Software overcomes major problems for scientists who operate research tools over the Internet

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Software under development at Ohio State University is helping scientists operate big-budget research instruments -- such as high-powered microscopes and telescopes -- over the Internet, more safely and efficiently than was possible before.

The need for such remote operation is growing, and it's driven by the costs of doing research, explained Prasad Calyam, a doctoral student in electrical and computer engineering at Ohio State. Calyam is a senior systems developer at the Ohio Supercomputer Center (OSC), where he and other researchers are developing the software in collaboration with materials scientists at Ohio State's Center for the Accelerated Maturation of Materials (CAMM).

Today, distant institutions often share the costs -- and also the use -- of expensive instruments. With the Internet, it's now possible for distant research partners to run their own experiments on shared instruments without leaving home.

But Internet traffic congestion can make remote operation slow, frustrating, and even dangerous.

"Communication delays can prevent remote operators from knowing exactly what is happening with an instrument at a particular moment, and that can lead to making the wrong decisions as a result," Calyam said.

When that happens, one wrong keystroke could spell disaster. Expensive physical components in the instrument could smash into one another. Repairing these damaged components can cost over $100,000 to fix. All because the remote video feed froze up, and the researcher couldn't see what he or she was doing.

Calyam and his colleagues began developing RICE -- short for Remote Instrumentation Collaboration Environment -- to prevent remote researchers from making such mistakes. It also helps them perform experiments more efficiently, regardless of network congestion.

At the IMMERSCOM conference in Verona, Italy, on October 11, 2007, Calyam described the first test of the software, which was conducted late last year at OSC with researchers from CAMM.

On the surface, RICE would look very familiar to anyone who's used Internet videoconferencing software, or even an Internet chat program. There's a window that lists the names of researchers who are logged in, and another window for text messaging. A third window shows a video feed of the object being studied, along with buttons to control the instrument. One primary user -- presumably, the lead researcher on an experiment -- can transfer control of the instrument from one remote researcher in one location to another.

For this study, the test subjects were researchers from the Department of Materials Science and Engineering at Ohio State. That department houses CAMM, which recently installed several of the world's most powerful electron microscopes with the idea of making them remotely operable.

The CAMM engineers and their students used RICE to operate a microscope from different locations -- first, directly at the microscope, then elsewhere inside the laboratory, then at another location inside the same building. Finally, they operated the microscope from two miles away at the OSC offices on Ohio State's west campus in Columbus. Each test utilized a different kind of network setup; the test at OSC was performed over the public Internet.

In each test, the CAMM engineers were able to operate their microscope without incident. While they experienced some delays in performance when using RICE over the Internet, they still reported a high level of satisfaction with the software.

Calyam was also pleased to note that the experiment at OSC didn't affect the network performance of the center's employees, despite the fact that the software's video feed requires 10-30 megabytes per second of bandwidth.

"The first question a system administrator in a campus environment has to ask before installing this kind of software is, 'If we use this in the laboratory, how will it affect all my other users in the building?'" Calyam said. "Now we know, if the lab has a well-designed network, RICE won't affect them -- they can go about business as usual."

RICE works so well because it relies on the economic principles of supply and demand to utilize network bandwidth. It's a unique way of understanding how network health affects end-user experience, and -- as it turns out -- it's a vitally important strategy for operating instruments remotely.

Special algorithms take control of the software when a user's commands -- in effect, the user's demands on the system -- outweigh the supply. In this case, the "supply" is bandwidth consumed by the video feeds from the instrument. For example, when Internet congestion has caused the video feed to freeze up, RICE blocks commands from the user, who may mistakenly think that the instrument hasn't moved, when it actually has.

He or she may even try to correct the mistake by pressing more buttons -- and may actually make the problem worse.

"It's just human nature -- when we hit a button, and nothing happens, we hit the button again," Calyam said. "We know from our previous studies that people using Internet software tend to click more buttons when the network is slow, and they also get less done.

"RICE notices when a user issues commands that are probably caused by network congestion, and it blocks those commands. In addition, it allows the user to tune their supply to cope with network congestion. In the end, the user is less frustrated, because they've gotten the result they wanted with fewer clicks and without worrying about potentially damaging the instrument."

OSC eventually plans to make the RICE software code publicly available. In the meantime, Calyam's team is continuing to test the software with other instruments in Ohio -- some located at the Department of Chemistry at Ohio State, the Electron Microscopy Facility at Miami University, and the Department of Physics and Astronomy at Ohio University.

The need for better software for remote operation is growing, Calyam said. The National Science Foundation recently began encouraging the use of remote operation on the major instruments that it funds. And some laboratories are seeking to recoup their investment in expensive instruments by allowing outside researchers to rent the use of instruments and related analytic tools over the Internet, for a fee.

Calyam's co-investigators on the study included Nathan Howes, an undergraduate in the Department of Computer Science and Engineering, and Abdul Kalash and Mark Haffner, both graduate students in the Department of Electrical and Computer Engineering.

Numerous Ohio State faculty members contributed to the project (some of whom also have appointments at OSC), including: Calyam's advisor, Eylem Ekici, assistant professor of electrical and computer engineering; Ashok Krishnamurthy, associate professor of electrical and computer engineering, associate professor of speech and hearing, and Director of Research and Scientific Development at OSC; Steven Gordon, professor of city and regional planning and Director of Education and User Support at OSC; and Dong Xuan, associate professor of computer science and engineering.

At CAMM, Peter Collins, a senior research associate, Robert Williams, a graduate research associate, and Daniel Huber, a student research assistant, aided in the study. CAMM is directed by Hamish Fraser, Ohio Regents Eminent Scholar and professor of materials science and engineering.

"CAMM provided feature sets, design goals, and also enabled pilot deployment of the software," Calyam said. "Without CAMM, this project would not have existed."

Source: Ohio State University

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