Adaptive Refinement and Structured Grids for Unsteady Aerodynamics

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The objective of this research is to develop robust adaptive refinement methods for unsteady geometrically complex (moving-body) applications that exploit the computational advantages inherent in structured data.

The physical domain of complex problems is decomposed into near-body and off-body regions. The near-body domain is discretized with "Chimera" overset grids that need to extend only a short distance into the field. The off-body domain is discretized with overset structured Cartesian grids (uniform) of varying levels of refinement. The near-body grids resolve viscous boundary layers and other flow features expected to develop near body surfaces. Off-body grids automatically adapt to the proximity of near-body components and evolving flow features (first figure).

The adaption scheme automatically maintains solution accuracy at the resolution capacity of the near-body system of grids. The approach is computationally efficient and has high potential for scalability. Grid components are automatically organized into groups of equal size, facilitating parallel scale-up on the number of groups requested. The method has been implemented in the OVERFLOW-D2 code being developed within the Computational Fluid Dynamics–Computational Technology Area of the Common High Performance Computing Software Support Initiative (CHSSI). CHSSI is, in turn, part of the Department of Defense High Performance Computing Modernization Program.

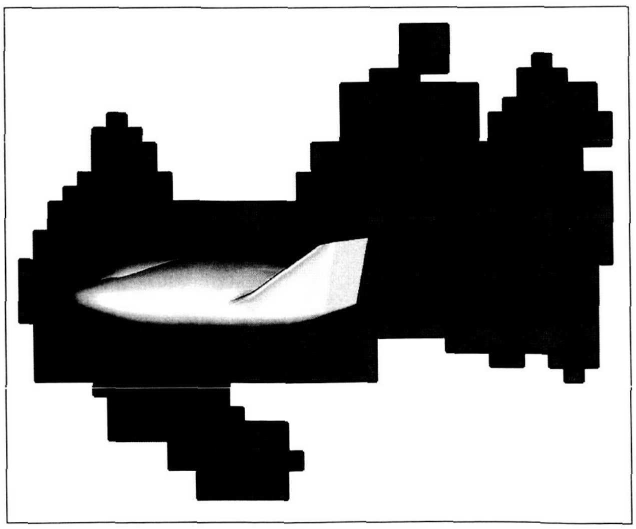

Fig. 1. Boundaries of finest off-body grids.

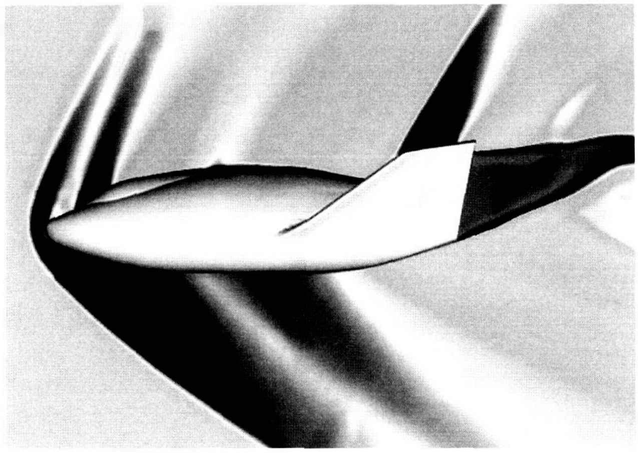

Fig. 2. X-38 Mach field after one adapt cycle.

The adaptive refinement capability within OVERFLOW-D2 has been demonstrated on the X-38 Crew Return Vehicle in a Mach 1.5 free stream (second figure), at an angle of attack of 15 degrees, and at a Reynolds number of 25 million. Test conditions and the near-body grid system were provided to the CHSSI CFD-4 software development team by R. Gomez of Johnson Space Center.

Demonstration of OVERFLOW-D2 on a large-scale application such as the X-38 is significant because of the broad class of problems of interest to the DoD and NASA. These problems require the accuracy available through adaption and the computational efficiency realizable through structured data. Some of the target problems for the method are unsteady moving geometry applications such as aircraft store separation, helicopter rotor-body interaction, crew escape systems, flight maneuvers, and launch vehicle staging.

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