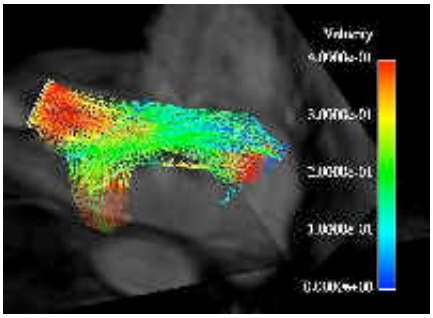
3D Visualization Used in Engineering Finds a Home in Human Heart Research

by Erin Hatfield

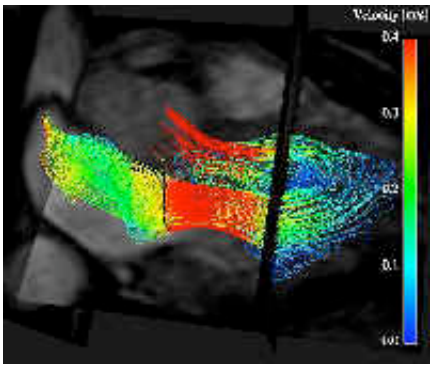
Three-dimensional visualizations of computational fluid dynamics (CFD), most often associated with mechanical engineering, are being used by international researchers to probe deep inside a completely different machine – the human heart.



A cooperative program between Sweden's Linkoping University and the University of California San Francisco is using EnSight software from CEI (Apex, N.C.) to create the first comprehensive 3D visualizations showing how blood flows within the heart. Researchers are currently studying the physiology of healthy hearts to better understand blood-flow problems caused by heart valve and muscle diseases.

Inside the Heart of Darkness

While scientists know much about blood flow throughout the body, they know very little about its flow within the heart. Ultrasound and Doppler methods were used as diagnostic tools for past studies, but were limited by their two-dimensional output. The Linkoping/UCSF project captures 3D magnetic resonance imaging (MRI) data from a live beating heart and imports it into EnSight, which allows blood flow characteristics to be depicted as fully animated particle traces. The 3D animations enable researchers to visualize the path and speed of blood flow through the heart at different times and in different types of circumstances. EnSight visualizations and findings are shared by participating scientists via the Internet.



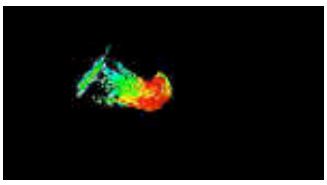
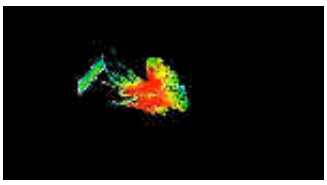
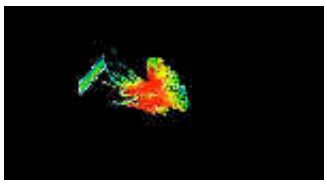
Being able to see detailed results in 3D is critical to the research process, according to Dr. Ann Bolger, associate professor of medicine at UCSF. Although scientists had 3D images to work with in the past, the technology was unable to handle the complexity the data required. "The models are very complex," says Bolger. "The blood moves, the walls of the heart move, there are a lot of things going on at once, so there are a number of things to study. With EnSight, we are able to more accurately study the data and truly see what is happening to each component."

Capturing the Flow

An accurate analysis of cardiac flow requires a detailed description of the velocity field in 3D. To do this, researchers used a new MRI technique that collects velocity vector information in a 3D spatial grid encompassing the heart during 32 phases of the cardiac cycle. Data was gathered from six healthy volunteers, age 24 to 63. Starting at a specified time and intracardiac location, the velocity field is integrated to calculate the path taken by the blood through the heart.

Particle traces are used to study the dynamic flow patterns in the heart, or as a basis for calculations of quantitative flow parameters. The traces are calculated from each pulmonary vein, starting at emitters placed near the intersections of the pulmonary veins and the left atrium wall. Particles are emitted at 16 time frames during the cardiac cycle and animated to study the path taken by the blood from each vein, and to demonstrate the interaction between concurrent flows.

From the 3D visualizations, researchers concluded that the flow pattern in the diastolic vortex, when the heart is relaxed and blood flows in, is less well organized and has generally lower velocity than the systolic vortex, when the heart contracts and blood flows out from the chamber. From the path-line animations visualized in EnSight, blood from the right-sided veins can be seen flowing over the vortex, effectively being squeezed between the vortex and the wall between the right and left atrium. In some cases, the right pulmonary vein flow skirts more than half the circumference of the periphery of the vortex.

Still images from particle trace animation of blood flow within the heart, beginning at the left lower pulmonary vein. This series of animation frames, created with CEI's EnSight software, depicts the swirling blood flow that creates the vortex within the atrium. Images courtesy of Linkoping University.

Where the heart leads...

Researchers plan to use the study results as a baseline in analyzing various diseases of the heart valves and muscle. Ultimately, this can lead to exploration of corrective options. By using 3D visualization software such as EnSight, doctors will be able to better understand how surgery, heart valve repair and other corrections will impact natural blood flow within the heart.

Beyond better analysis and understanding of research data, 3D visualization software is a natural tool for communicating complex processes and results. Dr. Bolger and her colleagues are using the EnSight visualizations for presentations at conferences. "Every time we present the data," says Bolger, "people are amazed at how much we can now see."

Bolger and other team leaders believe that opening up the secrets of the inner heart is just the beginning of what can be accomplished by combining 3D MRI data with high-capacity 3D visualization software. In this case, where the heart leads, other parts of the body are likely to follow.

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