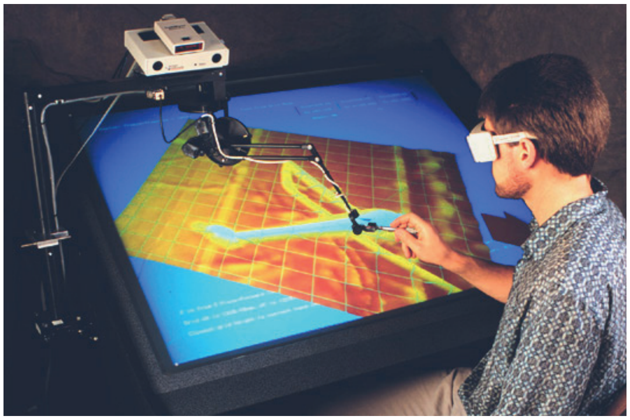
The nanoManipulator: A Virtual-Reality Interface to Scanned-Probe Microscopes

Computer Science, Physics and Astronomy, and Applied and Materials Sciences, UNC–Chapel Hill January 2005



Highlights

- **Tightly-knit team of computer scientists, physicists, and materials scientists constantly pushing the boundaries in each field to develop ever more powerful tools for the study of basic science at the nanometer scale.**
- **Puts scientists virtually on a nanometer-scale surface in direct control while experiments are happening.**
- **Current thrusts: telecollaborative access to the system, new instrumentation (SEM/ AFM, 3D force microscope), simulation alongside experiments, improved display and interaction techniques, and the display of multiple scalar fields on surfaces (visually and haptically).**
- **We're an NIH National Research Resource: we encourage biological and health scientists to contact us about using our Resource.**

The Challenge

Researchers in the departments of Computer Science and Physics and Astronomy at UNC–Chapel Hill are working together to develop the nanoManipulator system, an improved, natural interface to scanned-probe microscopes (SPMs). We are building *visualization systems* that intuitively map the additional senses made available by these microscopes into the human senses, and *control systems* that project human actions directly into this world. The nanoManipulator acts as a translator between the scientist and the instrument being controlled, allowing the scientist to concentrate more on the science. Two ongoing goals are: (1) richer and more intuitive data display to allow a scientist to understand more from the data more quickly, and (2) more powerful and more intuitive control of the SPM to allow the scientist to perform well-understood operations better and faster, and to perform qualitatively new experiments.

The Approach

A scientist places a sample in the SPM, which uses a nanometer-sized tip to scan its topography. A graphics computer provides 3D views of the sample while the experiment is taking place. This view highlights 3D features that may not be visible or understandable in a traditional 2D grayscale display of the data. The scientist can guide the tip directly in order to feel the surface using a haptic display (a Phantom force-feedback device), and can increase the force used in order to modify the sample. Because an SPM cannot scan and modify a surface at the same time, haptic feedback guides the progress of an experiment (you can't see what you're doing, but you can feel what you're doing). This system essentially magnifies the object under study up to a million times, allowing the scientist to see, touch, and manipulate it directly.

Science. Scientists have used the system to examine the mechanical and electrical properties of carbon nanotubes, the spreading of melting polymers, the rupture strength of DNA, the stiffness of the tobacco-mosaic virus, the strength of the adeno virus capsid (used in gene therapy), the behavior of nanochain aggregates, the differences between normal and hemophiliac blood clots, the structure and strength of pili fibers (bacterial grappling hooks), the behavior of optically-responsive materials under manipulation, the strength of microtubules (cellular scaffolding), colloidal metal particles, and voltage pulses on metals (nano spot-welding).

Tele-nanoManipulation. The microscope, haptics, and graphics are each controlled by separate computers on a network. We have run the system over the Internet to a local high school, Orange High School in Hillsborough, N.C., and over the Internet2 to Washington, D.C. These prototype demonstrations of *virtual laboratories* included audio and video links to facilitate collaboration between the distributed users. We are performing formal user studies to answer the question: "How effective is telecollaboration compared to side-by-side collaboration on the performance of scientific investigations?"

New Instrumentation. We are expanding our natural interfaces beyond SPMs to include two new forms of microscopy. The first is a system that combines an SPM with a scanning electron microscope (SEM). The combined system will allow both mechanical and electron-beam manipulation of samples and the overlay of data from the two different views to provide improved understanding of the sample's shape and chemical composition. The second is a 3D-force microscope that moves a particle in liquid (decoupled from an SPM cantilever) that will be targeted at biological investigation. This system will integrate volume and surface display (both visual and haptic), which we hope will enable scientists to see, feel, and manipulate the insides of cells.

Analysis and Simulation. We continue to bring image analysis techniques from the medical community to bear on the analysis of science experiments. Currently, we are working with the COREs-based object-center tracking code. We are also beginning to bring online simulations into experiments, to allow real-time "what if" analysis and direct comparison of theory (which drives the simulation) with experimentation (actually moving objects on surfaces).

Multi-Modal Visualization. Modern SPMs and SEMs can acquire multiple data sets—such as conductance, lateral force, temperature, and element labeling—at the same time that they sample the height of the surface. Normally, these data sets are displayed as several side-by-side grayscale images: one per data set. We are investigating the use of color and programmable shading to display these data sets overlaid on the topography, to allow the scientist to view correlations between topography and other data more naturally. We are also exploring richer force-feedback models (including compliance, vibration, and friction) to convey this information during manipulations.

Project Leaders

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Selected Publications

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For information about purchasing a nanoManipulator system for your own lab, see www.3rdtech.com.