by David Kenwright

Aerospace data analysis tools that significantly reduce the time and effort needed to analyze large-scale computational fluid dynamics simulations have emerged this year.

The current approach for most post-processing and visualization work is to explore the 3D flow simulations with one of a dozen or so interactive tools. While effective for analyzing small data sets, this approach becomes extremely time consuming when working with data sets larger than one gigabyte. An active area of research this year has been the development of data mining tools that automatically search through gigabyte data sets and extract the salient features with little or no human intervention. With these so-called feature extraction tools, engineers are spared the tedious task of manually exploring huge amounts of data to find the important flow phenomena.

Aerospace companies will benefit in two ways from this technology: it will reduce the time it takes to analyze a large data set by an order of magnitude, and it will provide quantitative information about the location and strength of specific flow features, such as vortices, shocks, and separation lines, that can be used in the engineering design process.

Feature extraction software was developed at MIT, NASA-Ames, NASA-Langley, Stanford University, and Mississippi State. The software tools identify features such as vortex cores, shocks, separation and attachment lines, recirculation bubbles, and boundary layers. Some of these features can be extracted in a few seconds; others take minutes to hours on extremely large data sets. The analysis can be performed off-line in a batch process, either during or following the supercomputer simulations.

These computations have to be performed only once, because the feature extraction programs search the entire data set and find every occurrence of the phenomena being sought. Because the important questions about the data are being answered automatically, interactivity is less critical than it is with traditional approaches.

Scientists at Ames applied feature extraction software to several large-scale CFD data sets provided by Boeing. The most notable was the simulation of a high-lift configuration that contained over 60 million grid points and 6 GB of data. The feature extraction software identified every vortex core and separation and attachment line in just 45 min. Locating the same features with interactive tools usually takes an experienced engineer several weeks.

Rotorcraft simulations are also benefiting from this new technology. Accurately predicting the rotor wake remains a crucial problem in rotorcraft CFD, where the tip vortices diffuse too quickly due to inadequate mesh resolution. Resolving the high gradients in these regions requires high mesh densities near the vortex cores. However, it is difficult to anticipate where these are likely to occur before running the flow simulation. Researchers at RPI solved this problem by linking a vortex core feature extraction program with an adaptive-parallel finite element analysis program. This system was able to locate the position and strength of vortex tubes during the flow simulation and refine the mesh accordingly.

Feature extraction techniques were also applied to parametric studies of NASA's X-33 Advanced Technology Demonstrator, for which hundreds of simulations were run with subtle changes in the flight conditions.

As these tools become more integrated in CFD flow solvers, the quantitative data they provide can be fed back into flow solver programs to produce higher-fidelity solutions or actively redesign a vehicle.

Commercial vendors of post-processing and visualization software such as Amtec Engineering, CEI, and Intelligent Light are currently working with academic and government researchers to bring this cutting-edge technology to the marketplace.

Vortex cores were automatically extracted from one of the 304 solution files in a 10 GB simulation of the F/A-18 at high angle of attack (a). A closeup of the wing's leading edge extension reveals the trapezoidal fence that induces a vortex burst (b). The vortex burst occurs where the vortex core starts to spiral, just above and behind the fence.

Figure 2.
A flow texture synthesis program reveals the skin

friction lines on the surface of this 13 GB simulation of a rolling delta wing. The separation and attachment lines are colored green and red respectively, and took less than 1 sec to locate on an SGI workstation using an automatic feature extraction program.

Figure 3.
A stationary shock finding technique was applied to this high-resolution simulation of the Space Shuttle that contained 10 million grid vertices. The shock surfaces were extracted in approximately 5 min on a Dell 610 Windows NT workstation.

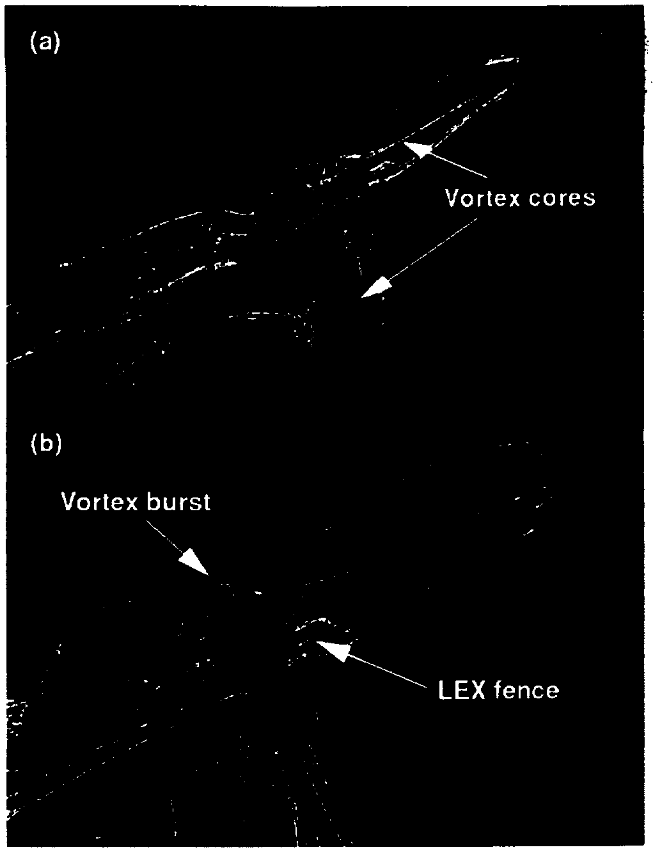

Figure 1

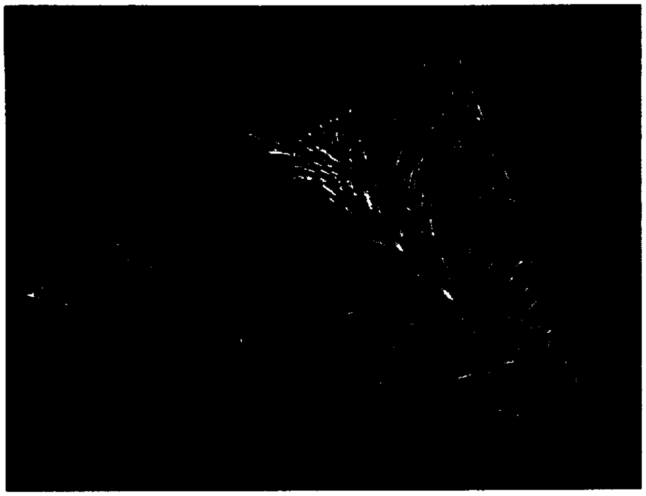

Figure 2

Figure 3