MORE THAN JUST MUSCLE

After years of using NCSA's supercomputers, Yuanhui Zhang's team works with the center's Faculty Fellows Program to get a new view of airflow in airplane cabins.

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Professor Yuanhui Zhang, of the University of Illinois at Urbana-Champaign's Department of Agricultural and Biological Engineering, has computed with NCSA for almost a decade. His team analyzes data from experiments that track airflow in enclosed spaces such as livestock barns and office buildings. This year the efforts expanded to include visualization of those airflows in virtual environments. Collaborating with NCSA's Alan Craig and Kalev Leetaru through the center's Faculty Fellows Program, the Zhang group tracks, analyzes, and visualizes the transportation and fate of pollutants in airplane cabins for the Centers for Disease Control and Prevention.

"We're very fortunate to have NCSA on our campus," Zhang says. Previously, "it's all been about the muscle" that NCSA's systems provide. That continues to be important, but "we're now getting lots of interaction. We've always wanted to have visualization to help with our public education efforts. It is an important part of our job."

1 FIVE ROWS, 35 MANNEQUINS, AND THOUSANDS OF BUBBLES

The Zhang group starts its studies in a five-row mockup of a Boeing 767. Mannequins fill the seats, complete with Goodwill wardrobes and enough rouge and blue eye shadow to make their mothers cluck their tongues. They also sport heating pads wrapped around their bodies to simulate body heat and its impact on air circulation.

Tiny helium-filled soap bubbles are pumped into the cabin. The airplane's ventilation system whirs, and the neutrally buoyant bubbles swoop about the cabin to expose the space's air currents. It "looks like a snowy room. Chaotic," Zhang says.

2 VOLUMETRIC PARTICLE TRACKING VELOCIMETRY

To hack through the chaos, Zhang and his team use what they call volumetric particle tracking velocimetry (VPTV). Two cameras at the front of the cabin take snapshots every few seconds. These snapshots record the bubbles' trajectories. By combining paired images from the two positions, the cameras allow for depth perception; 2D becomes 3D, just as it does with your own pair of eyes.

Sophisticated algorithms, developed by the team over the years and run on a succession of NCSA supercomputers, play the part of the brain. They clean the images, match individual particles from pairs of the 2D images, combine the 2D images into 3D images, and produce vector data for each bubble.

3 INTRODUCING SHADOWLIGHT

With vector data in hand, work with NCSA's ShadowLight begins. Previously used heavily in a faculty fellows project with the U of I architecture department's Joy Malnar, ShadowLight allows users to draw and create objects on the fly in the CAVE virtual environment. It also works in smaller-scale environments such as stereoscopic display walls.

Aijun Wang, a PhD student on Zhang's team, designed a 3D visualization of the airplane cabin's geometry in the VRML2 format on in-house machines. They are able to import and make changes to the visualization using ShadowLight, easily navigating through the space and adding new objects as necessary.

4 VECTORS NOW INCLUDED

That gives them a view of the environment, but what they really want is a view of the airflows from the vector data. Leetaru and Craig developed a plug-in for ShadowLight for those data. The vector viewer was a straightforward exercise because ShadowLight was designed to be very extensible and because Leetaru and Craig recently worked with a similar tool created by Valparaiso University as part of a collaboration with NCSA.

Back to reality

"Boiled down, there's never been a good quantitative way of measuring" the air's velocity and trajectory profile in a full-scale room, according to Zhang. Traditionally, anemometers or laser Doppler devices capture data at one physical point. VPTV gives researchers the massive amounts of experimental data–vectors for individual particles over time across the space–that they need. Those data allow them to develop and validate simulation software, which in turn can be used to model airflow in enclosed spaces more easily and inexpensively.

The combination of experiment and modeling allows engineers to bring their work back to reality–to model the conditions in a space, whether it's a barn or an airplane cabin, and explore methods of improving those conditions. "The fundamental information is flow patterns," Zhang says. With that, "we build a healthy, better environment for everybody."

Funding information

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For further information

http://www.age.uiuc.edu/bee/
http://www.ncsa.uiuc.edu/Cyberservices/Visualization/

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