# VOLUME RENDERING

*Volumetric rendering speaks volumes for data 20 orders of magnitude apart—from human anatomy to neuroanatomy, and from electrostatic charges of macromolecules to failure analysis of manufactured parts.*

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A young man in his late twenties suffered a crushed pelvis in an auto accident. His orthopedists said that the fracture was too complicated to operate on and elected to treat him conservatively; he would be in traction for a few months. The doctors were certain that the young man would be permanently crippled.

Luckily, the man's father, also a physician, knew of research in 3-D rendering of computed tomography (CT) scan data. He sent his son's CT scan studies to the researchers, a radiologist, an orthopedic surgeon, and a computer graphics expert, who studied the volumetric rendering of the pelvis that was created with specially designed hardware and software. Able to see it from all angles, they determined the extent of the fracture and the locations of several key fragments. The pelvis was operable and the next day, the surgeon set the fragments. Three months later the patient returned for a check up and demonstrated full-range hip motion.

This case coupled great medicine and great computer science. The technique of volume rendering changed the course of treatment by providing the physicians with more data. This data ultimately gave them the confidence to operate and thereby improved the patient's quality of life. While volume rendering helped manage the medical complexities, this case also represents departures from tradition for both disciplines.

In the medical realm, radiologist Elliot K. Fishman, Director of Computed Body Tomography at Johns Hopkins University, has been pioneering volume renderings of CT (also known as computerized axial tomography) data for three years. But not all radiologists, whose fundamental training involves interpreting two-dimensional data into three dimensions, have embraced this new technique. Many are concerned that computer-generated artifacts and pseudo-color can lead to misdiagnoses. Widespread use and acceptance of volume rendering has also been hindered by competing scanner vendors who have kept their data formats proprietary. This has forced those on the computer graphics end to reverse engineer tapes of data to uncover the formats. On the other hand, surgeons can benefit from the precision that volume rendered CT and magnetic resonance imaging (MRI) can yield.

On the computer graphics side, Bob Drebin and his colleagues at Pixar have departed from tradition by abandoning *surface* rendering, which has its foundations in geometry based modeling. They maintain that volumetric data should not be skimmed to yield only surface renderings. They have developed new algorithms that take full advantage of 3-D arrays of data, rather than just using the surface data found in such arrays. Their approach also reflects the early computer graphics dilemma over slowly generated, photorealistic graphics versus fast, less detailed image processing.

With the imaging and graphics application market expected to reach $1.6 billion by 1990, according to Dataquest, several graphics and medical imaging vendors are merging or teaming up on large projects. In 1987, Sun Microsystems, Inc. bought Trancept Systems, Inc. to form a graphics accelerator division in Research Triangle Park, North Carolina, where the TAAC-1 add-on for Suns was developed. Also that year, Philips Medical Systems, Inc., in Shelton, Connecticut, formed a partnership with Cemax, Inc. in Santa Clara, California, and Island Graphics and Pixar, both in San Rafael, California, to launch Project Pegasus. Fifteen medical centers (including Johns Hopkins) are exploring different challenges in medical imaging, evaluating equipment, and helping Philips develop hardware and software. Another project, named for the Renaissance artist Leonardo da Vinci, is a database of the entire human body on a Cyber 910. A joint effort of Control Data and the University of Illinois, Chicago, the project integrates the activities of medical illustrators, anatomists, radiologists, and biomedical engineers. Some researchers, like Craig Upson of Stellar Computer, Inc., in Newton, Massachussetts, say that volume rendering is doing for

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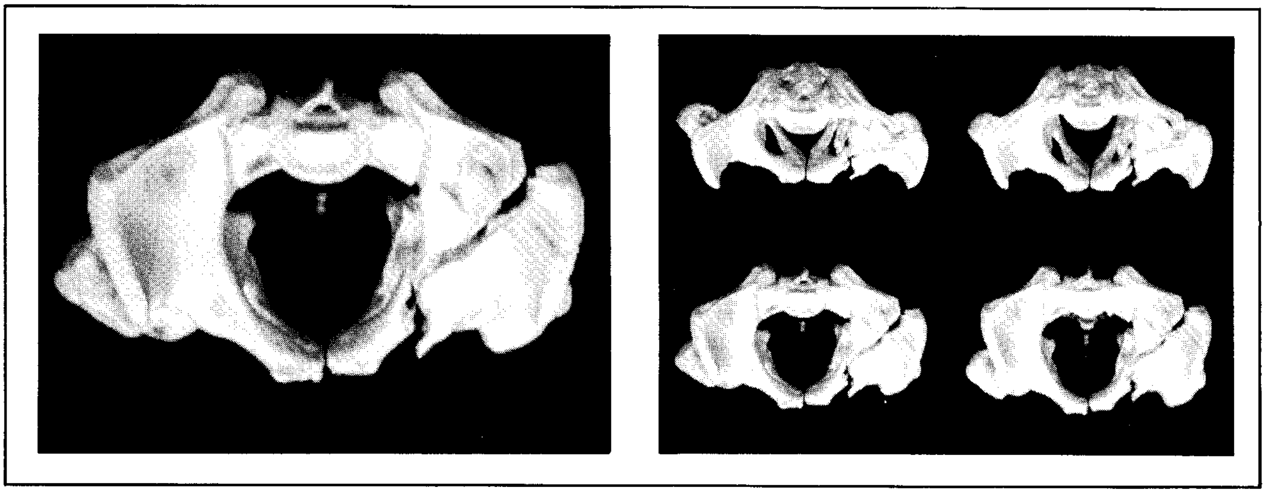

**Volume renderings of the broken pelvis using CT scan data by Elliot Fishman of Johns Hopkins. The extent of the fracture and location of the fragments is clearly visible. Although radiologists have been using CT data for almost 20 years, volume renderings of CT offer a new way of interpreting such data.**

computer graphics in the late 1980s what the introduction of perspective did for drawing and painting during the Renaissance.

Why is volume rendering more feasible now then ever before? In volume rendering, computer graphics has found a general means of visualization that is effective for *two* types of data—real (measured) and numerical (calculated). Huge amounts of data, collected a variety of ways, can be processed by miniaturized chips with immense, and often parallel processing, power. Besides CT and MRI data, 3-D measurements are now taken with the help of solid state cameras and lasers, and improved microscopes. One new device, the very high resolution, confocal microscope, is expected to vastly expand cell biology experimentation.

Neurobiologist Vincent Argiro of Maharishi International University in Fairfield, Iowa, who has used confocal data to volume render neurons, says, "Volume rendering is one of the most direct, straightforward ways of doing three-dimensional image processing. It's computer graphics on the one hand, but it's image processing on the other. You're dealing with real data about real structures. These are not synthesized pictures that just come out of a mathematical equation." Further, he sees volume rendering of any kind of data as a catholic approach to understanding a huge range of phenomena in nature. Far from belittling numerically based volumetric simulations generated on supercomputers, he adds, "It's intriguing that you have one method that can be used to display a three-dimensional relationship among either real data from the real world—from a huge variety of measurement methods that span a range of 20 orders of magnitude—that can also just as easily be applied to the simulation of phenomena generated on supercomputers by purely numerical methods. So it's a unifying approach to looking at the world."

In fact, researchers are volume rendering right up the scale, from molecules and their electron clouds measured in nanometers, to the distribution of gasses throughout the galaxy, measured in light years. Other applications include nondestructive testing and failure analysis of manufactured goods.

Interest in volume rendering among broad groups of researchers is growing. The volume imaging group that met at SIGGRAPH '88 had quadrupled to about 100 from the year before. Upon opening the meeting, Chairman Nick England of Sun Microsystems declared, "I'm going to teach radiologists to love voxels," and then polled the group to find out who they were. The group was equally divided between those studying real world and simulated data, as it was for dynamic and static, monochrome and color, and continuous and discontinuous. Between 10 and 20 were comparing multiple volumes and using stereo to help see an image more clearly. The smallest data set being massaged was 10 × 10 × 30 and the largest was 10,000 × 10,000 × 4,000 voxels. *Voxel* comes from *volumetric element*.

## THE MATERIAL MIXTURE MODEL

The geometry-based model that Drebin discarded calls for describing an object in terms of lines, polygons, patches, and other abstract geometrical concepts that are then converted into pixels. But few objects in nature lend themselves to such descriptors. Alvy Ray Smith, Pixar's Executive Vice President, points out that "Ninety percent of the data [in scientific visualization] does not come from geometric sources—geometrically described objects—in the first place." Instead, Drebin,