SOCIALLY RELEVANT COMPUTING: OUR HEALTH, OUR KNOWLEDGE, OUR PLANET
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For more information, go to research.microsoft.com/collaboration
Klaus-Peter Zauner of the University of Southampton, a 2005 Microsoft Research European Fellow.
Humankind faces momentous challenges—from climate change and dwindling energy resources to inadequate healthcare and disparities in education among much of the world’s population. Although many resources—public, private and individual—will be required to address these needs, recent breakthroughs in technology offer important opportunities to help meet these challenges and improve people’s lives.

In medicine, computers are helping to solve the genetic mysteries behind many human diseases and are enabling the delivery of vital medical services in underserved communities. In the environmental sciences, wireless sensors are sending huge volumes of information to researchers, who are using innovative software to gain a greater understanding of our planet. New technologies are helping to improve teaching, learning and information sharing among educators, academics and scientists.

For many years, Microsoft has been committed to investing in the kinds of basic and applied research that enable breakthroughs in computer science, which in turn are empowering researchers in other areas.

In collaboration with leading scientists and researchers in academia, government and industry, Microsoft Research and its External Research Division are helping to nurture discoveries in healthcare, education, energy, the environment and other fields. Across a broad range of fields, scientists are using the power of software—in combination with advances in computer hardware, devices and the Internet—to gather, analyze and make sense of data that could hardly have been imagined, or understood, just a few decades ago.

In the pages that follow, we showcase a number of these collaborations. In the Swiss Alps, for example, teams of environmental scientists and computer science experts are combining powerful data-gathering and visualization software with sophisticated remote sensor networks in a project that could significantly improve our ability to monitor and understand environmental conditions around the globe.

Bioengineering researchers at the University of Washington in Seattle are using innovative computer simulation techniques to reveal secrets of protein folding that could lead to breakthroughs in the battle against diseases such as Alzheimer’s, Parkinson’s and many forms of cancer.

At the Center for Socially Relevant Computing in New York, college students are learning the basics of computer science and engineering in order to help improve people’s lives. They are developing hardware and software systems that improve mobility for physically disabled children, networking devices to help emergency response personnel navigate more safely in dangerous conditions, and text-to-speech software applications that enable stroke patients to communicate.

Through these and many other projects, Microsoft External Research is assisting researchers by providing them with interoperable technologies, software tools, and financial and technical support. Collaboration and a willingness to share expertise are central to all of these endeavors.

By tapping into the talent and passion of scientists and researchers around the world—and by providing the tools and support they need to discover and collaborate—Microsoft External Research is helping to address many of society’s most significant challenges.
Protein folding image created by the Daggett Research Group at the University of Washington
Technology is revolutionizing the way we diagnose, treat and prevent diseases and other health conditions.

With support from Microsoft External Research, scientists around the world are building new data analysis and visualization tools that are rapidly advancing our understanding of the human genome and the function of cells. These technologies are enabling researchers to pursue breakthroughs in “personalized medicine” that could help solve some of our greatest healthcare challenges.

For example, scientists understand that glitches in protein folding are responsible for debilitating diseases such as Alzheimer’s, cystic fibrosis and many forms of cancer, but little is understood about how these molecular malfunctions occur. Using innovative computer simulation techniques, a team of scientists at the University of Washington is working to solve the mysteries of protein folding—research that could ultimately lead to more successful disease prevention and treatment strategies.

Microsoft is also supporting a broad range of research projects that tap into the increasing power and miniaturization of devices and sensors—from smartphones to ultrasound probes—to help make healthcare more affordable and accessible, especially in developing regions.

Researchers at Edith Cowan University in Australia are developing a smartphone-based fetal monitoring system that will enable expectant mothers in remote and rural Indigenous communities to monitor fetal heart rate and activity and then transmit the data in real time to regional health centers.

At the University of California, Berkeley, a research team has developed CellScope, a camera-phone microscope powerful enough to diagnose malaria and tuberculosis—diseases that kill more than 2.5 million people each year, according to the World Health Organization.

“The Microsoft Research funding opportunity was a fantastic way to move this idea of portable microscopy further,” says Daniel Fletcher, a bioengineering instructor at UC Berkeley who worked with students to create CellScope.

For other examples of Microsoft External Research projects, see page 50.
Camera-Phone Microscope: A Simple Solution That Could Help Tackle Killer Diseases

What started as a college class assignment spawned an invention that could help bring the benefits of modern microscopy to the developing world. Student researchers and their professor at the University of California, Berkeley, have developed a camera-phone microscope powerful enough to diagnose malaria and tuberculosis—diseases that still take a heavy toll in many parts of the world.

While diseases such as malaria and tuberculosis (TB) are largely under control in most of the developed world, they remain leading killers in many impoverished countries. Together, the two diseases kill more than 2.5 million people each year—the vast majority in Africa and other developing regions. More than 80 percent of the estimated 881,000 people who died of malaria in 2006 were African children under the age of five, according to the World Health Organization.

It was against this grim backdrop that Daniel Fletcher, an associate professor of bioengineering at UC Berkeley, posed a challenge to students in his Optics and Microscopy class. Imagine you are working in a remote African village at the time of a disease outbreak, Fletcher told his students, and among your meager supplies you happen to have a camera cell phone and an assortment of basic optics lenses and mounts.

Would it be possible, Fletcher asked, to convert the camera phone into a sort of mobile microscope that could be used to diagnose the disease?

While the students went to work on possible designs, Fletcher searched the Internet for some real-life examples. Surely someone had already come up with such a device, Fletcher thought. But to
his surprise, there were no high-magnification camera phone–based microscopes on the market. “It became clear to us that this is something we should actually build, test and use,” says Fletcher.

Using less than $100 in optics supplies—including a 40X lens system and a 3-megapixel cell phone borrowed from Fletcher’s sister—the students built a working prototype. Although the tabletop-mounted device wasn’t exactly portable, they had proved that their idea of converting a camera phone into a low-cost microscope was feasible.

They named their invention CellScope. With funding and software support from Microsoft External Research and other groups, Fletcher and his team of undergraduate, graduate and postdoctoral students continue to refine the device.

They have developed a functioning camera-phone microscope capable of taking and transmitting clinical-quality images, and they have demonstrated that it is powerful enough to spot malaria, TB and sickle-cell disease in blood samples. In 2009, Fletcher’s team expects to undertake field testing, in partnership with several organizations, in developing regions such as Africa, South America and East Asia.

In many remote or impoverished areas, there is little access to the tools of modern medicine—including microscopes, which are essential for diagnosing and tracking malaria and TB. But throughout much of the developing world, access to cell phones and wireless technology has become increasingly common.

“It’s really a perfect clinical niche” for CellScope, says Wilbur Lam, a pediatric hematologist/oncologist at the University of California, San Francisco, and a bioengineering postdoctoral scholar in Fletcher’s lab at UC Berkeley.

Lam envisions several ways that CellScope could prove to be a powerful tool for combating malaria and TB. In resource-poor regions, a lack of available microscopes and trained experts makes it extremely difficult to confirm a malaria diagnosis. This leads to missed diagnoses and unnecessary treatment of people who are not infected. Besides helping to spot new infections, Lam says, CellScope could also help reduce the overuse of antibiotics and thus prevent the breeding of drug-resistant strains of the diseases.

In the case of TB, Lam says, infected patients sometimes build resistance to a particular antibiotic. CellScope will enable healthcare workers to determine in real time which patients are not responding to treatment. “If someone is becoming resistant, we need to know this and we need to know it quickly,” Lam says.

Fletcher and his students have developed two lens systems for CellScope so far—a low-magnification scope for viewing conditions such as infections or skin rashes, and a high-magnification scope for analyzing microorganisms in blood, saliva or other samples. They used a standard clip-on cell-phone holder to make a mounting system for the lenses and the sample slides. They have
also developed an illumination system using light-emitting diodes (LEDs) powered by the cell phone battery.

While CellScope works on most camera phones, Fletcher says smartphones will be the main platform. The team is developing two open source software packages: CellScopeCapture, an imaging application that will run on the Windows Mobile® operating system, and CellScopeAnalysis, an image-analyzing program that will run on the Windows Vista® operating system.

CellScopeCapture will enable healthcare workers—or even someone with minimal training—to use a CellScope to take sample images and organize and annotate those images before transmitting them to a physician or medical specialist anywhere in the world. CellScopeAnalysis will enable the physician or specialist to analyze the images on a notebook or desktop PC and then send results or treatment recommendations back to the healthcare worker. The researchers are also developing automated image analysis software that will enable healthcare workers to make preliminary diagnoses in the field.

CellScope won’t take the place of conventional research microscopes. But Fletcher believes it will have many uses. In addition to helping diagnose diseases and track epidemics in poor or remote regions of the world, CellScope could have applications in the developed world as well.

Cancer patients, who often have to make frequent trips to the hospital for complete blood cell counts, could use a CellScope to do in-home tests and then transmit the results to their physician. Farmers could use the device to take images of crop blights and send the results to an agricultural expert. Fletcher and his team have submitted a patent disclosure on CellScope. But he says the researchers will follow UC Berkeley’s policy of offering free licenses for technologies used to improve health and welfare in developing countries.

The researchers have been working closely with the Blum Center for Developing Economies, a UC Berkeley–based organization that promotes technology innovation to advance the well-being of poor people in developing countries, and with the university’s Center for Information Technology Research in the Interest of Society (CITRIS).

Fletcher says one of the most exciting aspects of the CellScope project has been the students’ willingness to volunteer their time on the research and development work. He says the prospect of creating something that could improve people’s lives has been a big motivator.

“It’s really the idea that such simple technology can have such a big impact—that’s what has been such an eye opener for me and my students,” Fletcher says.

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**At a Glance**

**PROJECT:** CellScope  
**LOCATION:** University of California, Berkeley  
**PROJECT PRINCIPAL:**  
Daniel Fletcher, associate professor, Department of Bioengineering, UC Berkeley  
**WEB SITES:**  
bioeng.berkeley.edu/cv/dfletcher.php  
blumcenter.berkeley.edu/telemicroscopy-disease-diagnosis  
fletchlab.berkeley.edu/research_cellscope.htm  
**MICROSOFT TECHNOLOGIES:**  
Windows Mobile 6, Visual C++®
Unraveling Protein Folding:
High-Performance Computing Helps Shed Light on Diseases

Proteins are the workhorses of the body, and the enigmatic process by which a protein folds into a specific three-dimensional structure has vast implications for human health. Researchers at the University of Washington are using innovative computer simulation techniques to reveal secrets of protein folding that could lead to improved diagnosis and treatment of diseases such as Alzheimer’s, Parkinson’s and many forms of cancer.

More than a century after German physician Alois Alzheimer first published his observations about a progressive brain disorder that impaired patients’ memory, thinking and behavior, Alzheimer’s disease remains an incurable and largely baffling condition. Roughly 26 million people worldwide are afflicted with Alzheimer’s, and the number of cases is projected to quadruple by 2050, according to a 2007 study by the Johns Hopkins Bloomberg School of Public Health.¹

A research team at the University of Washington in Seattle is working to shed more light on the causes and potential treatments of neurological diseases such as Alzheimer’s by unraveling—literally and figuratively—the mysterious process by which proteins fold themselves into unique, three-dimensional structures that dictate their specific function. While scientists have determined that incorrectly folded proteins are responsible for Alzheimer’s and a host of other illnesses such as Parkinson’s disease, cystic fibrosis, Creutzfeldt-Jakob disease and many forms of cancer, little is known about how a protein undergoes this transformation.

“We are using computer simulations and other experimental methods to precisely characterize the structural changes that occur in protein folding, particularly changes that can trigger the onset of a disease,” says Valerie Daggett, a professor of bioengineering who leads the Daggett Research Group at the University of Washington. Daggett and her colleagues believe that the insights gained from these simulations will help uncover general rules of protein folding that medical researchers can use to create more successful diagnostic techniques, drug therapies and disease prevention strategies.

Software, financial and technical support from Microsoft External Research is helping the Daggett Research Group carry out its computer simulations, expand its database of protein folding images and make the results available broadly for other scientists to study. For example, the group uses high-performance computing systems built on Windows® Compute Cluster 2003, Windows Server® 2008, SQL Server® 2008 and SQL Server Analysis Services to handle the massive computational demands involved.

“Our protein simulations and structures involve hundreds of terabytes of data,” says Daggett. “Before Microsoft became involved, there really wasn’t a way for us to handle it all—we had data separated over hundreds of computer disks.” The team could analyze a
small number of proteins in detail but struggled to compare details about the unfolding process across all simulations.

“With this high-performance computing framework and the collaborative support that Microsoft Research provides, we can now ask bigger-picture scientific questions that enable us to really go after these diseases,” says Daggett. “We have also been able to streamline our work because we’re much better organized.”

The Daggett Research Group has compiled nearly 5,000 independent simulations of more than 650 protein folds—roughly half of all known protein structures—as part of its work in the field of molecular dynamoemetics. This research seeks to bridge a gap in scientists’ understanding of the transitions and structures that occur in a protein from the time it is created to when it achieves its folded state, a process that takes place in microseconds to minutes.

“The static structure of a protein doesn’t show you anything about how it moves or behaves, which is critical in order to really understand the protein’s function and its pathology if it is associated with a disease like Alzheimer’s or cancer,” explains Daggett. “I believe that this lack of dynamics is one of the biggest obstacles to more effective drug design.”

To simulate pathways of the protein folding process, Daggett’s team actually works in reverse: starting with a protein in its native, folded structure and applying heat to make it unfold. The group’s research has shown that protein unfolding follows the same pattern as folding, and creating a computer simulation from an existing structure requires far less sampling of structures.

Multiple different simulations are needed in order to capture an adequate record of the unfolding process. To perform these simulations, the Daggett Research Group developed a software code called “in lucem Molecular Mechanics” (ilmm) that runs on Windows Compute Cluster Server 2003 and employs Isaac Newton’s equations of motion to chart the path of every atom in the protein molecule over time.

As they home in on the folding pathways of proteins and begin identifying significant structural changes along the way, such as the instant when a protein misfolds and potentially becomes toxic, biomedical researchers will be able to investigate the underlying causes of those changes. “Then we can create diagnostic agents and drug therapies that target specific protein structures,” says Daggett.

“With diseases such as Alzheimer’s, the symptoms usually occur only after there has already been a great deal of damage,” she adds. “If physicians can detect the onset of the disease sooner and introduce therapy to inhibit protein misfolding or toxicity, a cure should someday be possible.”

Daggett’s team is in the second phase of testing diagnostic and therapeutic compounds to target the protein structures that
contribute to Alzheimer’s, Creutzfeldt-Jacob and bovine spongiform encephalopathy—commonly known as mad cow disease. In addition to their potential for inhibiting the structural changes that make a protein toxic, the compounds could eventually yield more effective methods of screening food supplies and blood supplies for infectious forms of these diseases.

Byron Caughey, a senior investigator in the Rocky Mountain Laboratories at the U.S. National Institutes of Health, says Daggett’s computer modeling of protein structures is contributing to significant gains in biomedical research.

“Some of the most persistent problems in protein science involve understanding how proteins misbehave by misfolding and assembling into toxic aggregates,” says Caughey. “Computational simulations are especially valuable in studying the process of protein misfolding and its connection to diseases. Valerie has made groundbreaking contributions to these efforts.”

Many of the computer simulations and related data are available on the Daggett Research Group’s Web site for general use, and team members collaborate regularly with other researchers who are studying specific proteins. The research group has also applied for patents related to its work.

Although Daggett cautions that breakthroughs in disease diagnosis and treatment stemming from her team’s protein research are still years away from reaching healthcare professionals and patients, she is encouraged by the initial results.

“A growing number of diseases are associated with protein unfolding, so this is a place where we can really intervene. Understanding the changes involved could have tremendous implications for millions of people who live with these conditions.”

—Valerie Daggett, professor of bioengineering, University of Washington

At a Glance

**Project:** Molecular Dynameomics

**Location:** University of Washington, Seattle

**Project Principal:** Valerie Daggett, professor of bioengineering, University of Washington

**Web Sites:**
www.dynameomics.org
depts.washington.edu/daglab

**Microsoft Technologies:**

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Smartphone-Based Fetal Monitors: Delivering Prenatal Care to Underserved Communities

For expectant mothers, particularly those with high-risk pregnancies, regular prenatal checkups can be crucial for detecting potentially life-threatening complications. Researchers at Edith Cowan University in Perth, Australia, aim to improve access to prenatal care in isolated communities by designing an affordable, portable fetal monitor that expectant mothers can use to check for signs of fetal distress and relay vital information to healthcare professionals.

Living hundreds of kilometers from the nearest hospital or health center in many cases, Indigenous women in remote and rural Australia experience premature births, fetal deaths and other complications at more than twice the rate of other Australian women. Limited access to fetal monitoring technologies such as ultrasound scans and heart rate tracing is a major factor in this alarming trend.

“The tyranny of distance and its associated costs remain a barrier for delivering reasonable-quality prenatal care to Indigenous women in these isolated communities,” says Alfred Tan, a senior lecturer in the School of Computer and Information Science at Edith Cowan University. “Because the nearest hospital or health center with an ultrasound monitor may be hours away, these expectant mothers often do not get the proper medical care to prevent or address prenatal issues.”

Tan, an expert in mobile and wireless technologies, and his colleague Martin Masek, a researcher in biomedical engineering, aim to improve the quality of prenatal care in rural and remote communities by providing expectant mothers with an inexpensive, portable, Doppler-based ultrasound device connected to a smartphone.
running Windows Mobile.

With technology, research expertise and financial support from Microsoft External Research, Tan and Masek are developing software that can be downloaded at no cost to any Windows Mobile smartphone. When connected to a low-cost fetal monitor, the smartphone will enable expectant mothers to track and keep a record of the fetal heart rate and activity in the womb and transmit that data to obstetricians or midwives at urban or regional health centers. The system also can be used to track and relay critical information during premature births.

Tan's team has been developing the system since early 2008, using Microsoft® Visual Studio 2008 software development tools and the Microsoft SQL Server 2008 data platform. Microsoft has also provided the smartphones used in the research.

In addition to transmitting data to a hospital or medical center, the smartphone software can process this information and provide important details to an expectant mother and her obstetrician or midwife.

For example, the system can track a baby's kicks inside the womb. With healthy babies, increased activity is typically associated with an accelerated heart rate. Kicking without any heart rate acceleration is a sign of distress—and a reason to see a doctor right away.

For mothers who go into early labor, the monitor can relay vital information to medical professionals while the patient is getting to the hospital. This is a significant improvement over having the mother—or a friend or family member—try to describe what’s happening over the phone.

“Especially with a woman’s first pregnancy, there can be a lot of unknowns and a great deal of anxiety that make communicating with the hospital staff difficult,” says Tan. “Using this type of mobile device, expectant parents will have greater peace of mind, and clinicians can receive much more complete and accurate data to monitor the baby’s condition.”

Tan and Masek’s system fills an important gap in the available technology, particularly for rural and remote use. On one end of the spectrum are inexpensive handheld monitors that can pick up a baby’s heartbeats but cannot process the information or transmit it in real time. On the other end is high-end portable monitoring equipment that is designed to transmit information to doctors remotely but costs hundreds of thousands of dollars. By contrast, the smartphone-based fetal monitoring software and portable Doppler ultrasound device together will cost only about US$50 per unit.

Interestingly, the technology also could reduce the amount of time that pregnant women from rural and remote communities spend in the hospital. That’s because Indigenous women with higher-risk pregnancies are often admitted to hospitals for monitoring because they live too far away to get regular checkups or cannot get to the hospital quickly in an emergency.

“By allowing prenatal care to be provided from home, our
“Using this type of mobile device, expectant parents will have greater peace of mind, and clinicians can receive much more complete and accurate data to monitor the baby’s condition.”

—Alfred Tan, senior lecturer, Edith Cowan University

solution will reduce the stress currently put on the health system,” says Tan. “This will further free up hospital beds and clinicians’ time to serve those who are in greater need.”

Tan and his colleagues have used information gathered from patients at Mercy Hospital Mount Lawley in Perth to test the system’s accuracy against the hospital’s commercial Doppler ultrasound unit. Among other things, they have investigated the length of time required for readings to produce an accurate measure.

“All signs indicate that the heart rate trace data being recorded and transmitted remotely via our smartphone-based software is just as reliable as what’s produced with the more expensive and bulky systems,” says Masek.

One of the team’s top priorities has been ensuring that the monitoring tools are easy to use. The software features simple menu-based commands, which have received positive feedback from patients thus far. “That’s largely thanks to the capabilities built directly into Microsoft’s technology,” says Masek. “When we were looking to add features like graphics and data charting formats, 99 percent of what we needed was already there.”

Additional tests with the hospital’s patients have confirmed the system’s compatibility with existing hospital equipment and its ability to keep patient data private and secure. Tan and Masek are also working with Mercy Hospital to carry out field tests in which Indigenous women are trained to use the equipment and then observed to determine the system’s ease of use, accuracy and security.

Results of the project will be published in technical journals and shared at conferences, and the software will be freely available on the Internet. Tan has talked to medical device companies to gauge their interest in the system and says they are excited about its potential.

Researchers also see broader potential uses for the software, such as for monitoring the heart conditions of elderly cardiac patients who have difficulty leaving their homes.

“Dr. Tan’s work offers much promise for women and families throughout the world who lack adequate access to medical care,” says Louise Schaper, chair of the Health Informatics Society of Australia, a nonprofit organization focused on advancing health-care through technology. “This research will lead to technologies and services that enhance the physical health and emotional well-being of potentially hundreds of thousands of women.”

At a Glance

**PROJECT:** Fetal Heart Rate Monitoring via Smartphones

**LOCATION:** Edith Cowan University, Perth, Australia

**PROJECT PRINCIPALS:**

*Alfred Tan,* senior lecturer, School of Computer and Information Science, Edith Cowan University

*Martin Masek,* senior lecturer, School of Computer and Information Science, Edith Cowan University

**WEB SITE:**

aise.scis.ecu.edu.au/index.php?title=Fetal_Heart_Rate_Monitoring

**MICROSOFT TECHNOLOGIES:**


**OTHER RESOURCES:**

Download a slide show and audio presentation by Alfred Tan at hisa.org.au/hitwa0&download
Students at the University at Buffalo work on a remote-controlled wheelchair.
Advancing knowledge is fundamental to our future as human beings, to creating and sustaining healthy economies and to protecting and enhancing the world in which we live. Software has an important role to play in advancing our collective knowledge through the development of information databases and sophisticated communication platforms and by enabling worldwide collaboration.

In partnership with innovators in scholarly research and communications, Microsoft is developing tools and services that make it easier for researchers to collect, analyze and preserve data, publish their findings, and collaborate and communicate with colleagues around the world.

For instance, Microsoft and The British Library worked with scientists across many disciplines to develop a Web-based “virtual research environment.” Called the Research Information Centre (RIC), it enables researchers to store, share and manage project components—including data, references, papers, bookmarks, proposals and findings. While geared toward biomedical research, the long-term goal is to make the RIC easily adaptable to support the research lifecycle in other scientific domains.

Microsoft is also helping to develop better teaching and learning tools for educators and students. Researchers from a consortium of U.S. universities have teamed up with Microsoft to create the Games for Learning Institute at New York University. This first-of-its-kind institute is conducting research to explore how computer games can enhance learning in math and science among middle-school students.

ConferenceXP, an Internet-based conferencing system developed by Microsoft Research, is helping to connect researchers and students around the world using real-time research collaboration, wireless-enabled classrooms and interactive distance learning environments. Currently, researchers at more than a dozen universities in Latin America and the Caribbean are using ConferenceXP to collaborate on projects aimed at providing technology solutions to improve healthcare, education and small-business development and to address other socioeconomic priorities.

“If we can build a virtual collaboration environment with ConferenceXP that enables Latin American and Caribbean researchers to work together more easily, it will make a huge difference in the quality and impact of our research,” says Ignacio Casas, associate professor of computer science at Pontificia Universidad Católica de Chile in Santiago, Chile.

For other examples of Microsoft External Research projects, see page 50.
Virtual Research Environments: Tackling Global Challenges Across Scientific Disciplines

Collaboration and information sharing among researchers are among the most important but challenging aspects of scientific research. In recent years, scientists have begun using “virtual research environments” to exchange information with colleagues in specific areas of study. Microsoft Research and The British Library are teaming up to build the Research Information Centre, a powerful tool that can help researchers tackle global challenges across a broad range of scientific disciplines.

More than ever, scientific research requires collaboration. Scientists today routinely work with peers from other disciplines, other institutions and other continents.

Take biology, for example. “You can’t really do modern biology by yourself in a corner,” says Carole Goble, a computer science professor at the University of Manchester in the UK who for years has specialized in developing software tools for scientists. “You have to collaborate across the fields of biology and chemistry. And you increasingly have to work with people outside of your own discipline—mathematicians, computer scientists, bioinformaticians and so on.”

The need for collaboration at every stage of the research process is a big part of what prompted Microsoft External Research and The British Library to begin developing a software tool called the Research Information Centre (RIC). The goal is to create a powerful new “virtual research environment” (VRE)—a simple browser interface that enables research partners to find, store, track, share and discuss all the components of a project, including data, proposals, papers, references, bookmarks and findings.
“The key to this tool is that it is intended to support the entire research lifecycle,” says Richard Boulderstone, director of e-Strategy at The British Library. “Researchers simply don’t have anything like that right now. It’s quite an ambitious goal.”

Such a tool could significantly increase efficiency in the research process and thus help scientists in their quest for breakthrough discoveries that improve healthcare or expand our understanding of a fast-changing environment.

Boulderstone, who heads the RIC project at The British Library, says some research groups have been developing VRE software tools for several years. But those tools are typically designed for narrower purposes. For instance, pharmaceutical companies have developed tools to help manage research workflows for clinical trials.

Likewise, The British Library has been involved in several pilot projects to develop VRE tools. But in each case, Boulderstone says, they had to start from scratch. “It occurred to us that there was a real need for a general-purpose VRE tool” that could be adapted to work in any research domain, he says.

The RIC project was launched in 2007. Built on the Microsoft SharePoint® Server 2007 platform, the initial prototype was geared toward biomedical research, building on The British Library’s strength in that domain. But the base architecture is designed so that it can be adapted to other scientific research domains.

To help test the beta version, The British Library enlisted two dozen biomedical research groups from academia and industry in the UK and the United States. Boulderstone’s team has also taken the lead in gathering input from other researchers—advice that Microsoft software developers are using to modify the tool and add new features.

“One of the great things about this project is that it really has helped us get into these research teams and find out what they’re doing and understand their workflows,” Boulderstone says.

Goble, who helped with the RIC beta testing, predicts that the tool could eventually become what she describes as the “über around-the-water-cooler experience for scientists.”

Indeed, the RIC is essentially a professional networking site for scientific researchers. It provides a Web interface that allows a researcher to conduct or manage most of the tasks for a specific project.

For example, a study planning feature helps the researcher to evaluate a particular topic and identify potential collaborators. In putting together a project team, the researcher can access a profile database that lists skills and contact information for other researchers. The tool can also be used to search for possible funding sources or even see what sorts of proposals have been selected for grants.

The biomedical-focused version of the RIC enables researchers to simultaneously search through millions of citations in multiple...
“The key to this tool is that it is intended to support the entire research lifecycle. Researchers simply don’t have anything like that right now. It’s quite an ambitious goal.”

—Richard Boulderstone, director of e-Strategy at The British Library

research literature repositories, such as the U.S. National Library of Medicine’s PubMed and the European Bioinformatics Institute’s CiteXplore, providing access to a broad range of scholarly journal articles, conference proceedings and dissertations.

The tool will also make it easier for a researcher to access multiple data repositories, such as those maintained by the National Center for Biotechnology Information and the European Bioinformatics Institute, which store huge volumes of data sets used in genomic research. It will include an enhanced query tool that enables researchers to easily rerun data or literature searches or to automatically receive updates—via e-mail or RSS feed—when new information is available.

The RIC will help researchers identify tools that are applicable to a specific type of project—such as protein-sequencing tools—and where to find them. Researchers will also be able to use the interface to manage the experimentation phases of their project and conduct real-time discussions with research partners. Finally, the tool will include features that make it easier for researchers to disseminate, publish and archive their findings.

One of the key strengths of the RIC will be its interoperability. Research teams will be able to customize the interface, adding tools and features that meet their needs. “You’re not going to produce a tool that meets everyone’s needs, so you have to create something that does a big chunk of the basics and then can be adapted,” Boulderstone says.

For example, researchers at Oxford University are designing a RIC-based cancer imaging platform that makes it easier for researchers to share and analyze images. As part of that project, Oxford researchers are working to incorporate other Microsoft technologies to help scientists manage their research workflow and data.

The timing is ideal because Oxford is already in the process of making a campus-wide conversion to Microsoft’s SharePoint and Exchange, says Anne Trefethen, professor of scientific computing and director of the Oxford e-Research Centre.

“We see this cancer-imaging project as an example of how we can use these technologies to support research in a specific domain,” Trefethen says. “If we can make it work, it has tremendous potential.”

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At a Glance

**Project:** Research Information Centre  
**Location:** The British Library, London  
**Project Principals:**  
Richard Boulderstone, director of e-Strategy, The British Library  
Lee-Ann Coleman, head of Science, Technology and Medicine, The British Library  
Stephen Andrews, project manager, Science, Technology and Medicine, The British Library  
**Web Site:** research.microsoft.com/ric  
**Microsoft Technology:** SharePoint Server 2007
Web-Based Videoconferencing: Enabling Collaboration Among Latin American Researchers

Academic researchers throughout Latin America and the Caribbean make important contributions to computer science, yet much of their work involves collaboration with project teams on other continents and does not directly address regional challenges. Several universities have joined forces to enable greater collaboration within the region—and more technology breakthroughs in areas such as healthcare, education, the environment, energy and business development—using ConferenceXP, a set of Web-based videoconferencing tools.

For computer science researchers at Latin American and Caribbean universities, collaborating with peers halfway around the world can often be easier than trying to initiate a research project with someone in a neighboring country. Lack of regional funding, a smaller pool of colleagues with similar research interests and limited incentives to form locally based research teams are among the hurdles that make Latin American researchers more likely to work on U.S.- or European-led projects than ones based closer to home.

“It is a problem of critical mass: Latin America has few researchers and we are very isolated,” says Ignacio Casas, an associate professor in the Computer Science Department at Pontificia Universidad Católica de Chile (PUC-Chile) in Santiago. Over the past decade, he says, 90 percent of the computer science research papers involving Latin American researchers and published internationally were written with colleagues on another continent.

“Clearly, there is tremendous value in working with North American and European institutions,” says Casas, who serves as executive director of the Latin American and Caribbean Collaborative ICT Research Federation (LACCIR). “However, such projects are not as likely to address the unique societal challenges and opportunities of Latin American communities.”

Through the LACCIR Virtual Institute, Casas and other academic researchers are working to expand and improve collaboration within the region using ConferenceXP, an Internet-based conferencing system developed by Microsoft Research. The ConferenceXP technology is designed to allow researchers, teachers and students to participate in real-time research collaboration, wireless-enabled classrooms and highly interactive distance-learning environments. The Center for Collaborative Technologies at the University of Washington has enhanced the ConferenceXP platform with additional tools to support education and collaboration.

“If we can build a virtual collaboration environment with ConferenceXP that enables Latin American and Caribbean researchers to work together more easily, it will make a huge difference in the quality and impact of our research,” says Casas. “We
believe that greater regional collaboration will lead to more technology breakthroughs that have the potential to improve healthcare, education, small-business development and other socioeconomic priorities in this region.” As a result, he adds, the work of Latin American researchers will gain more international attention and help attract additional research funding from corporations as well as government and nonprofit sources.

Available as a free download for educational and other non-commercial uses, the ConferenceXP software provides interactive video, audio and document-sharing tools along with the ability to connect hundreds of participants in the same Web conference. The LACCIR Virtual Institute is helping to install the ConferenceXP technology infrastructure at universities throughout the region. Microsoft External Research provided financial and software support to help form LACCIR and advance the federation’s goal of promoting academic research in technology fields.

LACCIR has established ConferenceXP hubs, which include a host server and related infrastructure pieces needed to manage the service, at PUC-Chile and Universidad de Chile in Santiago. The federation has also created a ConferenceXP user guide in Spanish and has helped to equip videoconferencing rooms with webcams and large video projection screens at nine other universities in Chile, Colombia, Uruguay, Mexico, Brazil, Argentina and Costa Rica.

Initiating or participating in a ConferenceXP videoconference session is free and requires only a webcam and a personal computer with high-speed Internet access. Meeting participants can share Microsoft Office Word documents, Microsoft Office PowerPoint® slides and other electronic files within a ConferenceXP session. ConferenceXP also integrates with Classroom Presenter, a presentation software application developed by University of Washington computer science researchers and Microsoft External Research that supports the sharing of digital ink content such as drawings and handwritten notes on a Tablet PC.

In addition to serving as a forum for live discussion and information sharing, Conference XP meetings can be recorded and archived for viewing by anyone to whom the session organizer has granted access. This makes the service an even more valuable resource for university researchers, professors and students around the globe who are interested in projects based in Latin America.

“We are able to share keynote presentations, classroom lectures, panel discussions and many other resources broadly at almost no extra cost,” says Sergio Ochoa, a LACCIR board director and assistant professor in the Computer Science Department at Universidad de Chile. “Students at a very small university or an individual researcher thousands of miles away can participate
“We believe that greater regional collaboration will lead to more technology breakthroughs that have the potential to improve healthcare, education, small-business development and other socioeconomic priorities in this region.”

—Ignacio Casas, executive director, LACCIR

almost as richly as if they were sitting in the same room with the presenter.” When conducting a doctoral thesis defense, for example, a university can host a virtual committee of professors from several locations, with minimal time or expense involved. And rather than invest hundreds or thousands of dollars to fly a keynote speaker from the United States or Europe to Chile, local event organizers can use ConferenceXP to stage a live presentation that can be viewed on the Web by a worldwide audience.

During the April 2009 Conference on Computer Supported Cooperative Work in Design, co-sponsored by LACCIR in Santiago, organizers used ConferenceXP to transmit each day’s keynote presentation and make the recordings available on the LACCIR Web site. Other ConferenceXP sessions presented by LACCIR members have included a seminar on software development cost estimations, in which university students in Argentina, Chile and Colombia collaborated on an assignment using ConferenceXP.

As part of its mission to promote greater research collaboration in the region, LACCIR annually awards five grants averaging US$50,000 each for computer science projects based in Latin America and the Caribbean. Requirements for funding include the involvement of researchers from at least two universities in different countries. “We hope this incentive will encourage more researchers to use ConferenceXP throughout their planning, research and evaluation,” says Ochoa. At least three of the five teams that received LACCIR grants in 2008 are collaborating via ConferenceXP, he adds.

LACCIR is also compiling an online library of videoconference presentations and educational materials for use by university faculty, researchers and other interested parties. Casas says he expects several more schools to join LACCIR’s ConferenceXP collaboration network by the end of 2009.

“People have seen how easily they can use ConferenceXP to connect with other researchers who are investigating similar challenges,” he says. “As the number of users and the variety of projects involved continue to grow, we believe ConferenceXP will help draw even greater attention and financial support to the strong computer science research that’s taking place in Latin America.”

At a Glance

PROJECT: LACCIR Collaboration Support Initiative
LOCATION: Universidad de Chile and Pontificia Universidad Católica de Chile (PUC-Chile), Santiago
PROJECT PRINCIPALS:
Sergio Ochoa, LACCIR board director; assistant professor, Computer Science Department, Universidad de Chile
Ignacio Casas, LACCIR executive director; associate professor, Computer Science Department, PUC-Chile
Claudia Leiva, LACCIR general manager; project manager, Computer Science Department, PUC-Chile
WEB SITES:
www.laccir.org
cct.cs.washington.edu
MICROSOFT TECHNOLOGIES:
Socially Relevant Computing:
Computer Science Solves Real-World Problems

Unfairly or not, computer science has gained a reputation among some college students as being a dull and abstract subject. Researchers at the Center for Socially Relevant Computing in New York are working to reverse this perception by promoting computer courses and software design projects that give students the opportunity to make a profound impact on people’s lives.

While some first-year computer science courses teach software programming by having students write applications that count ducks or play chess, researcher Michael Buckley’s students are creating software that enables speech-impaired adults to communicate and allows firefighters to work more safely in dangerous situations.

Teaching students the basics of computer science and engineering through projects that have the potential to dramatically improve people’s lives is a driving force behind the Center for Socially Relevant Computing. Buckley co-founded the center at the University at Buffalo (UB) in 2008 with financial and software support from Microsoft External Research. Its programs seek to attract more students—particularly women and minorities—to technology by changing the common perception of computer science as an abstract, isolated field and showing that the profession plays an important role in solving significant, real-world problems.

This objective reflects a broader concern among educators and business leaders that U.S. student enrollment in science, technology, engineering and math (STEM) courses is lagging behind the rapidly growing demand for qualified professionals in STEM fields. “A lot of people assume computer science has limited reach, that it’s all huge amounts of data and theorems and coding,” says Buckley, who is the director of the center and a UB associate faculty member. “We want to show that this is a helping profession, and that making a profound social impact through computer science is within the reach of any undergraduate student.”

The center’s initiatives include offering introductory computer programming course materials that weave social relevance and community outreach activities into students’ daily work, such as learning to construct data arrays by studying the movement of water pollution through the Great Lakes. Buckley and Kris Schindler, a teaching assistant professor in the UB computer science and engineering department, have also developed a pair of senior-level software engineering courses in which students work in teams to design and build technologies that solve real-world challenges faced by individuals and community nonprofit organizations.

Recent projects include the DISCO system, a programmable hardware and software system that employs lights, sounds and other sensory input to teach choice-making and other skills to physically and developmentally disabled children at a care facility near the university. In another project, students designed a wireless networking device for emergency response personnel, such as...
firefighters, that continuously monitors the wearer’s position and vital signs and provides two-way communications.

“These projects have showed us that when students are passionate about the work they’re doing, they will excel,” says Schindler. “The students recognize that long after they finish a project, real people are continuing to benefit from the technology.”

The vision for the center originated several years ago, when Buckley was looking for ways to get undergraduates more excited about introductory computing courses. “I found that a lot of the textbooks and sample programs used abstract lessons about separating cows from horses, or they mainly talked about how to design computer games,” he says.

Around that time, Schindler asked if Buckley and his students might like to help design a software application that could be used for communication by a stroke patient named David, who was unable to speak. “When we started rounding up students to work on the project, I was amazed at how charged up they got,” says Buckley.

Students met with David several times to learn more about his requirements and continued the project well after the end of their semester in Buckley’s class. They succeeded in building a communication device called the UB Talker that allows David to select preprogrammed phrases as well as type new words by touching the screen on a tablet PC, which then translates his selections into speech. The night that he received his UB Talker from the students, David used the device to make his first phone call in 20 years. Subsequent groups of students have continued refining the UB Talker software as a tool to help speech-impaired individuals communicate in school, at work and in social environments.

These days, Buckley and Schindler typically have more than a dozen socially relevant technology projects lined up each semester for students to pursue. Teams can also identify a need in the community and develop their own project. Nonprofits, government organizations and individuals can submit requests for technology
assistance to the Center for Socially Relevant Computing on its Web site. The site also provides sample curricula and other resources for university faculty members interested in launching their own socially relevant computing courses, as well as an invitation for companies to sponsor technology projects.

“In Mike and Kris’ classes, it’s a lot more interesting because we get to create real software that can make someone’s life dramatically better,” says Eric Nagler, a junior in computer engineering at UB who has worked on both the UB Talker and firefighter communication software projects. “I like the challenge of being given these development tools and having to figure out on my own how to design an application that works. That experience will make me a better computer engineer in the end.”

Support from Microsoft External Research is helping the center add new software and computers to its project design labs. Students do most of their development work using the Microsoft .NET Framework and the Microsoft Office Access® database application. “We like .NET because it’s powerful but also very stable, and students can get up to speed on it quickly,” says Schindler.

Other universities are joining the movement to make their computer science courses more relevant, in terms of both appealing to students’ personal interests and addressing important problems in society. At Rice University in Houston, Texas, three professors with ties to the Center for Socially Relevant Computing have launched a course that involves developing computational tools to assess hurricane risk and design evacuation policies. Teams of students in computer science, political science and civil engineering have shared their results with the City of Houston’s Office of Emergency Management to help plan for future disasters.

Jane Margolis, a senior researcher in the Institute for Democracy, Education and Access at the University of California, Los Angeles, who is also working to make computer science education more relevant for students, says the UB center provides an important resource for educators concerned with broadening participation in computing. “Finally, there is a center that centralizes, examines, designs and further explores socially relevant computing and makes it available to the larger community,” says Margolis, who adds that she plans to adapt some of the online resources for her organization’s work with Los Angeles high school students.

Buckley hopes this groundswell of interest in socially relevant computing education will enable the center at UB to connect more students and faculty members with community organizations that have problems to solve through technology.

“Students can make the world a better place, become experts in the latest software and hardware, and have fun doing it,” says Buckley. “With all of that, why wouldn’t computer science be the best major on campus?”

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**At a Glance**

**Project:** Center for Socially Relevant Computing  
**Location:** University at Buffalo (UB), New York  
**Project Principals:**  
*Michael Buckley*, associate faculty member, Computer Science and Engineering Department, UB  
*Kris Schindler*, teaching assistant professor, Computer Science and Engineering Department, UB  
**Web Site:**  
src.cse.buffalo.edu  
**Microsoft Technologies:**  
.NET Framework, Office Access, Tablet SDK, .NET Compact Framework, Speech API
A New Way of Learning:
Researchers Explore the Allure of Computer Gaming

For every parent or teacher who has yearned for a way to get students as excited about schoolwork as they are about computer games, a group of U.S.-based researchers may soon have some encouraging new insights. The Games for Learning Institute at New York University (NYU) is seeking ways to use computer gaming to more effectively teach science, math, literacy and other academic skills.

Millions of kids love computer games and can spend hours mashing buttons in front of a screen, destroying an alien army or escaping from hordes of the undead. Educators and game designers have long sought to capitalize on the allure of gaming to teach students important academic and life skills. However, pinpointing exactly what facets of these games appeal most to kids and what types of gaming experiences motivate students to learn has been difficult.

“There are plenty of studies showing that this or that game is educational under a particular set of circumstances,” says Ken Perlin, an NYU computer science professor with a background in computer graphics and media research. “But what you can’t do in that type of study is tease out which design factors within that game are responsible for the learning that took place.”

With financial, software and advisory support from Microsoft External Research, Perlin and a dozen other researchers from seven U.S. universities have formed the Games for Learning Institute at NYU to study what makes computer games engaging and educationally effective. The research team will observe children playing a broad range of educational and recreational games and apply the resulting insights to design prototypes of games for further testing.
with students. The study results will be shared with educators, software developers and other researchers interested in developing games that target the acquisition of specific knowledge and skills.

“Computer gaming is enormously popular and successful at capturing young people’s attention, which creates great potential for games to be used as educational tools,” says Perlin, who serves as director of the Games for Learning Institute, with Jan Plass, an associate professor of educational communication and technology at NYU, serving as co-director. “We want to better understand which key gaming design elements lead to different kinds of learning, what are the essential characteristics of a ‘fun’ game and how those elements can be woven together to motivate students.”

The research team includes a broad cross-section of computing and education scholars with backgrounds in graphics, animation, cognitive science, user interface design, social behavior and related fields. Perlin, Plass and several others have previously worked together on educational technology projects such as Rapunsel, which teaches software programming skills to students by challenging them to create a game in which the animated characters show off their dance moves.

“We hope to build this institute into a hub for teachers, students, game developers, computer scientists and education researchers with an interest in conducting solid empirical research to identify design patterns that make games effective for learning,” says Plass.

Initially, the team’s research will focus on evaluating computer games as potential learning tools for science, technology, engineering and math—the so-called STEM subjects—among students in sixth through eighth grades. Many educators and business leaders are concerned that traditional STEM education methods are not adequately preparing U.S. students for the demands of the 21st-century workforce, and previous studies have shown that middle school is often the time when students become discouraged academically or lose interest in STEM subjects.

In the first phase of the study, Games for Learning Institute researchers analyzed several dozen existing educational and mass-market entertainment games to begin forming theories about what makes a game enjoyable, frustrating or confusing for players. Since early 2009, the team has also been observing and interviewing New York City public school students as they play a variety of games.

Next, the researchers plan to design and build more than a dozen mini-games that incorporate various learning objectives, game-playing experiences and design facets geared toward testing their hypotheses about effective educational gaming. Much of the team’s software design work will use the Microsoft XNA game development format, which Perlin says he favors because it is easy to use and readily integrates with code from other sources. He and others
from the institute have also met with members of the Games User Research Group at Microsoft Game Studios to learn more about their techniques for evaluating players’ experiences.

The Games for Learning team’s analytical tools will include in-game monitoring software that can log details about players’ actions, such as what paths they choose for moving through the game and how many times they attempt a certain challenge before either succeeding or giving up. This data, combined with videotaped gaming sessions, physiological data such as heart rates and pupil dilation, and player interviews, will help the researchers more precisely identify how specific game design factors influence players’ enjoyment and learning.

Perlin and Plass are cautious about trying to predict which types of gaming activities will prove to be the most significant for learning. “The answers will hinge on a variety of factors,” says Plass. “We may discover that what makes games educational yet fun will depend on the game genre, subject matter and type of learner.”

Among the attributes of computer gaming that most intrigue the research team are its ability to support students in building procedural knowledge—such as the steps involved in accomplishing a given set of tasks—and becoming more aware of how they learn. “We are very interested in observing how computer games can build meta-cognitive knowledge—those moments when kids realize that they have just picked up a new concept,” says Perlin. “That type of knowledge is important in people’s ability to learn independently.” Plass adds. “Another intriguing aspect of games is that they help students apply their new knowledge to real-life situations, which can be very difficult to achieve with traditional schooling.”

The team aims to publish initial conclusions about what makes an effective educational gaming experience sometime in 2010. They also intend to share game design recommendations as well as guidance for other researchers who are pursuing advanced work in this field. Other long-range goals include establishing an NYU Center for Advanced Technology in Games for Learning, where researchers can collaborate with commercial game designers, education specialists and other interested parties.

The team’s quest to explore the core aspects of games that motivate people to learn is appealing to Mitchel Resnick, a professor of learning research at the Massachusetts Institute of Technology (MIT) and director of the MIT Media Lab’s Lifelong Kindergarten research consortium.

“In our research on children and learning, we’ve seen that the best educational activities connect not only to important concepts but also to students’ interests and passions,” says Resnick, one of the Games for Learning Institute’s external advisers. “Ken’s group is building on that approach through exploring how computer games can engage students in activities they are passionate about and connect them with ideas they care about.”

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**At a Glance**

**Project:** Games for Learning Institute  
**Location:** New York University, New York City  
**Project Principals:**  
*Ken Perlin*, professor, Department of Computer Science, NYU  
*Jan Plass*, associate professor of educational communication and technology, Steinhardt School of Culture, Education, and Human Development, NYU  
**Web Site:**  
g4li.nyu.edu  
**Microsoft Technologies:**  
XNA, Xbox*
A SensorScope weather station in the Swiss Alps—one of 16 deployed as part of the Swiss Experiment project.
Climate change and the pressures that population growth places on our natural resources pose major challenges for society.

The widespread availability of affordable sensor devices, combined with wireless technologies and new software programs, is enabling researchers in the earth and environmental sciences to collect and analyze large volumes of information that can dramatically improve our understanding of underlying environmental processes and develop more reliable models and prediction systems.

Microsoft External Research is collaborating with researchers around the world to develop sophisticated data management and visualization tools that make it easier for scientists to understand the huge volumes of information being collected in a range of fields, such as oceanography, astronomy, hydrology, climatology and energy management.

For instance, Microsoft researchers are helping to develop tools for the FLUXNET Project, a global network of scientists who are using micrometeorological towers to measure the role that plant photosynthesis plays in removing carbon from the atmosphere.

In an international collaboration called the Swiss Experiment, scientists are using Web-based tools developed by Microsoft researchers to view huge quantities of environmental sensor data more efficiently and in richer detail than previous technologies allowed.

Computer scientists at the Lawrence Berkeley National Laboratory and Microsoft Research have teamed up with hydrologists at the University of California, Berkeley, to create “digital watersheds” that combine decades of hydrological data with more recent data from sensor networks. The team is developing software tools that enable scientists to analyze large-scale data sets in a fraction of the time it would previously have taken.

“Microsoft has enabled me to undertake hydrologic investigations with data sets that are orders of magnitude greater in size than I would have ever thought possible,” says Jim Hunt, a professor of civil and environmental engineering at UC Berkeley.

Meanwhile, Microsoft researchers are developing a new tool called SciScope, a Web-based search engine designed specifically to locate meteorological, hydrological, and water and soil quality data from numerous data repositories and retrieve it in a consistent format. Still in its beta version, SciScope already provides access to data from about 9.5 million sensors across the United States, enabling users to locate a broad range of environmental data—from precipitation, snowpack and stream flow measurements to data on solar radiation, water quality and biodiversity.

For other examples of Microsoft External Research projects, see page 50.
Making Sense of Data: Helping Scientists Understand Our Changing Environment

Environmental researchers at the Berkeley Water Center in California have teamed up with computer scientists from Microsoft and the Lawrence Berkeley National Laboratory to create powerful new databases and software collaboration tools that are helping scientists to understand our changing environment and develop more reliable models for resource management.

Our planet’s climate is changing fast—and environmental scientists are working hard to keep up. Just ask James Hunt, who has been studying hydrologic systems in California for three decades.

Hunt, a professor of civil and environmental engineering at the University of California, Berkeley, says the historical approach to hydrology relied on a key assumption: “that the future will look like the past.” In other words, scientists could look to data from past observations to understand and predict ongoing or future environmental conditions.

“But climate change questions are forcing us to throw away those assumptions,” says Hunt, who also serves as co-director of the Berkeley Water Center, “and we don’t know yet what we’re going to use to replace them.”

As with other environmental science domains, hydrology is being transformed by both a changing environment and advances in technology. Amid global climate change and the pressure that population growth is placing on water and other natural resources, scientists today face greater challenges in creating reliable models to help guide future development and resource use. And, like their colleagues in other scientific disciplines, hydrologists are struggling to make sense of rapidly growing volumes of data from historical sources as well as from a proliferation of new environmental sensor technologies.

To help meet these challenges, Hunt has teamed up with computer scientists at Microsoft Research and the Lawrence Berkeley National Laboratory (Berkeley Lab) to establish the Berkeley Water Center Scientific Data Server, an interdisciplinary project focused on creating advanced database and research collaboration tools.

Catharine van Ingen, a software architect with Microsoft’s eScience group, says the key to the collaboration is figuring out how to enable environmental and computer scientists to communicate across disciplines. Van Ingen, who started her career in the 1970s as a civil engineer before switching to computer science, has an ideal background for her role as the bridge between Hunt’s work and that of Deborah Agarwal, head of the Advanced Computing for Science Department at Berkeley Lab.

Agarwal says the goal of the data server project is to provide “game-changing tools” that enable environmental scientists to easily browse large volumes of data without having to understand the underlying computer science. Agarwal and van Ingen and their team are using Microsoft SQL Server Analysis Services to build
“data cubes” that Hunt and other environmental scientists are using to analyze large-scale data sets in a fraction of the time it would previously have taken.

Also known as an OLAP (online analytical processing) cube, a data cube is a database structure that organizes data in multiple “dimensions” such as time, location and scientific variable. This multidimensional structure allows for significantly faster and simpler data access and analysis. First developed for businesses as a way to track sales trends and correlations, data cube technology is proving to be indispensable for scientific research.

Many areas of environmental science have historical data going back many years. The U.S. Geological Survey, for instance, has been gathering hydrologic and other data since the late 1890s. This wealth of historical measurements and the deluge of new data offer enormous opportunities for environmental scientists. But, says Agarwal, “Your science is going to leave you behind if you don’t figure out how to use these opportunities.”

Hunt, who accesses data cubes remotely over the Internet through the familiar Microsoft Office Excel® interface, is combining decades’ worth of historical hydrologic data with information that pours in continuously from remote gauges and sensors. Hunt believes this “digital watershed” approach will help hydrologists develop the “smarter models” they will need to keep pace with societal and environmental changes.

As an initial demonstration, Hunt has been using the new database tools to study environmental factors affecting threatened salmon species on California’s Russian River. Hunt says the Russian River is an ideal place to start because its relatively simple watershed faces many of the same pressures that affect watersheds elsewhere in California, such as spreading suburban development and the conversion of range land to vineyards.

Working in tandem with local, state and federal agencies, Hunt’s team has compiled some 60 years’ worth of data on factors that affect salmon migration and spawning, such as water flow and
temperature, sediment levels and ocean access. The information will help researchers, resource managers and citizen groups involved in land-use issues within the watershed.

Hunt says the new database tools are a vast improvement over the “brute force” methods he used throughout most of his career—essentially compiling and sorting data by hand. In one test of a simple watershed model, it took him more than a day to do the calculations to analyze data for just one gauge in one drainage area. “It was so painful,” Hunt says. “I just decided I wasn’t going to look at any more drainage basins.”

Now, however, Hunt can do similar calculations for an entire watershed in minutes or hours. Agarwal says perhaps the greatest benefit of data cubes and other computational tools is that they allow scientists to easily answer more narrowly focused questions that might depend on analysis of vast amounts of data, and those answers can help solve bigger scientific puzzles. In the past, Agarwal says, scientists often wouldn’t pursue such questions if they didn’t think the possible answer was worth the weeks or months of data analysis work it would require.

The Berkeley data server project is now pulling in hydrologic and meteorological data from throughout California, so Hunt and other researchers can compare and test findings across different watersheds and further benefit resource managers.

Meanwhile, the project is supporting other environmental science research efforts. For example, van Ingen is working with the San Diego Supercomputer Center to build digital watersheds as part of the Consortium of Universities for the Advancement of Hydrologic Science, Inc., an organization that includes more than 100 universities throughout the United States.

Agarwal and van Ingen are also providing database and research collaboration support for the FLUXNET Project, a global network of regional groups that are using micrometeorological towers to measure the role that plant photosynthesis plays in removing carbon from the atmosphere.

Working with the University of Virginia and a variety of other partners, van Ingen and Agarwal helped create fluxdata.org, a Web site that uses Microsoft SharePoint Server technology to help researchers gather and analyze more than 960 site-years of data from about 250 tower sites worldwide.

Hunt says collaborations with computer scientists will continue to open vast new research opportunities for environmental scientists. “They are getting rid of all the hurdles that were preventing us from accessing all of these big data sets,” Hunt says.

Likewise, Agarwal and van Ingen say they thrive on the opportunity to use their computer science expertise to assist scientists in solving pressing environmental problems. “It’s what gets me up in the morning—knowing that I’m actually changing the way environmental science is done,” says van Ingen.

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**At a Glance**

**Project:** Berkeley Water Center Scientific Data Server  
**Location:** University of California, Berkeley  
**Project Principals:**  
*James Hunt*, co-director, Berkeley Water Center; professor of civil and environmental engineering, UC Berkeley  
*Dennis Baldocchi*, professor of environmental science, UC Berkeley  
*Deborah Agarwal*, head of the Advanced Computing for Science Department, Lawrence Berkeley National Laboratory  
**Web Sites:**  
bw.c.berkeley.edu/DataServerdefault.htm  
bwc.berkeley.edu  
www.fluxdata.org  
**Microsoft Technologies:**  
The Swiss Experiment: Powerful Software Improves Environmental Forecasting

Environmental scientists face many challenges in monitoring and understanding our planet’s changing climate. Through an international collaboration called the Swiss Experiment, environmental scientists and computer science experts are deploying advanced sensor networks and data management tools to improve environmental monitoring and forecasting.

Mountains are the world’s water towers, capturing and storing moisture from the atmosphere. They spawn the rivers that nourish remote lowland ecosystems and supply water for our homes, as well as for irrigation, industry and hydroelectric power. By some estimates, more than half of the world’s population relies on fresh water that flows from mountains. And a large portion of the world’s people reside in mountain regions—their lives and livelihoods entwined with fragile alpine environments.

But there is growing evidence that the effects of global climate change are most pronounced at high altitudes. In many mountain regions, glaciers are receding and snowpack and permafrost patterns are shifting. Spurred by questions and concerns over these accelerating changes, scientists are turning more attention to the mountains.

One effort in this area is a project called the Swiss Experiment, a collaboration of environmental scientists and computer science experts from around the world. By combining powerful new data-gathering, sharing and visualization software with sophisticated remote sensor networks deployed in the Swiss Alps, the project could dramatically improve our ability to monitor and understand

Researchers make adjustments to a SensorScope weather station located on a debris-covered glacier on Le Génépi, a mountain in the Swiss Alps. The station was one of 16 deployed on the mountain as part of the Swiss Experiment project.
environmental conditions in the mountains as well as other geologic regions.

Launched in 2007 by the Swiss-based Competence Center for Environment and Sustainability (CCES) and the Swiss National Center of Competence in Research in Mobile Information and Communication Systems (MICS), the Swiss Experiment is supported by several leading research institutions and other organizations. Microsoft External Research is playing a key role, providing financial support and Web-based software tools that enable the scientists to quickly browse huge amounts of environmental data and visually explore the information in spatial and temporal contexts, such as through a 3-D mapping interface and over time.

Besides providing more insight into the local effects of climate change, the project could also enhance scientists’ ability to predict dangerous weather-related events such as floods, avalanches and mudslides. Another goal is to provide new tools for environmental educators and valuable information sources for policy makers, resource managers and the public.

“There is not a very good understanding of weather processes at the regional scale,” says Karl Aberer, a computer science professor at the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland and one of the lead researchers on the project. “That’s because they simply are lacking good models—and they are lacking models because they don’t have the data.”

Until recently, the technology available for many types of environmental monitoring had significant limitations. For instance, researchers studying alpine conditions typically had to rely on a small number of bulky and expensive measurement stations that could not be remotely controlled or monitored.

But recent advances in sensors and wireless technology are opening vast new research opportunities. With more powerful and affordable sensors, scientists today are able to gather environmental data on a scale hardly imaginable a decade ago.

Several of these new monitoring tools are being demonstrated in the Swiss Experiment by research teams from a broad range of disciplines, including hydrologists, climatologists, soil scientists, seismologists and avalanche experts.

“Swiss Experiment means not only faster and more efficient data access and data exploitation, it also means more data at a cheaper price,” says Michael Lehning, head of the snow and permafrost study unit at WSL, the Swiss Federal Institute for Forest, Snow and Landscape Research in Davos, Switzerland. “With the new sensor systems being developed, we can afford to have a higher density of measurement stations, which is of particular value in the very heterogeneous mountain environment.”

One particularly promising new sensor platform is EPFL’s SensorScope, a multi-purpose weather station that continuously measures conditions such as air temperature, precipitation, wind speed and direction, solar radiation and soil moisture. The stations, which cost many times less than traditional stations at about US$3,000 apiece, are solar-powered and equipped with wireless communications devices.

In 2007, researchers used helicopters to place 16 SensorScope stations on a debris-covered glacier on Le Génépi, a mountain in the Alps, to measure atmospheric conditions over a four-month period. Seven other, more conventional stations were deployed to create a permanent observatory at a site called Wannengrat.
about 2,400 meters (nearly 8,000 feet) above the city of Davos. The Wannengrat deployment, which was temporarily augmented by several SensorScope stations, is taking second-by-second measurements of snow levels and other weather conditions.

Swiss Experiment teams are using a variety of other sensor networks. For example, a project called PermaSense is gathering data from an array of tiny permafrost sensors mounted on the face of the Matterhorn.

While these sensor technologies are generating vast new volumes of research data, the flow of information also poses major computational challenges. Microsoft researchers have teamed up with other computer scientists at the Swiss Experiment to create a software platform that enables scientists to manage and make sense of the huge quantity of data. Two Microsoft technologies—SenseWeb and SensorMap—are key components of that platform.

In simplified terms, the platform gives scientists a dashboard of meters that show what's happening in the mountains.

SensorMap is a powerful Web-based tool that enables scientists to view large quantities of data more efficiently and in rich detail. For example, scientists can view data in real time, enabling them to make adjustments in their experiment or to spot anomalies that might indicate a malfunction with a particular sensor.

SensorMap also enables scientists to view data from a geospatial perspective. For instance, during the experiment at Le Génépi, the scientists could use measurements from the 16 SensorScope stations to produce a 3-D topography map showing temperature gradients over the entire terrain of the study site, plotted over a certain time period in an animation. This sort of capability makes it easier for researchers to spot interesting or significant trends and features in the data.

SensorMap's supporting infrastructure, SenseWeb, simplifies a lot of data management tasks for scientists such as cleaning up erroneous data, archiving and sharing massive data streams, and indexing them for efficient querying.

Another key benefit of the Swiss Experiment platform is that it enables scientists across disciplines to more easily share and reuse data and collaborate on research projects. And, the researchers say, the project is creating a universal platform that could be adapted for studying any sort of ecosystem or landscape—from deserts and rain forests to farms and urban settings.

“Instead of every person having to design and implement their own data infrastructure, which basically means reinventing the wheel over and over again, we now can benefit from a generic solution for many common data acquisition and analysis problems,” Lehning says.

Aberer envisions a day when virtually the entire planet will be monitored by increasingly elaborate sensor networks. “I think we’re just scratching the surface with this project,” he says. “There are big changes ahead.”

At a Glance

**Project:** The Swiss Experiment  
**Location:** Lausanne and Davos, Switzerland  
**Project Principals:**  
Marc Parlange, professor of environmental fluid mechanics and hydrology, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland  
Karl Aberer, professor of computer science, EPFL  
Martin Vetterli, professor of computer science, EPFL  
Michael Lehning, WSL Institute for Snow and Avalanche Research, SLF Davos

**Web Site:**  
www.swiss-experiment.ch

**Microsoft Technologies:**  
SenseWeb, SensorMap, SQL Server 2008, Virtual Earth™, Microsoft Research Networked Embedded Sensing Toolkit
Environmental Search: SciScope Speeds Data Retrieval from Multiple Repositories

For environmental scientists and engineers, finding and retrieving relevant data can be a daunting and tedious task. Microsoft Research is developing an online search engine called SciScope that enables researchers to search multiple data repositories simultaneously and retrieve information in a consistent format.

Brian Gallagher says one of his greatest challenges as an environmental scientist is figuring out how to make sense of the massive volumes of environmental data pouring in from a wide range of sources.

“We can’t really solve environmental problems or do natural resource development properly without good data—and, frankly, it’s hard to find,” says Gallagher, who runs a private environmental consulting company in Los Angeles and has been working in the field for nearly four decades.

Environmental scientists and engineers are awash in information. The Internet is a fast-growing resource for historical data, and vast new volumes of information are coming in from satellites and inexpensive sensing devices deployed directly in environmental settings.

While this mountain of data is opening new possibilities for scientific discovery, the breadth of information sources poses challenges for scientists and engineers. For instance, a scientist trying to assemble a data set for a particular research project typically has to go through multiple agencies to find relevant data. And that data has often been compiled in widely varying formats or uses different naming conventions, languages and timeframes.

A sample view of a SciScope search. Using a variety of search features, users can query data from multiple repositories and then retrieve the information in a consistent format.
To help make this task less burdensome, Microsoft External Research is developing SciScope, a Web-based search engine designed specifically to locate meteorological, hydrological, and water and soil quality data from numerous data repositories and retrieve it in a consistent format.

“As scientists, we probably spend 75 percent of our time looking for data,” Gallagher says. “SciScope will help us find data faster, or at least let us know when the data just isn’t there.”

SciScope melds two existing Microsoft technologies—Virtual Earth, a geospatial mapping platform, and SQL Server 2008, a database management program—into a single interactive interface.

Still in its beta version, SciScope already provides access to data from about 9.5 million sensors across the United States—in all, more than 358 million observational results. In essence, SciScope is a unified portal to the databases of the U.S. Geological Survey, Environmental Protection Agency (EPA) and National Climatic Data Center. Data from smaller regional agencies and individual researchers is also being added.

SciScope enhances Virtual Earth’s imagery with additional map layers that enable users to view features such as aquifers, watersheds and geology. SciScope users typically begin a data search by identifying a geographical area—either by selecting a particular geographical feature or by using a drawing tool to define the area—and setting a timeframe. They can then enter keywords for the specific type of data they are seeking. Once SciScope identifies relevant data sources, users can further refine their search and then download data directly using the interface. The data is provided in a Microsoft Office Excel format that includes contact information for the original sources.

Beran, who earned a Ph.D. in hydroinformatics before joining Microsoft External Research in 2007, believes SciScope will become an important tool for scientists and engineers.

To illustrate how SciScope could make the data search process more efficient, Beran paints a hypothetical scenario of a scientist studying eutrophication—the over-enrichment of water bodies—in North Carolina’s Neuse River Basin.

Without SciScope, Beran says, scientists would have to locate potential data sources and then identify all of the relevant observation locations for the Neuse River area—a painstaking process in itself. They would then have to separately search for data for the various indicators, such as nitrogen, phosphorus, turbidity and algae concentrations. And since the data would likely come from
“As SciScope is developed, I expect that it will become an indispensable tool for scientists and will facilitate many important discoveries about the interconnections between the earth’s landscape, atmosphere, oceans and ecosystems.”

—Ben Ruddell, assistant professor of engineering, Arizona State University

multiple agencies, they would have to reconcile differences in formats and data language before beginning an analysis.

With SciScope, scientists can simply select the Neuse River Basin by clicking on that area of the map, type “eutrophication” in the search window, set a timeframe and then start the search. SciScope translates this into a query for 59 parameters from four separate data repositories. Once the results are displayed on the map, users can select the data sites they want to add to SciScope’s Data Cart for retrieval.

SciScope, which Beran has been demonstrating at science meetings around the United States, is a work in progress. “We will be adding new features all the time, so SciScope will probably remain in beta version for quite some time,” he says. An upcoming version will enable users to sign up to receive new data at specified intervals or be notified automatically when new relevant sensors come online.

SciScope could eventually have applications beyond science, Beran says. For instance, river kayakers could use it to check water levels in a particular river. Or someone looking to purchase property could use SciScope to find all sorts of information about the local environment.

Beran has developed a prototype mobile phone SciScope application that allows users to locate nearby sensors using the phone’s built-in GPS or by entering an address and then check environmental quality conditions in the area. Instead of giving a specific measurement value that would require a certain amount of expertise to understand, the mobile version returns a message simply indicating whether the measurement meets EPA’s ambient environmental quality criteria.

Beran believes that, if successfully applied, Web 2.0 principles—collaboration and interactivity using the Internet as a platform—could enable SciScope to bring together unprecedented amounts of observational data. “There’s a lot of data out there collected by individual researchers, small groups and universities that often is not available on the Internet,” he says. SciScope could serve as a publishing platform for such data.

“Besides making data more widely available, data sharing through SciScope has the potential to lead to all sorts of new research collaborations,” Beran says.

Ben Ruddell, an assistant professor of engineering in the College of Technology and Innovation at Arizona State University, says he is excited to see a major software company investing in an informatics tool geared specifically to earth and environmental scientists.

“As SciScope is developed, I expect that it will become an indispensable tool for scientists and will facilitate many important discoveries about the interconnections between the earth’s landscape, atmosphere, oceans and ecosystems,” Ruddell says.

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At a Glance

**Project:** SciScope

**Location:** Microsoft Research, Redmond, Washington

**Project Principal:** Bora Beran, Microsoft Research

**Web Site:**

www.sciscope.org

**Microsoft Technologies:**

Virtual Earth, SQL Server 2008, Office Excel
Global Reach
Examples of Other Microsoft External Research Projects

Our Health
Cancer Image Analysis, University of Oxford: Advancing medical imaging technology to enable earlier and more effective cancer detection.
Cancer Research Repository, University of Virginia: Massive information network that enables cancer researchers to share data more easily and thus speeds the pace of discovery and helps with new drug development.
Connectome Project, Center for Brain Science, Harvard University: Using advanced data visualization and analysis tools to gain a better understanding of how the brain is “wired.”
USB-based ultrasound, Washington University in St. Louis: Developing ultrasound probes that can run on smartphones.
BioHPC, Cornell University: Bringing the power of high-performance computing to thousands of researchers worldwide.
rCAD, University of Texas, Austin: Data management and analysis tools to help scientists better understand RNA structure and function.
Picture-based communication for autistic children, Claremont Graduate University and Old Dominion University: Software that allows children with autism to easily create picture-based messages on a mobile device.
Pontificia Universidad Católica de Chile and the Instituto Politécnico Nacional, Mexico: Using computer-vision technology to improve quality control in the food industry.
Indian Institute of Science, Molecular Biophysics Unit: From Genomics to Function project uses computers to gain a better understanding of how organisms’ genes relate to their function and role in the lives of humans.

Our Planet
GrayWulf, The Johns Hopkins University: Combining inexpensive computer hardware with powerful computing and database software to help manage growing volumes of scientific data.
SciScope, Microsoft Research: Interactive online tool that helps environmental scientists quickly search and retrieve data from multiple repositories.
Health-e-Waterways, University of Queensland: Data management tools that enable the streamlined generation of online interactive “environmental report cards.”
Climateprediction.net, University of Washington: Creating high-resolution regional climate models.
Life Under Your Feet, The Johns Hopkins University: Using wireless sensor networks to better understand underground ecosystems.
Climate Induced Vegetation Change Analysis Tool, Space Research Institute (IKI) and Geophysical Center (GC) of the Russian Academy of Sciences (RAS): Merging large archives of satellite images with historical data on vegetation and climate for the territory of North Eurasia.

Our Knowledge
Institute for Personal Robotics in Education, Georgia Institute of Technology and Bryn Mawr College: Using personal robots to teach students the basics of computer programming.
Wi-Fi enabled phones for the classroom, Pontificia Universidad Católica de Chile: Exploring the use of mobile phones and low-cost portable devices to encourage collaborative learning.
Mobile and Immersive Learning for Literacy in Emerging Economies, University of California, Berkeley: Using e-learning games and smartphones to create engaging, affordable language education tools.

Classroom Presenter, University of Washington: Digital ink tools and applications for Tablet PCs that empower teachers to give dynamic presentations and enable interactive learning for students.
Pen-Centric Computing, Brown University: Providing students, teachers and professionals with fluid integration of handwritten symbols in areas such as mathematics, chemistry, design and music.
Semantic Computing, 21 universities: Developing Internet technologies that improve how information is discovered and shared.
Nanyang Technological University, Singapore: Development of a digital data format and a new method of securing digital ink data to help prevent tampering in documents.
Institute of Software, Chinese Academy of Sciences: GeoAssistor, a pen-based geometry learning tool for students.

For more information, go to research.microsoft.com/collaboration