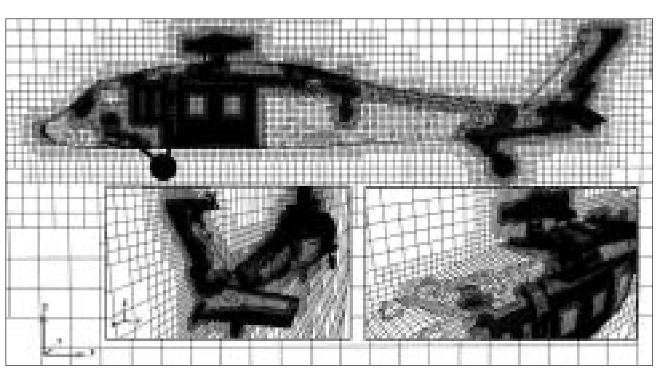
Meshing, visualization, and computational environments

by **Peter A. Cavallo**

With computing capacity continuing to grow every year, analysts throughout the industry seek to model increasingly larger and more physically complex problems. Computational fluid dynamics models containing tens of millions of cells and solved on hundreds of processors are now commonplace. With this comes the need to generate suitably large and accurate meshes, and the ability to render and visualize large, distributed data sets efficiently. This year saw numerous advances in mesh generation and visualization technologies designed to meet these challenges.

Three areas of notable interest in mesh generation are shrink wrapping, hex core meshing, and hybrid meshing. Shrink wrapping is a way of smoothing over defects in geometry without having to resort to repair, effectively treating flaws in CAD data. The resulting “wrap” can also serve as a lightweight geometry definition by hiding all the interior detail, and can be used to filter small geometric details. The simplified surface definition also facilitates surface meshing. Hex core meshing, which is based on Cartesian-Octree methods, results in hex-dominant grids and provides for very rapid problem setup. Millions of cells per minute may be generated on conventional PCs. Significant improvements in meshing productivity for very complex geometries have been demonstrated.



A 2-million-cell CFD mesh of a Sikorsky Blackhawk was created in 2 min on a conventional PC using CEI’s Harpoon.

Hybrid meshes continue to gain popularity for viscous flow simulations. They inherit advantages from both structured and unstructured meshes: prismatic and/or hexahedral layered elements effectively resolve the boundary layers, while tetrahedra fill the rest of the domain to retain the desired automation and flexibility. However, two important issues remain to be addressed. One is the existence of singular points, where conventional elements (tetrahedra, prisms, hexahedra, and pyramids) are difficult to place. The other is the treatment of sharp convex corners. A multiple marching direction approach developed at the University of Alabama at Birmingham shows promise, as it facilitates the generation of semi-structured elements around singular points and enables placement of high-quality elements around sharp convex corners.

CRAFT Tech developed an approach for adaptive coarsening and refinement of unstructured meshes for transient flows. The mesh is modified automatically at variable intervals as relevant flow structures evolve, without user specifications. Refinement is projected ahead of where solution errors are estimated, ensuring solution features propagate into a fine grid. By examining how solution errors subsequently accumulate, the next adaptation is triggered.

CRAFT Tech also continued development of automated mesh adaptation strategies for problems with moving boundaries. Using this approach, a single grid is created initially, the mesh deforms as boundaries move, and local coarsening/refinement operations correct the grid quality. Mesh deformation measures are monitored to trigger local mesh adaptation as required. The technique is being used for store separation calculations from aircraft weapons bays.

In visualization technologies, CEI released its EnSight DR (Distributed Rendering) software for postprocessing and visualization of large-scale data on cluster computers, enabling the evaluation and rendering of models containing hundreds of millions of cells. A Linux Networx LS-V (LS Visual) Supersystem set a world record by rendering 1.5 billion polygons per second while running EnSight DR, three times the previous record. One of the newest computers installed at the Army Research Lab, it is available to DOD’s high performance computing modernization program community for remote visualization.

Sadly, 2006 also witnessed the passing of a giant in the mesh generation community, Timothy Baker. An internationally respected researcher, he contributed several key works in the field of unstructured mesh generation during his career at Princeton University, particularly in Delaunay triangulation methods. His most recent work had explored mesh adaptation and morphing, feature extraction, and the relationship between mesh quality and solution accuracy. An invited lecture in his memory is planned for the 2007 Aerospace Sciences Meeting.