Digging Deeper, Seeing Farther: Supercomputers Alter Science

By JOHN MARKOFF
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SAN FRANCISCO — Inside a darkened theater a viewer floats in a redwood forest displayed with Imax-like clarity on a cavernous overhead screen.

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Jim Wilson/The New York Times

DUET "Life: A Cosmic Journey" relies not just on computer animation techniques, but on a wealth of digitized scientific data as well.

The hovering sensation gives way to vertigo as the camera dives deeper into the forest, approaches a branch of a giant redwood tree, and then plunges first into a single leaf and then into an individual cell. Inside the cell the scene is evocative of the 1966 science fiction movie "Fantastic Voyage," in which Lilliputian humans in a minuscule capsule take a medical journey through a human body.

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Life: A Cosmic Story

A video trailer for the new planetarium show at the California Academy of Sciences.

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There is an important difference — "Life: A Cosmic Journey," a multimedia presentation now showing at the new Morrison Planetarium here at the California Academy of Sciences, relies not just on computer animation techniques, but on a wealth of digitized scientific data as well.

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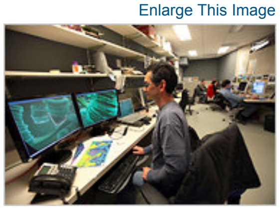

Jim Wilson/The New York Times

The visualization studio in the basement beneath the planetarium.

The planetarium show is a visually spectacular demonstration of the way computer power is transforming the sciences, giving scientists tools as important to current research as the microscope and telescope were to earlier scientists. Their use accompanies a fundamental change in the material that scientists study. Individual specimens, whether fossils, living organisms or cells, were once the substrate of discovery. Now, to an ever greater extent, researchers work with immense collections of digital data, and the mastery of such mountains of information depends on computing power.

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The physical technology of scientific research is still here — the new electron microscopes, the telescopes, the particle colliders — but they are now inseparable from computing power, and it is the computers that let scientists find order and patterns in the raw information that the physical tools gather.

Computer power not only aids research, it defines the nature of that research: what can be studied, what new questions can be asked, and answered.

"The profound thing is that today all scientific instruments have computing intelligence inside, and that's a huge change," said Larry Smarr, an astrophysicist who is director of the California Institute for Telecommunications and Information Technology, or Calit2, a research consortium at the University California, San Diego.

In the planetarium's first production, "Fragile Planet," the viewer was transported through the roof of the Morrison, first appearing to fly in a graceful arc around the Renzo Piano-designed museum and then quickly out into the solar system to explore the cosmos. Where visual imagery was once projected on the dome of the original Morrison Planetarium using an elaborate home-brew star projector, the new system is powered by three separate parallel computing systems which store so much data that the system is both telescope and microscope. From incomprehensibly small to unimaginably large, the computerized planetarium moves seamlessly over 12 orders of magnitude in the objects it presents. It can shift "from subatomic to the large-scale structure of the universe," said Ryan Wyatt, an astronomer who is director of the planetarium.

It is, said Katy Börner, an Indiana University computer scientist who is a specialist in scientific visualization, a "macroscope." She uses the word to describe a new class of computer-based scientific instruments to which the new planetarium's virtual and physical machine belongs. These are composite tools, with different kinds of physical presences that have such powerful and flexible software programs that they become a complete scientific workbench that can be reconfigured by mixing and matching aspects of the software to tackle specific research problems.

The planetarium's macroscope is designed for education, but it could be used for research. Like any macroscope, its essence is its capacity for approaching huge databases in a variety of ways. "Macroscopes provide a 'vision of the whole,' " Dr. Börner wrote in the March issue of The Communications of the Association for Computing Machinery, "helping us 'synthesize' the related elements and detect patterns, trends and outliers while granting access to myriad details.' " She said software-based scientific instruments are making it possible to uncover phenomena and processes that in the past have been, "too great, slow or complex for the human eye and mind to notice and comprehend."

Computing is reshaping scientific research in a number of ways, Dr. Börner notes. For example, independent scientists have increasingly given way to research teams as cited by scientific papers in the field of high-energy physics that routinely have hundreds or even thousands of authors. It is unsurprising, in a way, since the Web was invented as a collaboration tool for the high-energy physics community at CERN, the European nuclear research laboratory, in the early 1990s. As a result research teams in all scientific disciplines are increasingly both interdisciplinary and widely distributed geographically.

So-called Web 2.0 software, with its seamless linking of applications, has made it easier to share research findings, and that in turn has led to an explosion of collaborative efforts. It has also accelerated the range of cross-disciplinary projects as it has become easier to repurpose and combine software-based techniques ranging from analytical tools to utilities for exporting and importing data.

A macroscope need not be in a single physical location. To take one example, a midday visitor to the lab of Tom DeFanti, a computer graphics specialist, in the Calit2 building in San Diego is greeted by a wall-size array of screens that appears to offer a high-resolution window into a vacant laboratory somewhere else in the world. The distant room is a parallel laboratory at King Abdullah University of Science and Technology, in Thuwal, Saudi Arabia. Four years ago representatives of that university visited Calit2 and initiated a collaboration in which the American scientists helped create a parallel scientific visualization center in Thuwal connected to the Internet by up to 10 gigabits of bandwidth — enough to share high-resolution imagery and research.

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