE VISCOUS FLOW IN A CHANNEL USING SPECTRAL TECHNIQUES. Weizhu Bao and Houde Han. *Department of Applied Mathematics, Tsinghua University, Beijing, 100084, People's Republic of China.*

In this paper the numerical simulation of the steady incompressible viscous flow in a no-slip channel is considered. A sequence of approximate nonlocal artificial boundary conditions on a given segment artificial boundary is derived by a system of linearized Navier–Stokes equations and spectral techniques. Then the original problem is reduced to a boundary value problem in a bounded computational domain. The numerical examples show that these artificial boundary conditions are very effective and are also more accurate than Dirichlet and Neumann boundary conditions, which are often used in the engineering literature.

ON BI-GRID LOCAL MODE ANALYSIS OF SOLUTION TECHNIQUES FOR 3-D EULER AND NAVIER–STOKES EQUATIONS. S. O. Ibraheem and A. O. Demuren. *Department of Mechanical Engineering, Old Dominion University, Norfolk, Virginia 23529, U.S.A.*

A procedure is presented for utilizing a bi-grid stability analysis as a practical tool for predicting multigrid performance in a range of numerical methods for solving Euler and Navier–Stokes equations. Model problems based on the convection equation, the diffusion equation, and Burger's equation are used to illustrate the superiority of the bi-grid analysis as a predictive tool for multigrid performance in comparison to the smoothing factor derived from conventional von Neumann analysis. For the Euler equations, bi-grid analysis is presented for three upwind difference based factorizations, namely spatial, eigenvalue, and combination splits, and

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two central difference based factorizations, namely LU and ADI methods. In the former, both the Steger–Warming and van Leer flux-vector splitting methods are considered. For the Navier–Stokes equations, only the Beam–Warming (ADI) central difference scheme is considered. In each case, estimates of multigrid convergence rates from the bi-grid analysis are compared to smoothing factors obtained from single-grid stability analysis. Effects of grid aspect ratio and flow skewness are examined. Both predictions are compared with practical multigrid convergence rates for 2-D Euler and Navier–Stokes solutions based on the Beam–Warming central difference scheme, and 3-D Euler solutions with various upwind difference schemes. It is demonstrated that bi-grid analysis can be used as a reliable tool for the prediction of practical multigrid performance.