MEETING BRIEFS

Supercomputers Image the Body in Three Dimensions

Supercomputers are usually thought of in connection with problems like analyzing the shower of particles from collisions in a billion-dollar accelerator. But high-performance computing is now being applied to an arena closer to everyday life: modeling the human body. That development drew investigators from as far away as New Zealand to a "Symposium on High-Performance Computing in Biomedical Research," held 14 to15 October at the North Carolina Supercomputing Center (NCSC). The applications described there ranged from radiation profiles in cancer therapy to fluid flow through the heart.

Tumor Targeting

Radiation oncology is a relatively imprecise business. It usually begins with a series of two-dimensional images of the target tumor, and, because of the forbidding complexity of the computations involved, physicians generally evaluate only a few of the myriad possible treatment plans (detailing the target area and duration of radiation). But Julian Rosenman of the University of North Carolina at Chapel Hill is trying to build a system that would compare a multitude of different plans based on three-dimensional images of the body. "We are trying to build a really good model of the patient, something where we can really see what's going on, and then give me the doses fast. And I don't mean half an hour, I mean a second."

The brain of Rosenman's nascent tumor-targeting machine is Pixel-Planes 5, a highly parallel graphics computer developed at the University of North Carolina that displays a three-dimensional image of the tumor and surrounding tissue. The oncologist picks out a direction for the radiation beams and the radiation dose distributions are then cranked out in 1 second by a Cray Y-MP supercomputer—a computation that would take half an hour on a typical workstation. The dose distributions are then superimposed on the three-dimensional image of the body.

To achieve the speed Rosenman feels is required by his system, Pixel-Planes 5 and the Cray will be connected with a gigabit-per-second network being developed at MCNC, a private company located at Research Triangle Park, North Carolina. Rosenman says his ultimate goal in modeling treatments is to give the physician something much more like a driver's experience in a car—where each turn of the steering wheel is immediately translated into effects on the vehicle. "The closer one gets to actually 'driving'—that is, you do something and something happens—the more adventuresome we will become...and the more likely we will be able to come up with neat and original ways of doing these things."

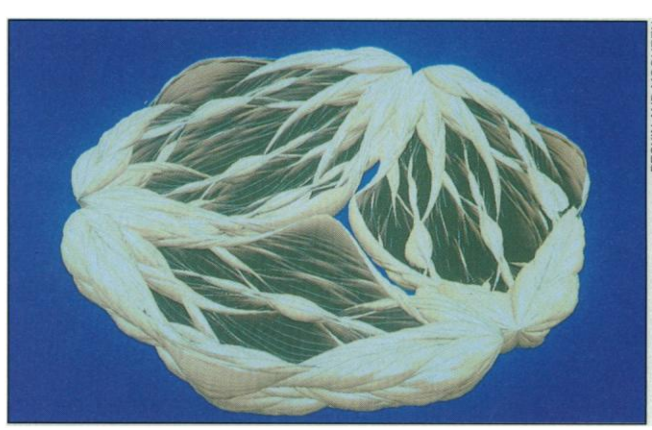
The Model Heart

Charles Peskin of the Courant Institute of Mathematical Sciences at New York University is also moving from two-dimensional images to three-dimensional ones—but in this case his object is fluid flow in the heart. Using the "immersed boundary technique," Peskin and his colleague David McQueen treat the muscles and connective tissue of the heart as a special part of the enclosed blood. McQueen explained that "the solution process is not just to determine where the fluid is going, but also the motion of the heart that is interacting with the fluid."

In the past, Peskin and McQueen worked with a two-dimensional model, concentrating on the mitral valve, which separates the left atrium from the left ventricle. The equations produce such an accurate simulation of the contraction of the atrium and blood as it flows through the mitral valve that, as the valve closes, there is a vibration, corresponding to part of the "lub" in the heart's "lub-dub."

Peskin and McQueen used such simulations to test the function of several artificial valves and came up with modifications that improved the devices. But they're not satisfied, and they're working on a three-dimensional model. That's not an easy task, and Peskin concedes their efforts so far haven't quite mimicked the healthy organ. "It's something like a heart, but it's in bad shape," he chuckled.

After experiencing difficulties in designing the aortic valve, they generated a partial differential equation that describes the equilibrium position of the fibers in the valve under pressure. The solution produces a structure strikingly similar to a biological aortic valve. That success helped put them on the road to a more accurate model of blood flow. And that success isn't the end of the story, since other investigators have used versions of their model to study swimming fish, clotting blood, and the vibration of the basilar membrane in the inner ear.



PESKIN AND MCQUEEN

Hearty effort. One of Charles Peskin and David McQueen's computer images of the heart's aortic valve.

The Power of Teamwork

Many experts contend that the greatest power of future computers may derive from virtual systems, in which a variety of machines are connected via a network to create the optimum approach to a problem. At the conference, William Johnston of the Lawrence Berkeley Laboratory presented a test case: an interactive display of three-dimensional magnetic resonance images (MRIs). Using this system, an investigator can view a three-dimensional version of an MRI and then rotate the view to any angle. But that's not all. If the image was of the brain, say, the researcher could instruct the computer to remove the brain's entire right side and then rotate it—amounting to an electronic dissection.

The capacity for viewing MRI images is not new. What is new in this system is speed. Three-dimensional MRI's require as much as eight-and-a-half megabytes of data apiece; viewing, rotating, and dissecting such an image requires extensive computation. That kind of computational intensity can eat up a lot of computer time, but Johnston's system is designed to display three to five massaged images per second. Such performance is far beyond the abilities of a workstation, and even beyond those of a single Cray Y-MP processor.

Therefore Johnston and his colleagues came up with a strategy of employing specialized machines for each part of the job and then linking them into a more powerful system: A Connection Machine CM-2 reads the MRI data and then the CM-2 calculates the surface of the image. This information is passed to a Cray Y-MP, which renders the three-dimensional geometry. Finally, the image is passed to a workstation for display.

–Mike May

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