Conference tries to define computing-research agenda

Galen Gruman, Soft News Editor

With the goal of agreeing on an agenda for computer research that would represent the computing community's interests to US policy makers, about 170 people attended the Strategic Directions in Computing Research Conference Oct. 11-13 in Arlington, Va. The Association for Computing Machinery and the Computing Research Board cosponsored the conference. (The CRB is a group of 25 computer scientists, most of whom head computing departments or research labs.)

The participants agreed to endorse the proposed high-speed research network proposed by the White House Office of Science and Technology Policy ("Lawmakers Focus on High-Performance Computing," Soft News, *IEEE Software*, November, p. 81). They made no recommendations on other funding, education, or research directions, although the panelists will reconvene in February at the American Association for the Advancement of Science's annual meeting to work on such recommendations.

Although the panels largely focused on research subdisciplines, several overarching concerns seemed to emerge during panel presentations, question-and-answer sessions, and hallway conversations:

- Funding. Concerns included the balance of federal money spent for mission-oriented research versus basic research, the perception that computer science is underfunded compared to other sciences, and the field's dependence on a small set of federal agencies for funds.
- Education. The main concerns were the increasing evidence that the US precollege educational system is failing to prepare students for college computer-science study and the outmoded facilities most computer-science departments have for teaching students.
- Profession's role. Participants seemed split on whether the profession was becoming perceived to be merely a support service for other sciences. Several people expressed concern that other sciences' moves to establish computational subdisciplines might threaten computer science's ability to compete for the students and funding needed to build the foundations on which the other sciences' computation should be based. Others argued that the problem was merely that computer science's importance was not well communicated to the public.

The conference's six panels covered high-performance architectures, algorithms and theory, artificial intelligence, systems and software, neural networks, and computer-based collaboration.

Concerns included the balance of basic and mission-oriented research, perceived underfunding, and reliance on only a few federal agencies.

Funding. "We're way behind the times in presenting our discipline to the public and other scientists," said David Gries of Cornell University. "If we don't do something, we're going to have trouble finding funding," he said.

Although the government's increasing concern about computing has resulted in more funds for the National Science Foundation and for efforts like the national supercomputer centers, "the pace of technology is so [fast] that we can't afford to keep all [the centers] at the state of the art," said Rep. Bill Green of New York in his keynote address. Green is the top-ranked Republican on the House Appropriations subcommittee that oversees funds for the National Aeronautics and Space Administration, the NSF, and other independent agencies. He suggested that researchers look to the states for funds, citing the success of the state-funded supercomputer center at Ohio State University.

"I'm optimistic that we're making strides within NSF in an era of dwindling resources. Research funds have improved," Green said. But "we are going to be working in a constrained budget for the foreseeable future," he warned, "You have to define what your priorities are."

The conference panels did not recommend priorities for specific areas of research. "The real problem for the science community is to increase the total pie" — not to fight over the existing resources, said William Wulf, director of the NSF's computing directorate. In the US, 2.8 percent of the gross national product is spent on research and development, compared to about 1 percent each in Japan and West Germany, he said. However, those nations' R&D budgets are increasing while US spending rates have remained static, he said. About half the US R&D spending is defense-related, several speakers said.

Education. Problems with the educational system was a frequent topic. For example, participants argued over the implications of news reports showing that high-school students interested in pursuing computer-science careers had low Scholastic Aptitude Test scores.

Several reports in recent years have warned that US students are less educated in math and science than either foreign students or earlier generations of US students.

"We need to find and retain top talent wherever it comes from — [we need to] retain foreign students and get more US ones," said Joseph Traub of Columbia University. The increase in research and education spending in Asia and Europe is translating to "a loss of foreign students needed here — the half of our good students who come from abroad that we're dependent on," he said.

"I am concerned about the lack of software labs in computer-science departments," said Susan Gerhart of the MCC Software Technology Program. She recommended that a software lab have a robust database system, several language-based tool sets including analyzers and verifiers, low-end and high-end CASE systems, code libraries, and videotaped training courses. Such material — including technical support and licenses — would cost about $200,000 a year, she estimated, but the cost could be defrayed with educational licenses and funding from programs like the NSF's software-capitalization program.

Profession's role. "If we want to set the agenda, we need to get scientists from the various [computer-science] disciplines talking to each other," said Paul Young of the University of Washington and president of the CRB.

At the opening session, panelists and audience members focused on how to raise computer science's profile. Several audience members complained that the field was little understood and unappreciated. Computer scientists must make the public see the field as an "enabling technology for all sciences and engineering," Gries said.

"There is a lack of respect from other disciplines [because] the community has not made itself available or visible to other disciplines," said Peter Denning of NASA's Research Institute for Advanced Computer Science. This has resulted in the desire of other disciplines to set up computational-science branches — "even though that is covered by scientific computing in computer science," he said.

The professional reward structure — having papers published in journals or presented at conferences — limits the field's visibility, Denning argued. "There are *New York Times* best-sellers from mathematicians, physicists, and biologists. Why not computer science?" he said. "Other disciplines seem to value having some of their scholars getting their books out into the public domain. Knowledge is not worth very much if no one else understands it," he said.

Conference focus questioned. Despite the conference's stated focus on setting an agenda, several panelists reported recent results in their fields. At the artificial-intelligence session, for example, one member of the audience remarked to the panel that the conference focus was to have been on setting agendas, not reporting results.

In an impromptu session organized because of such complaints, Barbara Simons of IBM San Jose (Calif.) chided the conference organizers for straying from the conference's stated focus and listed several areas she thought the panels ignored: the lack of women and minorities in computer-science schools and researchers' dependence on Defense Dept. funding.

Simons recommended that the federal government directly fund graduate students to encourage students to enter the profession (something it used to do), that it pay faculty 12-month salaries so they could concentrate on teaching and research rather than on commercial side projects, and that researchers look to agencies other than the Defense Dept. for funds, both to be less reliant on a single funding source and to apply their skills to areas like transportation, aid to the handicapped, and the environment.

The six panel sessions identified several potential research-agenda items.

Systems and software. Understanding systems and software is like the three blind men trying to identify the elephant — each feels only a seemingly unconnected part of the whole — said Victor Basili of the University of Maryland at College Park. "Environments, objects, metrics, operating systems, formal methods — they all add up to software," he said.

"One of our problems is to model things so they are tractable enough so they can be analyzed," Basili said, citing correctness, reliability, portability, maintainability, performance, and user-friendliness as tough-to-model characteristics.

In a February workshop described for the panel by Mary Shaw of Carnegie Mellon University, the National Research Council's Computer Science and Technology Board found three dominant needs:

- better understanding of software systems and methods, particularly recognizing that change is intrinsic and should be treated that way,
- increased use of engineering practices like collaboration and the use of codified knowledge and practice, and
- better understanding of the interaction among modes of research, particularly between building and theorizing, which requires studying large, real systems.

Software's grand challenge, said MCC's Gerhart, is to "develop techniques that allow analysis of a critical system — its reliability, safety, and correctness. We need to develop a theory of

Computing-agenda reports

Several organizations have released reports in the last year meant to help set research and policy agendas for computing. They include:

- "Strategic Directions in Computing Research," a conference report available from the Association for Computing Machinery, New York, 1989.
- "Bugs in the Software," a report by the US House of Representatives' Science, Space, and Technology Committee's Subcommittee on Investigations and Oversight, US Government Printing Office (stock 052-070-06604-1), 1989.
- "A Field in Transition: Current Trends and Issues in Academic Computer Science," a 1989 report for the ACM Special Interest Group on Automata and Computability Theory, by Joel Yudken and Barbara Simons, PO Box 9896, Stanford, CA 94309; (415) 321-6178. (This report caused some controversy at the Strategic Directions in Computing Conference. Although the federal data it is based on is not in question, William Wulf of the National Science Foundation questioned how funds were ascribed to specific research areas. Several research areas receive funds from more than one NSF program, making it difficult to count total funding by reasearch area, he conceded. Furthermore, some years cited are anomalous, Wulf said, because of special appropriations like a one-time increase in 1990 for supercomputer-center upgrades and because of effects of the budget-deficit ceiling law in 1986. The issue is complicated by the 1987 NSF reorganization that changed funding categories for computing research. However, a careful reading of the report does provide insight into overall federal funding patterns for computing research.)
- "Scaling Up: A Research Agenda for Software Engineering" by the National Research Council's Computer Science and Technology Board, National Academy Press, 1989.
- "The National Challenge in Computer Science and Technology" by the National Research Council's Computer Science and Technology Board, National Academy Press, 1988.
- "Towards a National Collaboratory," a workshop report available from William Wulf of the National Science Foundation's Computer and Information Science and Engineering Directorate, 1989.

Unless noted, all organizations listed are based in Washington, D.C.

changes to understand the range of effects of changes."

Furthermore, "building large systems is a multidisciplinary area. It requires expertise across several areas — and trade-offs among the qualities [like reliability and performance] becomes a key problem," Gerhart said. She recommended cross-disciplinary programs in college, with "at least two disciplines."

Software science has moved from tool-centered to data-centered to process-centered, said Lee Osterweil of the University of California at Irvine. This movement to a higher abstraction level holds the promise of "reusable, superior processes and process formalisms that are more widely applicable," he said. "Software engineering is in the unique position to put formalism in processes — [which would be] a benefit to all science and engineering," he said.

Algorithms and theory. "The grand challenge to computer-science theory is to understand what is and is not feasibly computable," said Juris Hartmanis of Cornell University during the theory panel. Theoreticians should try to resolve the "Does P equal NP?" problem, which seeks to determine if the solution times for problems with nondeterministic polynomial complexity match those with deterministic polynomial complexity, Hartmanis said. All nondeterministic polynomial problems can be solved by deterministic programs, but not necessarily in polynomial time.

Determining the separations between such major classes of complexity will help computer scientists "understand the trade-offs between computational models and [the application's] constraint bounds," Hartmanis said. "These are the fundamental problems about quantitative relations between deterministic, nondeterministic, sequential, parallel, and probabilistic resource-bounded computations," he wrote in a conference position paper, "Our challenge is to develop the tools to attack and solve these problems."

Theoretical research since the mid-1970s in new areas — like cryptography, computational geometry, distributed and parallel computation, and probabilistic analysis — has had practical benefits, said Richard Karp of the University of California at Berkeley. These benefits include enriched programming tool kits (he cited fast Fourier transforms), intellectual breakthroughs with long-term usefulness to tackling fundamental challenges, and contributions to specific application areas, Karp said. However, application-domain contributions "is where computer science falls down," he said, "We train narrowly, and [to change this] computer scientists today must roll up their sleeves and investigate these areas."

Among the challenges Karp described for the 1990s were robotics, computational statistics, understanding heuristic algorithms, and influencing computer architectures. "Our models of computation are so featureless compared to real architectures," he said, arguing that under current models a RISC-based machine is equivalent to a Cray supercomputer.

"The goal of programming theory is to produce understandable software systems, which lead to maintainable, reliable, and portable software," said Albert Meyer of the Massachusetts Institute of Technology, "You can't have confidence in what you've done if you don't have a grip on confidence of its abstractions."

Meyer decried the "very little work on errors and debugging." Theoreticians have "a handle on correctness but we haven't really made a start on defining what 'wrongness' is," he said.

To encourage theoretical research, the NSF plans to spend $6.4 million on it, said Richard DeMillo, director of the NSF's Computer and Computational Research Division. Two Defense Dept. agencies, the Advance Research Projects Agency and Office of Naval Research, also support theoretical research, he said. The NSF will change its funding patterns for theory, reversing recent reductions in grant size that had been made to fund more projects, DeMillo said, although this will mean funding for fewer projects. To help offset this, the NSF will increase its cooperation with other federal agencies, he said.

High-performance initiative. "High-performance computing brings the possibility of building bridges between computer science and engineering and our customers," said Jim Browne of the University of Texas at Austin. For this initiative to succeed, he said, computer scientists "need to scale software and theory/algorithm research to architecture and applications," he said.

Despite "broad" federal-agency support and President George Bush's endorsement, "the funds remain problematic," said the University of Washington's Young.

The initiative is "very crucial," congressman Green said, especially because it might help the government process the huge amounts of scientific data it receives. For example, NASA's Earth-monitoring project will generate 10 Gbytes of data a day, he said. "It's important not only to produce the raw data but to process it, and we need to get the data circulated among the community," he said.

But "I'm worried that the high-performance-computing initiative will not cover foundational research. It sounds very mission-oriented," said Arnold Rosenberg of the University of Massachusetts.

Collaboration technology. High-resolution workstations, high-bandwidth networks, and multimedia technology can make possible research "collaboratories" composed of researchers at separate sites working together in real time and on the same applications, said the NSF's Wulf. Unlike video conferencing, a collaboratory would give all participants tools to view and manipulate common data, both globally and locally, he said.

It would also increase access to colleagues, let researchers remotely operate instrumentation their institutions do not have or cannot afford, and aid interdisciplinary efforts like the study of global climate change, he said. Other benefits include reducing the effects of the predicted shortfall of 675,000 engineers and scientists predicted for the early 21st century by increasing productivity and promoting technology transfer, he said.

However, "collaboration will benefit and appeal to a subset of the research community. Only a small subset may know how to take advantage of it at the start," cautioned Robert Kahn of the Corp. for National Research Initiatives. "The motivation for collaboration must be present a priori," he said. Furthermore, "not all collaboration requires the use of the most advanced technology," he said, citing fax as a current example and faxes for floppy disks as a potential example.

"If [the collaboratory concept] is accepted by scientists, it will come to change [research's] very character," said Lee Sproull, a social scientist at Carnegie Mellon University. "A collaboratory means that lower status but perhaps equally competent people will communicate more equally than in face-to-face meetings," she said, citing this trend in electronic-mail communication. Sproull warned that "participation is not enough. You also want coordination over the long term" for collaboratories to succeed.

AI and neural networks. At both the artificial-intelligence and neural-network panels, the emphasis was on determining the fields' scope, not setting a research agenda. For example, the NSF's Yi-Tzuu Chien said an "emerging force" in AI is measuring its research progress as a science, which would help define its scope and increase its credibility as a discipline. In neural networks, "there are many models but very few detailed fundamental studies," said the NSF's Barbara Yoon.