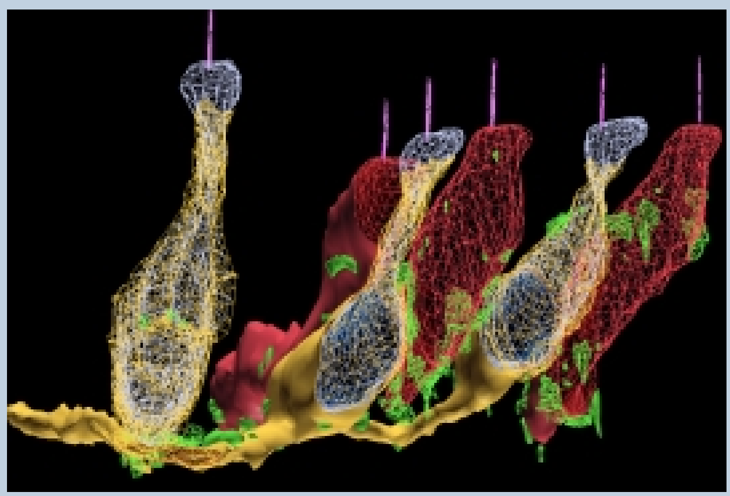
Virtual Reality Meets Real-World Medicine

Dr. Muriel Ross and her colleagues at the Center for Bioinformatics at the NASA Ames Research Center have used the advanced computational tools they developed for space life sciences research to advance the field of medical imaging. Their Reconstruction of Serial Sections software package, originally created to investigate changes in inner-ear neurons during space flight, is now being used in such diverse applications as surgical planning and telemedicine.

Many advances in technology have sprung from a scientist's need to perform an experiment that simply could not be accomplished with existing methods. In the process of studying how the nervous system adapts to space flight, Muriel Ross and her colleagues at the Center for Bioinformatics produced a new tool for computerized image reconstruction of neurons with wide-ranging applications to surgery, telemedicine, and beyond.

Dr. Ross's original research interest was neural plasticity–how the nervous system, its neurons, and synaptic communications adapt to changes in environmental stimuli. Her specific interest lay in the hair cells of the inner ear that compose part of the gravity-sensing system for humans and animals. She theorized that the synapses of the hair cells do not remain static but instead adapt to environmental change. Space flight, with its weightless environment and the challenges this environment poses to the nervous system, was expected to provide an excellent tool for studying neural plasticity. Prior to her first experiment on the Spacelab Life Sciences-1 (SLS-1) mission in 1991, Dr. Ross decided that she needed a way to physically show the connections between the hair cells and nerve fibers to prove her theories about neural plasticity. Her plan was to take serial transmission electron microscope (TEM) images, called serial sections, of inner ear samples obtained during a space flight experiment and reconstruct them in three dimensions, so they could be viewed from any angle on a computer screen.

At that time, in the early 1980s, the only technology available for reconstructing three-dimensional objects was a technique called contour reconstruction. With this technique, simple outlines of serial microscopy sections are stacked up to show the basic shape of an object. Ross likens this to a stack of dinner plates. The stack is a cylinder; but when working at the microscopic level, the gaps between plates can leave out significant information, hampering detailed analysis. An improved technique, called slice reconstruction, filled in the slice outlines but still left out information. Neither technique provided the image detail that Ross and her colleagues required.



The NASA Ames Center for Bioinformatics first developed the ROSS software to visualize complex neural structures of the inner ear.

Putting the Pieces (Back) Together

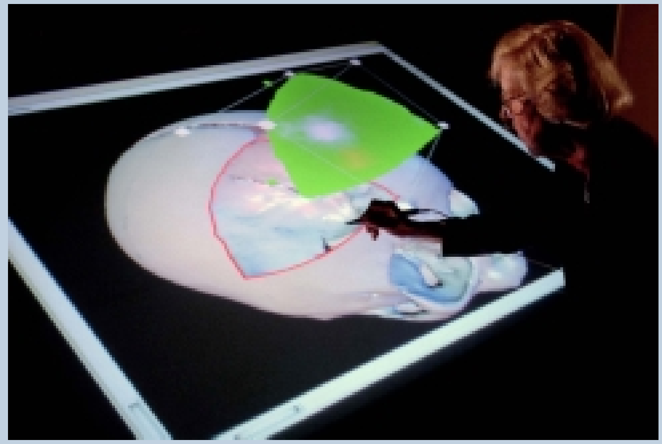
After years of research at the Center for Bioinformatics (originally named the Center for Biocomputation), founded by Ross at NASA Ames Research Center in 1988, she and her colleagues produced a software package called Reconstruction of Serial Sections (ROSS). The software uses a technique called mesh generation to fill in the gaps between digitized serial sections. Following the dinner plate analogy, the distance between the rims of stacked plates is filled in, clearly outlining the cylinder. Likewise, if the spaces between microscopy sections are filled in, a scientist can view the 3-D shape of the object. Using this new software, Ross was able to collect evidence in support of her theory on neural plasticity, showing that certain connections in the inner ear increase in number in response to exposure to microgravity.

The original software was built for analyzing TEM sections, but can be successfully adapted for use with most types of imaging equipment. The scientific community soon expressed interest in the ROSS software package, which was released for general use through Space Act Agreements. Since then it has been put to use in more than 30 laboratories across the country, in academic disciplines as varied as botany and plasma physics. It was even used to reconstruct the surface of Mars from data provided by the Mars Rover.

Medical Applications

So far, the major practical application of the ROSS software has been to medicine. Stanford University Medical Center expressed an interest in using the software as a tool for surgical planning. To test the concept, the Center for Bioinformatics generated 3-D images of a patient's face and skull from computed tomography (CT) scans provided by Stanford surgeons. Separate, layered reconstructions of bone and skin were projected onto a 3-D virtual reality workbench, and a virtual cutting tool called the Cyber-Scalpel was used to mark where surgical incisions would be made. The ROSS software allowed the results of the incisions to be visualized in near real-time. Stanford hopes to expand this technology into a practical tool for training surgeons and allowing doctors to practice surgery using actual patient data.

Out of these experiments came a collaborative agreement between Stanford and the NASA Ames Center for Bioinformatics to form a National Center for Biocomputation. This new collaborative venture conducts research to further the use of virtual reality techniques in surgical training and telemedicine. In May of 1999, the Center participated in a Virtual Collaborative Clinic experiment, where doctors at five remote sites across the country simultaneously viewed reconstructions of patient-specific data broadcast over a high-speed computer network. Doctors at all of the sites were able to interact with the data in real time and communicate their opinions to each other. The Center hopes to expand the ROSS technology for use in telemedicine to aid clinics in remote regions.



Using a 3-D workbench and virtual cutting tool, a doctor can view the results of potential surgical incisions before operating on a patient.

Ross, now retired from NASA, and her collaborators have many plans for upgrading their software over the next five years. They hope to add force feedback to the virtual cutting tool for surgical applications, so a trainee using the virtual surgery workbench can get an approximate feel for each cut. The challenge in this, says Ross, is "how much 'feel' do you need? The more accuracy you require, the harder it is to execute."

The software developers are also addressing the fact that the ROSS reconstructions currently require expensive supercomputer workstations to render in great detail. To make the system practical in a wider variety of research environments, they are working on scaling down the process while maintaining accuracy in the reconstructions. A scaled-down version will require less powerful computers and allow the reconstructions to be manipulated on an ordinary PC. With this refinement, the reconstruction software package will be suitable for use in a variety of settings, from medicine to biological research to planetary sciences.

References

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