COMPUTING RESEARCH NEWS

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Membership of Congress changes significantly

By Fred W. Weingarten
CRA Staff

Although incumbents fared better in the November elections than was expected, the membership of Congress has changed significantly. Congress has 118 new members, and some key members were defeated or retired, so there will be quite a bit of change in the membership of committees and subcommittees concerned with research.

House of Representatives

Rep. George Brown (D-CA), chair of the House Committee on Science, Space and Technology, who narrowly won a race many expected him to lose, most likely will continue to chair the science committee. For many years he has been considered one of the most knowledgeable members of the House on science policy. His calls for priority setting, increased accountability and demonstrated social benefit from research investments have alarmed some members of the basic research community. However, the community considers him a strong congressional supporter of science and his warnings an attempt to improve science policy. Brown also has led, with mixed success, the fight against "pork" in science appropriations.

Rep. Rick Boucher (D-VA), chair of the House Science, Space and Technology Subcommittee on Science also was re-elected. He has proven to be an effective and well-informed chair, but given the turnover in the House and his rising political star, he may not remain active in R&D policy. Boucher also served on the Energy and Commerce Subcommittee on Telecommunications and Finance, where he expressed a great deal of interest in stimulating the creation of a broadband, digital national information infrastructure. This interest has been reflected in his ongoing scrutiny of the National Science Foundation's management of the National Research and Education Network (NREN).

Actions taken this year by Boucher's subcommittee will be particularly critical for the computing research community. The subcommittee will consider NSF's reauthorization, a process that will help define the agency's mission and organization for the next several years. The subcommittee will continue its oversight of the High-Performance Computing and Communications Act and conduct hearings on the future of US R&D policy, as a follow up to the full committee's Task Force Report on the Health of the US Research Enterprise released last year [November *CRN,* Page 1].

The House science committee often has a heavy turnover in members because it is not viewed as a "major" committee. This year, with all the attention on high-technology, the committee possibly will attract more members. But it will never have the attraction or political power of the Energy and Commerce Committee, the Ways and Means Committee or the Appropriations Committee, which also will have openings. Unless they have specific interests and expertise in science and technology, members with seniority and influence tend to gravitate toward those major committees, particularly if they have an opportunity to chair a subcommittee.

Rep. Bob Traxler (D-MI), chair of House Appropriations VA, HUD and Independent Agencies Subcommittee, retired this year and Rep. Bill Green (R-NY), the ranking minority member of that subcommittee, lost his seat. Although that subcommittee made large cuts in NSF's budget request, Traxler and Green were considered to be understanding friends of research. Rep. Louis Stokes (D-OH) is next in seniority for chair of that subcommittee. His attitude toward science and technology is not well-known.

Senate

The Senate is stable because there was less turn-over and science is under the Commerce Committee, which is a plum. Vice President-elect Al Gore will be replaced as chair of the science subcommittee. Sen. Jay Rockefeller (D-WV) is the next-ranking member on the subcommittee and reportedly is ready to take over as chair. His interests are described as "more technology than science," but he is seen as open-minded and informed. Rockefeller was a strong supporter and a cosponsor of the HPCC Act. He most likely will introduce some form of the digital infrastructure bill introduced last fall by Gore and cosponsored by Rockefeller. His subcommittee also will consider NSF reauthorization.

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Inside CRN

News Analysis

How will S&T policy fare in new administration?

By Fred W. Weingarten
CRA Staff

Political transitions, particularly ones reflecting a major political shift, are times when great hopes—and fears—are raised about possible changes in all areas of public policy, ranging from the most fundamental, such as national prosperity and security, to the most arcane. This transition has been no different. Because President-elect Bill Clinton's campaign emphasized change, expectations seem to be even higher. (Some reports estimated that the Little Rock transition office received nearly 30,000 letters per day after the election.)

Most of these hopes and expectations diminish as the new president starts focusing on hard priorities, deciding where to expend political capital and where to wait for a better opportunity or a better idea of the real cost of some proposed programs. Although Democrats control Congress and the White House, political power still is diffuse, and there are many conflicting pressures. In the past, science and technology (S&T) policy almost immediately was relegated to the back seat in transition politics.

This past history should be a warning to the research community. There is good reason to expect that S&T policy will be emphasized and restructured over the next few years, both for reasons detailed in recent issues of *CRN* and because science and technology was a serious focus for the Clinton/Gore campaign. The research community will be responsible for helping create public and political support for S&T initiatives, and actively participating in the political debate so a well-informed and sensible set of policies is developed. Let's look at four dimensions of this responsibility.

Public and political support

Any major policy initiative requires broad public support and the understanding and support of the political leadership. Nearly one-quarter of Congress is new this year. These new members did not vote for the High-Performance Computing and Communications Act, nor were they party to the "agreement" made in 1987 to double the research budget of the National Science Foundation. Few of the new members, even if they were active in local politics, have any S&T policy experience.

The public, in general, has a poor and simplistic understanding of science and technology and how it is linked to economic growth. Although the public seems to accept that the government should support some level of R&D funding, that support is thin, at best. Science policy-makers have said that the computing research community needs to prepare a careful case explaining the nature of research and the benefits to the nation, then communicate it in clear and understandable terms to the public and the politicians.

Consensus

S&T policy will emphasize consensus, which also is expected to be the basic style of the new administration. S&T policy is not an area in which politicians like to spend political capital to resolve conflicts, and politicians seldom are effective when they do try. On most science and technology issues, politicians want experts to identify areas where there is agreement in the community. They have too many other things to fight about, and they understand that they lack the necessary expertise to make a judgment call. (Political controversy does exist—there have been debates over the Strategic Defense Initiative and floor fights over funding for the supercollider.)

The High-Performance Computing and Communications Act passed unanimously in the House and Senate. It was clear that, if unanimity did not exist, the bill would not have been taken to the floor.

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Opinions

CS community reacts to NRC report

Effective CS researchers must compute for the future

BY Rob Kling

The National Research Council's *Computing the Future: A Broader Agenda for Computer Science and Engineering* is a welcome report that argues that academic computer scientists must acknowledge the driving forces behind the generally good federal support for the discipline. The explosive growth of computing and demand for computer science in the last decade has been driven by a diverse array of applications and new modes of computing in diverse social contexts. The report takes a strong and useful position in encouraging all computer scientists to broaden our conceptions of the discipline.

The report's authors encourage computer scientists to envision new technologies in the social contexts in which they will be used. The numerous examples of computer applications that the authors identify as having significant social value rest on social analyses of these technologies. Further, the report tacitly requires that the CS community develop reliable knowledge, based in systematic research, to support effective social analysis. And it requires an ability to teach such skills to practitioners and students. Without a disciplined skill in social analysis, computer scientists' claims about the usability and social value of specific technologies is mere opinion, and bears an exceptional risk of being self-serving opinion.

Computer scientists who do not have refined social analytical skills have sometimes conceived and promoted technologies that were far less useful or far more costly than they claimed. Effective CS practitioners who "compute for the future" in many organizations need some skills in social analysis to help understand appropriate systems requirements and the conditions which transform high-performance computing into high-performance organizations. Because the report does not spell out these tacit implications, I would like to explain them here.

System usability

Because the usability of systems and software is a key theme in the history of computer science, we must expand beyond mathematics for our conceptions of "theory" for the discipline. Some applications, such as supercomputing and computational science, are evolutionary extensions of traditional scientific computation, even though they have taken a new direction with rich graphical front-ends for visualizing enormous amounts of data. But some other, newer modes of computing, such as networking and microcomputing, changed the distribution of applications. While they support traditional numerical computation, albeit in newer formats such as spreadsheets, they also have expanded the diversity of non-numerical computations. These modes of computing have made digitally represented text and graphics accessible to tens of millions of people.

None of these advances are inconsistent with "mathematical foundations" in computer science such as Turing machine formulations. But they are not well-conceptualized by the foundational mathematical models of computation. Nor do our foundational mathematical models provide useful ways of conceptualizing advances in even more traditional elements of computers systems such as operating systems and database systems. Mathematical analysis can play a central role in some areas of computer science and an important role in many areas. But we cannot understand important aspects of usability if we limit ourselves to mathematical theories.

Of the diverse trends in computing, the growing emphasis of usability is one of the most dominant. The usability tradition has deep roots in computer science, and extends back into the design of programming languages and

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Merging CS and CE disciplines is not a good idea

BY John McCarthy

McCarthy was involved in a petition that called for the withdrawal of Computing the Future. *Many of the petitioners' problems with the report were resolved in a joint statement by the sponsors of the petition and NRC.*

I have some other problems with the NRC report. These comments are mine and may not reflect the views of the petitioners. Some of my comments do not address the report itself.

Merging the two disciplines of computer science and computer engineering into a single discipline called CS&E is not a good idea.

• Science is concerned with finding out about phenomena, and engineering is concerned with making useful artifacts. While science and engineering are closer together in computer science than in other fields, the distinction is important. For example, the scientific problem of the relation between specifications of a program and its text needs to be studied independently of program verification systems.

The engineering problem of making changes in systems of programs that are too big for any one person to fully understand needs to be studied apart from formal methods—and should make use of formal methods, as well. Merging computer science and computer engineering encourages research that is not really basic and has only a metaphorical relation to applications.

• Artificial intelligence has both engineering and scientific aspects, but it is a mistake to identify them. Scientifically, artificial intelligence involves understanding how to achieve goals in open-ended, informationally complex situations. Because the AI field does not yet understand some difficult conceptual problems, it is not known when human-level intelligence will be achieved. It is necessary to measure progress in the scientific side of AI by scientific criteria—what is understood now that was not understood before. In my opinion, the discovery of formalized non-monotonic reasoning was a major advance.

The applied aspect of artificial intelligence is expert systems, which has some basic technological problems, such as creating tools. But the criteria for evaluating most of its work are practical. Are expert systems useful?

• It is a mistake to identify basic research with theory, and writing programs with applications. Artificial intelligence, for example, has a large component of experimental basic research, where experimental programs are written for what they will teach us rather than for their direct useful. Advising someone to always do programming in connection with applications is like advising geneticists to use elephants instead of fruit flies, because no one needs a better fruit fly, and smaller elephants might be quite useful in some underdeveloped countries.

Criteria for what constitutes scientific progress in various computer science disciplines need to be discussed and clarified. I believe much of today's work in computer science will not meet these criteria.

• The report recommends tying computer science and engineering to limited-duration giant projects like the High-Performance Computing and Communication (HPCC) initiative.

This enlarges and formalizes a layer of bureaucracy into the proposal mechanism. While research proposals are peer-reviewed, whether they fit into the HPCC program is an administrative decision.

When HPCC ends, the long-term research in science or engineering supported under its umbrella goes into limbo. There is no reason to suppose that many areas of computer science or computer engineering will be synchronized with HPCC. If HPCC was not regarded as a success—like the Japanese fifth-generation project—then the basic research it supported is in additional bureaucratic trouble. HPCC might end up regarded as a failure for a variety of reasons: foreigners do better; US companies unsupported by the government program do better (as happened in the early 1960s with the development of integrated circuits); and the supposed beneficiaries of the gigabit communication might decide that what

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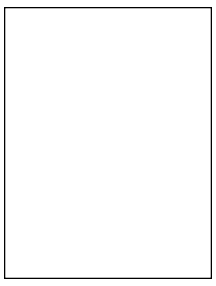
Expanding the Pipeline

Childcare an issue for conference attendees



BY Elaine J. Weyuker

Childcare, or the lack thereof, is an issue for all of us. It affects us, at least tangentially, whether we are female or male, old or young, parents or not. There have been many articles decrying the lack of high-quality, affordable childcare, and a variety of suggestions about what employers and the government should do to alleviate the problems.

In this article, I will focus on one narrow aspect of this broad and complex topic: how childcare issues affect the ability of a researcher with young children to attend and participate in conferences, and consequently how career advancement is affected. As a mother who has no option but to travel with her 4-year-old daughter, I write from first-hand experience.

The first issue to consider, and one that frequently is the deciding factor, is the traveling expenses of a child. Expenses include:

- airfare (full fare starts at age 2),
- childcare (in addition to normal childcare expenses at home, which must be paid whether or not the child attends),
- car rental (cabs rarely have seatbelts, therefore child safety seats cannot be used),
- meals (for logistical reasons, these often must be bought in the notoriously expensive hotel restaurant) and
- additional hotel costs.

Usually, none of these costs are reimbursable by a research grant or employer. These costs are not even tax-deductible, although they are mandatory for the employee to attend the conference. It is not unusual for it to cost $1,000 to take my child to a conference. How many conferences can a parent afford to attend with this type of financial burden? How many people at the junior level can afford any such trips?

Given that the parent somehow manages to handle the expense, the real challenge still looms. How do you arrange for childcare in an unfamiliar, distant place? If you can locate a caregiver, how can you feel secure about leaving a child with a caregiver you have never met?

Frequently, large hotels list babysitting as an available service. However, my personal experience is that the babysitters rarely exist. My daughter was 5 months old when I took her with me for the first time. It was the most important conference in my field. I was on the program committee, and I had a paper in the conference. I would not have missed it for the world. I phoned the hotel and was told they had a babysitting service and that no reservations were needed. When we arrived, I learned the reality—maybe they could think of someone I could phone and ask if they wanted to come to the hotel and babysit. After some discussion, they concluded they could not think of anyone. My daughter therefore attended her first conference. Needless to say, it affected my ability to participate.

Similar situations happened at the next several conferences we attended. Finally, I realized I was not likely to find childcare at a hotel, and had better make other arrangements. I have devised many creative ways to arrange for childcare when I attend a conference. When I cannot locate what seems to be high-quality, safe childcare, I simply do not attend the meeting.

Several months before the conference, I begin phoning everyone I know who lives and works in the conference area. I ask if they have colleagues with children my daughter's age. I then phone those "leads" and ask about their childcare arrangements. Could they find out whether their caregiver would take an extra (wonderfully bright, easy-going, ever-cheerful) child for the necessary days? If not, could they ask their caregiver for a recommendation? If this does not produce leads, I look for faculty members near the conference and ask them to ask students if they would like to earn extra money babysitting. I ask colleagues whether their teenage children will be attending and might be interested in babysitting. It is a lot of work, and it is not for the faint-hearted. I have had some wonderful luck, but on other occasions, I have come up empty-handed and simply decided there was no solution, and that I would just have to miss the conference.

The bottom line is that I am a fairly senior researcher and much better able to absorb the costs than many other people. Being senior, I know lots of people around the country and therefore have good contacts. Still, travel to a country where English is not the primary language seems impossible to me now. I simply do not submit papers to conferences overseas, and I do not attend those conferences.

It is certainly true that there are men who are single parents or the primary caregivers for their children, and who face these problems. And there are women whose personal situation allows them to travel without their children. Still, at the present time, childcare responsibilities, especially for young children, fall disproportionately on women, and therefore women suffer most often and most directly.

How many women face these situations and find them insurmountable? How does this affect their careers? Are they taken less seriously because they cannot attend meetings, and therefore publish less than their male colleagues? Are they considered unprofessional if they attend with a young child because that is the only way they can attend? Even if a parent manages to attend and arrange childcare, it is difficult, if not impossible, to attend the social events surrounding the conference. What contacts are missed as a result?

We need creative solutions, or we will continue to lose the participation of valuable members of our professional community. Possible solutions include:

- Professional societies can adopt the policy that all sponsored conferences should be held at hotels that provide childcare facilities. Hotels, like other businesses, are responsive to what they perceive as their economic self-interest. If major organizations, such as ACM and IEEE, demand on-site childcare, change is much more likely to occur than if individuals simply request it or individual conferences require it.

Although I believe there is a reasonable argument that the cost of this childcare should be borne by all since it is for the common good of the professional community, I am not proposing that. I am only suggesting that our professional societies require that a fee-for-services facility be *available* at the conference site.

- Rules of granting agencies could be changed to permit additional expenses to be charged, when necessary, for the grantee to travel. I frankly have mixed emotions about this suggestion. There generally is a fixed, finite amount of travel money available, and funds used to pay for a child's travel could not be used by a student or grantee. However, if this is the only way for someone to attend, then perhaps it is worth the tradeoff.

Another possibility is that if the grantee can obtain another source of travel funds for themselves, the grant travel money can be spent to pay for a child's travel. It is sometimes possible to arrange to give a colloquium at an industry or university site near the conference. If that source pays the grantee's expenses, then the grant money could be used instead for the child, thereby allowing the grantee to attend.

Whatever solutions we settle on, it means changing public policy. We are not likely to accomplish this in the near future. As long as it is not perceived by our community as a serious problem requiring action, nothing will change.

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they need most is not more gigabit communication, but a variety of other things.

- Focusing research on committee-determined methodology is a recipe for narrowness. In the 1970s, DARPA had a speech recognition project that set out to pick five research teams initially, then narrow it to three, then later end up with one enormously narrowed speech recognition research. Everyone hoped to be part of the team that was finally selected and knew quite a lot about the prejudices of the committee members.

Although there is a government crisis over the support of basic research, I believe that computer scientists should act collectively with other scientist in its defense and not try to take advantage of the others by an illusory merger of computer science and computer engineering.

In this connection, the NSB commission's report on NSF [See Page 4] is encouraging. It emphasizes the importance of investigator-initiated research, restates the mission of NSF as being the support of basic research and shows no bias in favor of research empires. In this, it agrees with the petition rather than with the NRC report and the line taken by Peter Likins and Fred W. Weingarten in the September issue of *CRN.*

John McCarthy is a professor of computer science at Stanford University.

Please note: The 1991-92 CRA Taulbee Survey results will be printed in the March issue of *CRN.* One copy of the results will be mailed in January to department chairs who participated in the survey.

Correction: The first paragraph of a page 1 article on federal policy in the November issue incorrectly identified a House subcommittee.

Policy News

Committee responsible for all CISE directorates

BY Jean Smith

The newly restructured National Science Foundation Computer and Information Science and Engineering (CISE) Advisory Committee met for the first time in Washington in late November. This was the committee's first meeting since NSF Assistant Director A. Nico Habermann, who heads CISE, changed the advisory committee structure. Previously, each of the six CISE divisions had its own advisory panel, which Habermann reportedly saw as cumbersome and ill-equipped to deal with cross-cutting directorate issues. The new 15-member advisory committee, chaired by Alfred Aho of BellCore, was formed so it would have directoratewide responsibilities.

Habermann said at the meeting that the committee was formed because computer science is now a mature discipline and the committee's recommendations will carry considerable weight. His remarks emphasized NSF's strategic planning exercise, which has five basic themes: intellectual integration, partnerships, people, an agile organization and accountability. The plan offers three choices for NSF growth. The first choice offers limited growth, essentially supporting only basic research; the second allows for incremental growth, representing a continuation of current operations; and the third suggests a broader mission for NSF to meet critical societal needs.

Habermann outlined two topics to be addressed by the committee—intellectual integration and human resources. Intellectual integration includes encouraging and supporting cross-disciplinary connections with other research fields and with industrial researchers. He asked the committee to consider how much of such work is desirable; whether other disciplines should be included or excluded; whether other supercomputer centers, networks, science and technology centers and the like should be emulated; whether intellectual integration is affordable and achievable; whether there are obstacles to such integration; and what actions CISE should take.

In the area of human resources, the basic goal was to ensure that, in the future, the nation has people with knowledge, skills and understanding of science and technology, not only at the Ph.D. level, but across a much broader population. The committee was asked to consider goals, working conditions and relevant issues, such as NSF support for industrial employees at universities, connections between academic tiers and sabbaticals in industry.

Susan Gerhart, director of the CISE Division of Computer and Computation Research, presented an outline of intellectual integration in theory and software. She discussed what could be learned from past examples, such as the computational biology initiative (cross-disciplinary research), formal methods in system engineering (transfer from theory to practice), and Science and Technology Centers for High-Performance Computing (institutional support). An important integration theme is to create problem solving environments including high-performance theory and systems.

John Cherniavsky, head of the CISE Office of Cross-Disciplinary Activities (CDA), discussed human resource programs in cross-disciplinary activities. He reviewed the problems being addressed in CDA in faculty training and education, new researcher opportunities, graduate student education, undergraduate education, K-12 activities and underrepresented groups. In his view, several major questions must be addressed:

- How can opportunities for minorities and women in information technology careers be increased?
- Is CISE involved enough—or too much—in education?
- What information technology training needs will teachers have in 2010? and
- How can sharing responsibilities through the levels of the educational enterprise be encouraged?

Following the presentations, there was a general discussion by the committee.

On the second day, the committee broke into three groups to develop recommendations. One group, stating that software engineering is a core technology for US industry, said CISE should play a lead role among federal agencies in co-sponsoring basic academic research in this area. Such research might include new parallel architectures, distributed computing and software development collaboration. The group considered examples of grand-challenge problems and, looking forward to a possible "High-Performance Computing and Communications Initiative II," recommended that planning for the initiative should begin now. Pilot projects and a workshop were suggested.

Grand-challenge projects that combine CISE and non-science applications should be evaluated according to their promise of contributing significant new knowledge in computer science and engineering and the impact or interest inherent in the application. There was support for convening study sections similar to those used by the National Institutes of Health, if necessary, to adequately review such proposals.

The second group examined intellectual integration involving CISE and other disciplines. It cautioned that such applications should have substantial computer science intellectual content, and that both multidisciplinary and interdisciplinary research should be considered. Discussion did not include the arts, humanities, entertainment or business, but the group recommended that these areas be considered in the future. The group warned that interdisciplinary applications should not eclipse

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S&T community interested in report on the future of NSF

BY Fred W. Weingarten
CRA Staff

In late November, as scheduled, the Special Commission on the Future of the National Science Foundation (NSF) issued its report to the National Science Board (NSB).

The commission was co-chaired by William Danforth, chancellor of the Washington University in St. Louis, and Robert Galvin, chair of the executive committee of Motorola and former chief executive officer of that company. NSF Director Walter Massey requested that the commission be established to examine how the agency's mission and programs could change due to major shifts in the political, economic and social environment for science [November *CRN,* Page 4]. The commission's report originally was intended to serve as input to the NSB's strategic planning process. However, the commission's work attracted more attention in the scientific community than expected when prominent scientists said they feared the commission was a stalking-horse for plans to turn NSF into a technology agency that will redirect money away from basic research.

Despite these fears, the 11-page report remained objective. It strongly upheld the importance of continuing NSF's responsibility for supporting long-term basic research. The report also acknowledged the validity of the political and social forces that have forced this re-examination of NSF's role and raised questions about the structure of government science and technology policy.

The commission did not seem to see any conflict in these positions. It recommended two basic objectives for NSF research support:

- The agency will support first-rate research at many points on the frontiers of knowledge, which will be identified and defined by top researchers.
- In response to scientific opportunities to meet national goals, resources in strategic research areas will be allocated fairly.

It is in the national interest to pursue both goals with vigor and in a balanced way. The allocation of resources should be reviewed regularly with these two goals in mind. Positive responses to both goals will enhance the standing of science.

The commission also seemed to say, in careful words, that redefinition of mission was not solely NSF's responsibility. The commission's first general recommendation was for "a stronger and more coherent policy wherein science and engineering can contribute more fully to America's strength."

NSB is encouraged to work with the president, his science adviser and the Federal Coordinating Council on Science, Engineering and Technology to broadly assess the health of science and engineering and generate a stronger policy into which the NSF mission fits.

Given that the new administration already has committed itself to restructuring federal R&D policy, such a recommendation can be seen as a sensible caution to NSB and Congress not to move too hastily on redefining NSF's mission.

The commission also said that although NSF controls only a minuscule fraction of the overall federal R&D budget (now estimated at $70 billion), it historically has played a dominant role in federal support for basic research. The commission said the US has a good record overall of capitalizing on the results of research. That success, coupled with a growing convergence between science and technology, suggests an even greater need and emphasis on long-term fundamental research.

The commission recommended that "the board and foundation's key role in the support of research in science and engineering should be strongly reaffirmed." This recommendation was followed by more specific recommendations on NSF research support.

The commission's report also focused on science education, and identified it as a "major priority" for NSF, not only in curricula but in "methodologies of teaching and training for research." The commission identified K-12 and undergraduate education as "critical areas needing improvement."

The commission acknowledged that its recommendations implied a need for more resources for NSF, not a reallocation of existing funds. But it said the case was strong and the links to national priorities clear.

The original purpose of the report, and one that Massey still supports, is to use it as a longer-term NSB strategic planning exercise. However, political events may put more weight on the recommendations.

In mid-December, NSF was expected to submit its revised spending plan to congressional appropriations committees to show how the final appropriated funds will be allocated within the agency. The Senate Appropriations Committee told NSF to take the commission report into consideration when revising the plan.

There are rumors that the new administration will request a supplemental appropriation for NSF's current budget. If such a request were made, Congress most likely would want to specify to some extent how the supplemental funds would be allocated. The commission's report may influence that debate. The scientific community may find the report useful in helping it make its case for supplemental funding to Congress.

Policy News

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As a result, to speak effectively on S&T policy, we need to be able to reach a reasonable consensus within our field. The computing research community needs to use mechanisms such as workshops, studies and conference sessions to determine our own research priorities and needs.

We also need to work more closely with colleagues in other disciplines, because restructuring science policy is not a zero-sum game. Since joining CRA, I have been astounded at how seldom the scientific societies have worked together on issues affecting them. Even more broad-based scientific organizations such as the National Academy of Sciences and the American Association for the Advancement of Science focus primarily on discipline studies and do little cross-cutting policy work.

At that level we get bland, generic and unconvincing paeans to the wonderfulness of science. Below that level, the knives usually are out. When we face problems such as redefining NSF's mission, structuring civilian technology policy and improving US science education, such zero-sum thinking does not help at all.

Political support for R&D will be based largely on its contributions to economic health, so the computing research community needs to work more closely with the computer and communications industry, which is the presumed beneficiary of the research. The Computer Systems Policy Project (CSPP), for example, has been instrumental in raising political support for the High-Performance Computing and Communications initiative. CSPP now is focusing on proposals for a new national information infrastructure. We need to work with CSPP and other such industrial organizations to ensure that the programs are compatible with and supportive of the nation's research capability.

"I have been astounded at how seldom the scientific societies have worked together on issues affecting them."

—Fred W. Weingarten

Need to negotiate

One of the characteristics of politics is the need to negotiate and compromise. The scientific community must engage in political negotiation to create the new "contract" with the public. The first step is to acknowledge the validity of the political demand that R&D support be tied more closely to some definable benefit or output. It is, after all, the taxpayer's money.

Demanding that NSF be "left alone," as some have urged, will not do. We need to articulate clearly, first among ourselves, what is fundamental to the process of research and what is negotiable, and we need to understand the nature of the other side's demands. For example, if the current political debate is any guide, three aspects are inevitable in any new regime—more priority setting among research areas, greater accountability for results and closer ties between technology and science and between industry and academic research.

The research community may wish to argue strongly that long-term research must be emphasized, that a broad support for research remain, that political concerns must not supplant peer review as a mechanism for determining merit, and that concern about appropriating economic benefit must not disrupt the tradition in research of open publication and information flows.

Broader social impacts

Computing research stands to gain from an emphasis on social return, because it generally is assumed among policy-makers that information technology is critically important to the economy. However, we have a corresponding responsibility to be the leaders in thinking about potential applications and the implications of our technology.

Information technology, if poorly designed and used, can do more harm than good. Information technology itself rarely is the solution to any problem. If the technology is to improve economic performance, we need to better understand the human, social and institutional aspects of how information systems are used. Otherwise, we run a serious risk of technological oversell, resulting later in a painful backlash.

We also need to acknowledge that information technology, like all technology, carries with it potential problems, such as privacy abuse, new risks and vulnerabilities, intellectual property issues, equity of access to information and the effect of automation on jobs and the nature of work. We need to help the public understand and resolve these problems, lest the issues become generic excuses for Luddism.

While an economic agenda seems to dominate policy, we should remind policy-makers that there are many other needs information technology can help address. We need to improve education, health care and the quality of government services to the elderly. Many other applications related to economic performance are waiting in the wings. We should take an expansive view of public benefit from research.

These four challenges mostly are new to the research community. We have not had to explain ourselves to the public. We have not had to work for consensus within computing or within research as a whole. We have not had to negotiate in the grubby arena of politics. Although some hardy souls continue to work in the area of human and social implications of computing, the field has not received broad acceptance within the community.

These are not, however, insurmountable difficulties, and there already is some indication that attitudes are changing. In some sense, it is the price computing research will have to pay for moving from the margins to the center of the R&D policy debate.

Congress from page 1

Barbara Mikulski (D-MD) was re-elected and is expected to continue as chair of the Senate Appropriations Subcommittee on VA, HUD and Independent Agencies, the subcommittee that oversees NSF appropriations. She has received mixed reviews on her support of basic research. Her social services and jobs agenda and her interest in NASA sets NSF back in line for funds. But she has never shown hostility toward NSF. The agency simply has not seemed to be a high priority of her subcommittee.

Overall

A major implication of these changes is that the research community must make a great effort to educate Congress. With a few exceptions, the new members do not have political or professional backgrounds in science and technology policy. Few have heard of the High-Performance Computing and Communications initiative.

Although they may have heard President-elect Bill Clinton's campaign call for investment in a national information infrastructure, not many new members know what NREN is or its relationship with the national infrastructure issue.

However, this year several new legislative initiatives, both from the administration and Congress, are expected, and they will affect federal science and technology policy, particularly computing and communications. For example:

- Some observers expect the new administration to immediately request a supplement for NSF's current budget. (The agency suffered a 2% cut in research funding, rather than its 17% requested increase.)
- NSF's reauthorization will be up this year, and some people are strongly considering changing the agency's basic charter.
- Some reorganization of the executive branch around "technology policy" is inevitable, and many proposals already are floating around town.
- NSF and the other science agencies will go through the usual appropriations process. But cuts as severe as in last year's appropriations would be difficult for the agencies—and the research community—to accommodate.
- The High-Performance Computing and Communications initiative ran into some funding problems last year, and may encounter more severe funding cuts this year.
- The debate over networks will take many forms. The new administration is likely to introduce legislation promoting the development of a broadband, digital national information infrastructure.
- Some version of the Information Infrastructure and Technology bill (S 2937), submitted last year by then-Sen. Gore, likely will be resubmitted and sponsored by Sen. Rockefeller.

CISE from page 4

pure computer science research.

The third group considered education. For K-12, it recommended that CISE influence the appointment of program directors in the NSF Directorate for Education and Human Resources (EHR) to ensure that more staff members with computer science and engineering backgrounds are hired. The group said the relationship between special programs with CISE and EHR be formalized, and that a committee be established to discuss education and CISE at the next advisory committee meeting.

In undergraduate education, the group suggested revisiting the recommendations of the National Research Council's report, *Computing the Future: A Broader Agenda for Computer Science and Engineering.* The educational needs of non-computer science students at the undergraduate level also were raised.

Two subcommittees were set up to provide a focus for the committee's next meeting, tentatively scheduled for May. The subcommittees will consider undergraduate education and areas of potential collaboration with CISE, such as the arts and humanities, not addressed at this meeting.

Jean Smith is a consultant who formerly was on the staff of the Telecommunication and Computing Technologies Program at the Congressional Office of Technology Assessment.

Kling from page 2

operating systems. Each of these topics also rested on mathematical analysis, which computer scientists could point to as "the foundations" of these subdisciplines. The growth of diverse applications for non-technical professionals, including text processing, electronic mail, graphics and multimedia, has placed a premium on making computer systems relatively simple to use. Human/computer interaction (HCI) now is considered a core subdiscipline.

One important repercussion of the integration of HCI into the core of computer science is the resulting need to expand our conception of the theoretical foundations of the discipline. Although every computational interface is reducible to a Turing computation, the foundational mathematical models of computer science do not (and could not) provide a sound theoretical basis for understanding why some interfaces are more effective for some groups of people than are others.

The theoretical foundations about effective computer interfaces must rest on sound theories of human behavior and their empirical manifestations. Further, interfaces involve capabilities beyond the primary information processing capabilities of a technology. They entail ways people can learn about the system and ways to manage the diverse data sets that routinely arise in using many computerized systems. Under-

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Research News

Workshop attendees tackle research problems

BY Barbara Liskov

This is the second of two articles.

A workshop held in the fall of 1991 on improving research in experimental computer science resulted in recommendations that attempt to correct current problems in university computing research. The workshop was cosponsored by the Office for Naval Research, the National Science Foundation, the Defense Advanced Research Projects Agency (DARPA) and other science agencies that participate in the Federal Coordinating Council on Science, Engineering and Technology (FCCSET).

A session on benchmarking, measuring and comparing focused on techniques for evaluating system performance. Group participants noted the difference between benchmarks, which are a way of comparing the performance of systems, and workloads, which are a way of evaluating how a particular system performs.

The group made several recommendations:

• Incentives, funding and professional recognition should be granted for creating and disseminating benchmarks and instrumentation tools. Journals should have a section in which papers on such things as new workload-gathering tools could be published.

• Benchmarks need to be discarded periodically and replaced with new ones to avoid the problems of systems that are optimized to work well on particular benchmarks.

• Researchers need better methodologies to build and understand benchmarks. In particular, we need scalable benchmarks that allow extrapolation from short runs to larger systems and interpolation from long runs to intermediate points.

• Reports on benchmarks need to be presented in enough detail to permit reproduction by those skilled in the state of the art.

The session on industry-university collaboration discussed what works in encouraging university-industry collaboration and technology transfer, and what changes would make such collaboration easier. The panel also discussed the differences in time frames for projects undertaken in industry and academia.

The panel suggested ways to improve collaboration:

• Academia should reward technology transfer to industry and take that into account when making promotion decisions.

• The reward system in industry should encourage people to spend time working in academia with research groups. The duration of these visits should be at least a year. Many attendees at the meeting felt that US companies did not value university interaction as much as they should, and that such visits were a way to improve things and to enhance technology transfer.

• Industry is more likely to use robust technology that has been stress-tested in conditions similar to those faced in industry. To encourage academics to carry through their research to this stage, funding should be provided for hiring technical staff members in universities whose job is to transform research prototypes into plausible models for industry. Funding is needed to support the prototypes (or to transfer their support to an industrial organization).

The group felt that universities are the right place to do long-term research. Because such projects are risky, the right source of funding for them is government agencies. The group recommended that researchers structure their work to produce interesting and demonstrable artifacts along the way to ensure that their results remain relevant in spite of technological shifts. Such artifacts should be specified as milestones in planning the research.

The reward system in industry should encourage people to spend time working in academia with research groups.

Quality of work

A session on experimental methodology suggested improvements to the quality of experimental work. The group classified research projects based on whether the research goals were known when a project started, and whether the measurements to be taken were well-understood. The categorization is useful because it affects the experimental methodology. For example, the choice of benchmark is important for projects in which both the goals and the measurements are well-understood (RISC architectures), less important when the goals are well-understood but the measurements are not (software engineering), and largely irrelevant when neither goals nor measurements are well-understood (the Arpanet in the early days).

The group came up with recommendations concerning funding, the validity of experimental results and education:

• Funding agencies should sponsor the development of good quality workloads for different applications. Examples include workloads for integer and floating point intensive computation, database, graphics, speech and signal processing applications. In addition to workloads, instrumentation tools should be developed so new workloads can be generated easily as requirements change.

• Create sections in journals, analogous to the correspondence section in *IEEE Transactions on Computers,* specifically for validating others' work. The importance of articles in this section would be less than that of regular articles.

• Reviews for funding agencies should include a specific category for work which has a primary purpose of validating other work, so the proposal would be reviewed in the proper light.

• Proposals to do experimental research should have detailed sections on the methodology and the criteria that would constitute success of the experiment.

• This latter point should apply to the reviewing process as well. Empirical papers submitted to conferences and journals should contain enough methodological details so that the work is helpful to other researchers.

• Create a collection of great examples of experimental research in each field of computer science, in essence developing a paper role model for others to follow. These papers should be summarized in a survey paper and compiled into books.

• A curriculum should be developed for a course in experimental methods and statistics for computer science research, and offered in university departments.

A session on infrastructure and funding focused on how projects should be organized to maximize results, and what form funding should take. This group discussed various forms of infrastructure, including support staff, hardware and software artifacts. Such infrastructure might be shared within a single large research group, among many groups at a university or even nationally.

Charged atmosphere

This session proposed funding a small number of broadly based research institutes at universities. This proposal was an attempt to recreate the atmosphere (and hopefully the productivity) of the big computer science labs (Project Mac, for example). An institute would receive a large amount of money with relatively little direction on how it would be spent; most likely the project would span universities and focus on work in a particular area. Something like this has been tried in Canada at the Canadian Institute for Advanced Research. An institute would free people from having to write proposals so frequently. Attendees felt that writing proposals consumes too much time. Also, an institute would free people to follow new paths.

However, attendees disagreed about whether such an institute would be a good idea. Some people believed the money would be wasted and that funding specific, more directed proposals (perhaps very big ones) would be better.

A related proposal was to pair strong institutions with weak ones, possibly as part of an institute. This might be a way of improving the quality of weaker institutions. Some attendees felt that the CER grants had not been as effective as had been hoped, even though there have been some conspicuous successes, and that the adoption plan might work better. There was broad agreement that the goal now is not to increase the number of Ph.D. recipients, but rather to increase the quality of their education and research.

The panel proposed several other action items:

• Funding of infrastructure is a good way to leverage the number of competent systems people (who are scarce).

• Funding of entry-level researchers is a good way of increasing the number of good experimentalists.

• A variety of funding models is needed.

• Competing proposals should be funded.

• Funding agencies should be careful not to micro-manage research. A particular concern was the current emphasis in some funding agencies on dividing up a project area into subparts and assigning the subparts to individual institutions. This is not a sensible approach to doing research, and it is likely to be time-consuming and unfruitful.

• Standards must not stifle research. For example, Mach is a good platform for applications being built today, but research is needed into the platforms of tomorrow.

• Universities should not be treated as development organizations.

The session on theory and practice discussed ways to increase the interaction between researchers in these two areas. The group agreed that such interaction was useful. Theoreticians benefit by discovering interesting problems to work on, and experimentalists obtain useful products, such as algorithms and impossibility results.

The group suggested several approaches for fostering interaction between theory and practice:

• The best paper from a systems conference should be presented at a theory conference, in the hopes that it will trigger theoretical research. The dual proposal of presenting a top theory paper at a systems conference generated interest but was less clearly supported.

• Ask funding agencies to support collaboration between theoreticians and practitioners. Proposals for joint work should be encouraged. Another possible organization is to have theoreticians act as consultants on systems projects.

• Encourage teaching and use of engineering analysis in computer science. Engineering analysis involves the careful use of approximations at each step. It can be contrasted to the more common pattern for computer science theory, in which an initial large approximation is made in creating the abstract model of a problem. Subsequent analysis is precise and rigorous, but the problems that are important to practitioners may be lost in the initial abstraction.

• Identify good examples of fruitful interaction between theory and practice.

• Encourage experimentalists to propose simple models that can be tractable for theoreticians. This might motivate theoreticians to work in an

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Research News

SIGACT trying to get children excited about CS

By Michael R. Fellows and Ian Parberry

As an emerging discipline, computer science has a serious communication problem. The public generally is ignorant of what computer science is and what computer scientists do. They tend to hear the word "computer" and assume that we are some kind of technicians. Is it any wonder then that computer science is represented in many schools by either computer games or some antiquated approach to programming, which at worst concentrates on a litany of syntax and at best emphasizes expediency over effectiveness and efficiency? But computer science is *not* about computers—it is about computation.

What would we like our children—the general public of the future—to learn about computer science in schools? We need to do away with the myth that computer science is about computers. Computer science is no more about computers than astronomy is about telescopes, biology is about microscopes or chemistry is about beakers and test tubes. Science is not about tools, it is about how we use them and what we find out when we do.

It may come as a surprise to some that computer science is full of activities that children still find exciting even without the use of computers. Take theoretical computer science, for example, which may seem an unlikely candidate. If computer science is underrepresented in schools, then theoretical computer science is doubly so.

Theoretical computer science is built on the foundation of discrete mathematics, which generally is ignored in schools in favor of continuous mathematics such as geometry, algebra and calculus. While the reasons for studying these subjects have been valid for centuries, and are still valid, an argument can be made that the citizen of the future who lives in the "information age" might benefit from at least a passing knowledge of the type of mathematics that underlies computer science and the ubiquitous computer.

Problems for children

Children come with built-in abstraction abilities that seem to get lost before they become adults. They have no trouble imagining that a block of wood is a house and a piece of driftwood is a boat. Experience has shown that children can imagine that a dot on a piece of paper is a house, that lines connecting them are streets and that numbers labeling the streets represent distances. With these representations in mind, the children are ready for the "Muddy City Problem."

The children are given a map of Muddy City and told the story of its woes—residents sink in mud up to their elbows when it rains. The mayor insists that some of the streets must be paved, and poses the following problem: Enough streets must be paved so it is possible for a resident to travel from their house to anyone else's house by a route consisting only of paved roads. But as little paving material should be used as possible so there will be funds remaining to build the town swimming pool. This, of course, is the familiar minimum-cost spanning tree problem.

The children can work on the problem, usually in small groups, with the immediate objective of finding the best possible solution. This is recorded in a place that everyone can see. Students are asked to describe their strategies and ideas, both as they work and in a concluding discussion. In classrooms where the students keep mathematics journals, they write descriptions of the problem and of their ideas on how to solve it.

CS is no more about computers than astronomy is about telescopes, biology is about microscopes or chemistry is about beakers and test tubes.

This simple (and fundamental) problem has excited children whenever it has been posed. The problem exercises children's problem-solving skills, gets them to think and write about the way they tackle problems, and incidentally, provides them with a meaningful opportunity to use their basic arithmetic skills (adding a list of numbers is needed to determine the cost of a solution).

This kind of meaningful, multileveled problem-solving experience is exactly the sort of thing called for by the new National Council of Teachers of Mathematics (NCTM) curriculum standards for school mathematics. Problems such as these can show children that science and mathematics are exciting frontiers, not dry, boring topics in which everything is known in advance and nothing is left to discover.

The minimum dominating set is another mathematically rich problem, and it illustrates the idea of computational complexity. A *dominating set* in a graph is a chosen set of vertices such that every vertex is either chosen, or has a neighboring vertex that is chosen. The problem is to choose such a set that is as small as possible. The stories told for this problem generally run to the theme of *facilities location.*

For example, in Tourist Town, we want to place ice-cream stands at corners so that no matter which corner you stand on, you need only walk one block at most to get ice cream. We allow some time for the children to puzzle over the map of Tourist Town, and they gradually produce more efficient solutions. Often, no one is able to find the optimal solution.

The children usually get an intuitive sense that Tourist Town is harder than Muddy City; the former does not seem to lend itself to solution by a quick and simple algorithm. The contrast between these two problems—one solvable in polynomial time and the other apparently intractable—provides a concrete introduction to the notion of computational complexity.

One-way functions are another fundamental topic of modern computer science accessible to children. After explaining that no one knows a good algorithm for Tourist Town, one can show that there is, however, a simple algorithm for "working backwards," i.e., starting with a set of vertices V' that is to become an efficient solution, and constructing a Tourist Town G = (V, E) around it. First, one forms a number of "stars" made up of "rays" (edges) emanating from the vertices in V'. (Two rays from different vertices in V' are allowed to have a common endpoint.) This graph clearly has V' as a solution.

The second step is to "disguise" this easy-to-solve graph by adding more edges. This does not increase the number of vertices required in a dominating set, but it does make the original built-in solution harder to see. This is a nice example of the idea of a one-way function. The children may look forward to trying out on their parents the process of creating a graph for which they secretly know a difficult-to-match solution. (One-way functions such as these are the basis of modern cryptography.)

Collective efforts

The Association for Computing Machinery Special Interest Group on Algorithms and Computation Theory (SIGACT) has formed a committee with the idea of compiling a compendium of theoretical computer science topics for children. The SIGACT compendium project was initiated at the business meeting at ACM's Symposium on the Theory of Computing last May. This project is a collective effort at science popularization, by one of the modern branches of mathematical science.

The SIGACT project joins a number of recent initiatives by professional science organizations to bring "live" science more directly to children. The Center for Discrete Mathematics and Theoretical Computer Science, located at Rutgers University, now publishes the newsletter *In Discrete Mathematics,* which contains articles on topics in discrete mathematics intended to be useful to teachers introducing discrete mathematics to their classes. The newsletter also serves as a networking service and clearinghouse for ideas and materials related to discrete mathematics in education in the lower grades. For more information, contact Joe Rosenstein at E-mail: joer@math.rutgers.edu.

The goal of the Los Alamos National Laboratories Megamath Project is to influence classroom practice by making schoolwork more like the experience one has in a good science museum. That is, the goal is to make mathematical science something in which students can actively participate.

The Megamath Project is exploring such things as (1) finding mathematics research problems that are accessible to children, (2) possible forums for children to present the results of their mathematical investigations, (3) extended projects for classroom investigation, (4) the classroom use of personal mathematics journals and (5) opportunities for children to communicate with larger mathematical communities.

The three aforementioned initiatives in discrete mathematics and computer science join other efforts involving research scientists in elementary education. These include the Mathematicians and Education Reform Network sponsored by the American Mathematical Society and the National Science Foundation, and the Scientists in the Schools programs of the national research laboratories. Many scientists are looking for more direct ways to work with children and stimulate grade-school educational reform. This seems to be an idea whose time has come.

Topics in theoretical computer science provide some ideal material for using the National Council of Teachers of Mathematics' new curriculum standards. These standards stress the importance of mathematical thinking, problem-solving, communication and connections between mathematics and the world, and represent an ambitious program for fundamental reform in mathematics education.

The idea of presenting the mathematics of computers without machines has attracted the attention of several organizations interested in promoting opportunities for women and minorities in science and technology, particularly in situations where funds for education are severely limited.

One of the sponsoring organizations of the Los Alamos Megamath Project is the American Association of Historically Black Colleges. The Kovalevskaia Fund, a foundation for women in science in developing countries, has organized lectures and demonstrations on discrete mathematics in the classroom at a number of universities in the Third World.

We believe that the computer science community has an important role in the ambitious curriculum reform projects articulated by NCTM and other organizations. Theoretical computer science includes a tremendous wealth of vivid, accessible, applicable, engaging and active mathematics in its treasury of ideas. The involvement of computer scientists in elementary education can have several effects—first and foremost in helping to clarify what computer science is really about.

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Ian Parberry is a professor of computer science at the University of North Texas.

Professional Opportunities

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University of Washington

Department of Computer Science and Engineering

The Department of Computer Science and Engineering at the University of Washington expects to have one or more tenure-track openings starting in the 1993-94 academic year. We seek outstanding applicants who add to our existing research strengths, particularly in compilers and computer systems engineering, or who bring significant new research strength to our department.

A moderate teaching load allows time for quality research and close involvement with students. We expect applicants to have a strong commitment to both research and teaching, and an outstanding record of research for their level.

Interested applicants should send a letter of application, a resume and the names of four references to Faculty Recruiting Committee, Department of Engineering FR-35, University of Washington, Seattle, WA 98195. Candidates are encouraged to apply as early as possible.

The University of Washington is an affirmative action, equal opportunity employer. A doctorate is required for these positions.

University at Albany, State University of New York

Department of Computer Science

Subject to administrative approval, the Department of Computer Science expects to be able to hire for a position beginning in September 1993. We invite applications for a tenure-track position at the assistant professor level, although applications at higher ranks also may be considered. Candidates must have a doctorate in computer science or a related field and have a demonstrated research capability in a systems-building area. We especially seek applications in the applied areas of databases, operating systems, programming languages, software engineering, distributed computing, networking and architecture. We also welcome applications involving interdisciplinary research with traditionally non-CS fields. The department has an active research program and offers bachelor's, master's and doctoral degrees.

Applications should be sent to Thomas Narten, Chair, Faculty Search Committee, Computer Science Department, University at Albany, 1400 Washington Ave., Albany, NY 12222. E-mail: narten@cs.albany.edu.

The University at Albany is an equal opportunity, affirmative action employer. Applications from women, minorities, handicapped persons and special disabled or Vietnam-era veterans especially are welcome.

Southern Methodist University

Computer Engineering Department

Applications are invited for a faculty position in computer engineering. The position is open to all levels (tenure-track assistant professor to full professor). Minimum qualifications include a doctorate (or being close to earning one) in computer engineering, electrical engineering, computer science or a closely related field. Candidates for tenured positions must have a solid research record as evidenced by publications in technical journals. Candidates must have demonstrated potential for a successful research and teaching career. Senior candidates will be evaluated on their research record and their teaching and professional activities.

SMU is a private university with about 8,000 students. The Department of Computer Science and Engineering is in the School of Engineering and Applied Science, where a close working relationship exists with the Department of Electrical Engineering and Mechanical Engineering. The CSE Department presents a balanced program of research and education at all levels and has been offering doctorates since 1970. The department has extensive contacts with computer-related and engineering-oriented industrial companies that distinguish Dallas as one of the top centers for high technology.

Applicants should send a complete resume, including the names of at least three references, to Jeffery L. Kennington, Professor and Chair, Department of Computer Science and Engineering, Southern Methodist University, Dallas, TX 75275-0122. E-mail: jlk@seas.smu.edu. Applications will be accepted until Feb. 15.

SMU is an equal opportunity, affirmative action, Title IX employer. Applications from women and minorities particularly are encouraged.

University of Waterloo

Department of Computer Science

The University of Waterloo invites applications for two tenure-track faculty positions in computer science. The department is looking for candidates in computer graphics, algorithms and data structures. In computer graphics, the incumbent will be an active contributor to the Computer Graphics Laboratory and provide leadership in core areas such as information visualization, rendering or user interfaces.

In algorithms, the incumbent will complement ongoing research activities within the Data Structuring Group, especially in the design and analysis of efficient algorithms for managing data. A doctorate in computer science or equivalent and evidence of outstanding research accomplishments or potential are required. Candidates at all levels of experience are encouraged to apply. Rank and salary will be commensurate with experience.

The Department of Computer Science comprises more than 40 full-time faculty members engaged in research and teaching, covering a broad spectrum of disciplines. The department and its research laboratories are housed in the new 300,000-square-foot William G. Davis Computer Research Center. The department is a key participant in the Information Technology Research Center, which is a Center of Excellence funded by the government of the Province of Ontario. ITRC supports basic and applied research in information technology.

Applications should include a curriculum vitae and the names of three references and should be directed to Professor Frank Tompa, Chair, Department of Computer Science, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1; E-mail: fwtompa@uwaterloo.ca.

In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. The University of Waterloo encourages applications from qualified women and men, members of visible minorities, native peoples and persons with disabilities. This appointment is subject to the availability of funds.

Ohio State University

Department of Computer and Information Science

The Department of Computer and Information Science is seeking highly qualified candidates for faculty positions at all levels and in all areas of computer science. Applicants should submit a vita and at least three letters of reference to Chair, Faculty Search Committee, Department of Computer and Information Science, Ohio State University, Columbus, OH 43210-1277. The search committee began reviewing applications Jan. 1, and will continue until the positions are filled.

Ohio State University is an equal opportunity, affirmative action employer.

George Mason University

Department of Computer Science

We invite applications for faculty at all ranks, permanent and visiting. We are particularly interested in persons who are dedicated to teaching, research and professional service. Our priorities in research are software engineering and software systems, distributed computing, computational sciences, multimedia computing and user interfaces. Applicants should be prepared to teach in these areas, plus programming languages, operating systems, algorithms and theory. Appointments start Sept. 1.

George Mason University is located in Fairfax County, VA, 17 miles west of Washington, DC. The Department of Computer Science is in the School of Information Technology and Engineering, which has made a commitment to engineering education in a world shaped by information technologies. This region offers numerous opportunities for government and industrial interaction.

To apply, send a letter of application, a resume, two recent writing samples and the names of four references. The application letter should state (1) your professional objectives, (2) your experience and goals in research and (3) your experiences and effectiveness in teaching. All of these items should be submitted together for proper consideration of your application.

Send all material to Professor David C. Rine, Chair, Recruitment Committee, Department of Computer Science, George Mason University, Fairfax, VA 22030-4444. Send inquiries to recruit@cs.gmu.edu. The application deadline is Feb. 1.

The university is an affirmative action, equal opportunity employer.

Georgia Institute of Technology

College of Computing

Located in Atlanta, the Georgia Institute of Technology's College of Computing provides leadership in computer science, with a current faculty of 37 and a research faculty of 12. The college offers degrees at the undergraduate and graduate level, and enrolls 500 undergraduate students, 120 master's and 135 doctoral students.

Research programs and computing facilities are enhanced by a variety of laboratories addressing interdisciplinary topics, including computer graphics, user interfaces and visualization; discrete mathematics; cognitive science, robotics and vision; distributed and parallel computing; software engineering; and telecommunications.

The college invites applications for faculty positions at all levels. Our current areas of need include most core disciplines of computer science, as well as the interdisciplinary activities mentioned above.

Candidates should send complete resumes and names of at least three references, preferably by Jan. 15 or until positions are filled, to Professor Karsten Schwan, Chair, Faculty Search Committee, College of Computing, Georgia Institute of Technology, Atlanta, GA 30332-0280. Tel. 404-894-2589; fax: 404-853-9378; E-mail: recruiting@cc.gatech.edu.

Georgia Tech is an affirmative action, equal opportunity employer, and it encourages applications from women and underrepresented minorities.

University of Arizona

Department of Computer Science

The Department of Computer Science at the University of Arizona invites applications for faculty positions at all ranks to begin in August. Applicants must have a doctorate in computer science or a closely related field. Applicants for junior positions should show promise of future excellence, while applicants for senior positions should have made substantial research contributions to the field.

The department has 14 faculty members with research areas spanning the field—from software systems to programming languages and theory of computation. For recruiting purposes, current areas of high priority include graphics, user interfaces, databases, programming languages, parallel computing, computer architecture, performance evaluation and computational biology. Exceptionally well-qualified people working in other areas also are encouraged to apply.

The research program is supported by numerous grants to individual faculty as well as a second departmentwide infrastructure grant from NSF. Computational facilities are diverse, including numerous Sun workstations, a Silicon Graphics 4D/340 VGX and several Personal IRIS Indigo graphics workstations, several DECstation 5000s and HP Apollo 9000/700s, a Sequent Symmetry, a NeXT machine and dozens of Macintoshes. Also available are high-resolution color terminals, a QMS color PostScript printer, color scanners, numerous laser printers and an L-300 imagesetter.

Send a complete resume and the names of at least three references to Larry L. Peterson, Faculty Recruiting Committee

Professional Opportunities

Chair, Department of Computer Science, University of Arizona, Tucson, AZ 85721. Applications will be reviewed beginning Jan. 15, but the positions will remain open until filled.

The University of Arizona is an equal opportunity, affirmative action employer.

University of Texas, Arlington

Computer Science Engineering Department

You are invited to apply for tenure-track or visiting faculty positions in all areas of computer science and computer engineering. Applicants with expertise in one or more of the following areas will be given preference: database systems, networks and telecommunications, parallel and distributed systems, programming languages, robotics and intelligent systems, software engineering, and VLSI and digital systems.

Rank is open. An earned doctorate and a commitment to teaching and scholarly research are required. Openings are expected for September. Applications will be accepted until all positions are filled.

Interested persons should send a resume and a list of references to Bill D. Carroll, Professor and Chair, Computer Science Engineering Department, PO Box 19015, University of Texas at Arlington, Arlington, TX 76019. Tel. 817-273-3787; fax: 817-273-3784; E-mail: carroll@cse.uta.edu.

The University of Texas at Arlington is an equal opportunity, affirmative action employer.

University of Michigan

Electrical Engineering and Computer Science Department

The Department of Electrical Engineering and Computer Science at the University of Michigan invites applications for positions at all levels in its Computer Science and Engineering Division.

Our emphasis is on operating systems, distributed systems and networks, database systems, programming languages, computer vision, robotics, graphics and artificial intelligence. Exceptional candidates in other areas of computer science and engineering also will be considered. All candidates who apply should have an interest in teaching and a strong research orientation.

Send your resume and the names of at least three references to Professor Toby J. Teorey, Chair of the Faculty Search Committee, CSE Division, EECS Department, University of Michigan, Ann Arbor, MI 48109-2122.

The University of Michigan is an equal opportunity, affirmative action employer.

University of Oklahoma

Department of Computer Science

Applications and nominations are invited for the position of the director for the School of Computer Science at the University of Oklahoma at Norman starting fall 1993. A candidate for this position must have an earned doctorate in computer science or a closely related field, a distinguished record in research and teaching and some administrative experience. The salary is competitive, and the university offers very good fringe benefits. The university has made a strong commitment to develop this school in the near future.

We are seeking an individual who has a distinguished and continuing record in research, excellent interpersonal communication, management skill and strong leadership. The individual should be willing to be a mentor for junior faculty, work with the faculty to pursue research funding and work closely with industrial corporations and government agencies.

The School of Computer Science is in the College of Engineering and offers bachelor's, master's and doctoral degrees. The school has 11 faculty positions, 242 undergraduates and 80 graduate students, with 25 in the doctoral program. Major research areas include artificial intelligence, computer vision, database management, image processing, parallel processing, software engineering and theoretical computer science. Computing facilities at the university include an IBM 3081, a 10-processor Multimax, an Alliant FX/8, VAX machines, a number of IBM RISC System/6000s, Sun and DEC workstations and a large number of PCs.

Applications and nominations should be sent to the Director of Search Committee, School of Computer Science, University of Oklahoma, 200 Felgar St., Room 114, Norman, OK 73019. All applications should include the curriculum vitae and the names of four references. Screening will begin Feb. 15, but the search will continue until the position is filled.

The University of Oklahoma is an equal opportunity, affirmative action employer. Women and minorities especially are encouraged to apply. OU has a policy of being responsive to the needs of dual-career couples.

University of Oklahoma

Department of Computer Science

The School of Computer Science at the University of Oklahoma invites applications and nominations for the position of a chaired professor (Hitachi Endowed Chair) starting fall 1993. A candidate for this position must have an earned doctorate in computer science or a closely related field, a distinguished and continuing record in research and funding, strong commitment to teaching and willingness to work with students and other faculty to lead the research and funding effort of the school to a new level. The candidate should be willing to be a mentor for junior faculty and to establish a major research team within the department. The university has made a strong commitment to develop this school in the near future.

Though applied computing areas are preferred, candidates from all specialties in computer science and computer engineering will be considered. The school offers bachelor's, master's and doctoral degrees and has 11 faculty positions, 242 undergraduate students and 80 graduate students, with 25 in the doctoral program. Major research areas include artificial intelligence, computer vision, database management, image processing, parallel processing, software engineering and theoretical computer science.

Computer facilities at the university include an IBM 3081, a 10-processor Multimax, an Alliant FX/8, VAX machines, a number of IBM RISC System/6000s, Sun and DEC workstations and a large number of PCs.

Applications and nominations should be sent to the Director of Search Committee, School of Computer Science, University of Oklahoma, 200 Felgar St., Room 114, Norman, OK 73019. All applications should include the curriculum vitae and the names of four references. Screening will begin Feb. 15, but the search will continue until the position is filled.

The University of Oklahoma is an equal opportunity, affirmative action employer. Women and minorities especially are encouraged to apply. OU has a policy of being responsive to the needs of dual-career couples.

Florida Atlantic University

Department of Computer Science and Engineering

The Department of Computer Science and Engineering, in the College of Engineering, seeks applicants and nominations for faculty positions at all levels. A doctorate in computer science, computer engineering or a closely related field is required. The department also seeks a coordinator of undergraduate programs; this position requires at least a master's degree. The appointments will begin in August. The closing date for applications is Feb. 15, although applications will be reviewed until suitable candidates are found. The department offers bachelor's, master's and doctoral degrees. The university is a member of the Florida State University System and has more than 15,000 students.

Applicants should send a resume, including the names and telephone numbers of three professional references, and a cover letter specifying the professorial rank desired to Faculty Search Committee, Department of Computer Science and Engineering, Florida Atlantic University, PO Box 3091, Boca Raton, FL 33431-0991. Tel. 407-367-3855; fax: 407-367-2800, E-mail: searchcomm@cse.fau.edu.

Florida Atlantic University is an equal opportunity, affirmative action employer. Members of protected classes are encouraged to apply.

University of Wisconsin at Madison

Computer Sciences Department

The Computer Sciences Department at the University of Wisconsin–Madison invites applications for one or more tenure-track positions beginning August 1993. Applicants should have a doctorate in computer science, or a closely related field, with a demonstrated ability in relevant scholarly research. Of particular interest are applicants with research interests in operating systems, networks, parallel and distributed systems, artificial intelligence, and numerical analysis. Applicants in these areas will be considered for a position at the assistant professor level.

The department has active research projects in a broad number of areas, including artificial intelligence, computer architecture and VLSI, database systems, mathematical programming, modeling and analysis of computer systems, networking and distributed systems, numerical analysis, operating systems, parallel processing, program development environments, programming languages and compilers, and the theory of computing.

The department has received three National Science Foundation Coordinated Experimental Research (Institutional Infrastructure) grants. The previous two projects emphasized loosely and tightly coupled parallel computing. Our new project, PRISM, addresses parallel processing on machines that offer credible paths to teraflop computing.

Research computing equipment is plentiful. The department has several hundred DEC, HP, IBM and Sun workstations, plus numerous file servers and special-purpose devices for computer vision and computer architecture. Equipment for research in parallel computing currently includes a Thinking Machines CM-5, three Sequent shared-memory multiprocessors, an Intel iPSC/2 Hypercube and a Tandem CLX multiprocessor. An Intel Paragon is scheduled to arrive early this year.

Applicants should submit a vita and the names of at least three references to Chair, Faculty Recruiting Committee, Computer Sciences Department, University of Wisconsin–Madison, 1210 W. Dayton St., Madison, WI 53706. To ensure full consideration, material should be received by March 15.

The university is an equal opportunity, affirmative action employer and encourages women and minorities to apply. Unless confidentiality is requested in writing, information about applicants must be released on request. Finalists cannot be guaranteed confidentiality.

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Professional Opportunities

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Auburn University

Department of Computer Science and Engineering

The Department of Computer Science and Engineering invites applications for one or more tenure-track faculty positions at the assistant professor level, beginning in September. Responsibilities include research, supervision of master's and Ph.D. graduate student research, and graduate and undergraduate teaching. Candidates should have a doctorate in computer science, computer engineering or a closely related field. Although applicants in all areas of computer science and engineering will be considered, preference will be given to those with research specialties in software engineering and parallel computation.

The department currently has 11 full-time faculty members and supports strong undergraduate and graduate programs. Faculty research areas include parallel computation, software engineering, artificial intelligence, computer networks and human/computer interaction. Departmental resources include a network of Sun workstations linked to the College of Engineering's Sun network. Parallel computing research is supported by a network of 16 T800 Transputers accessible from any of the department's workstations. Network access also is available to the university's general computer facilities and the Alabama Supercomputer Network's Cray and nCUBE supercomputers.

Auburn University is located in the city of Auburn in east-central Alabama, 100 miles southwest of Atlanta on I-85. The current enrollment at this land grant university is more than 21,000 students.

Applicants should send a curriculum vitae and the names, addresses and telephone numbers of three references to Professor Stephen B. Seidman, Head, Department of Computer Science and Engineering, Auburn University, Auburn, AL 36849-5347.

Questions can be E-mailed to seidman@eng.auburn.edu. Review of applications will begin Jan. 15 and continue until the position is filled.

Auburn University is an affirmative action, equal opportunity employer; women and minorities are encouraged to apply.

University of California at Berkeley

Department of Electrical Engineering and Computer Sciences

The University of California at Berkeley invites applications for a tenure-track position in computer science beginning fall 1993. At least one, and possibly two, faculty positions are expected, pending budgetary approval. Applications for appointments at the assistant professor level will be given highest preference, but other levels also will be considered.

Applicants should have received (or be about to receive) a doctoral degree in computer science or a closely related field. All areas of research in computer science will be considered. A principal requirement of the candidate is demonstrated research accomplishments at a stellar level. Teaching promise and leadership qualities also are highly valued at Berkeley. Applicants will be expected to set up a quality research program and be good at teaching core undergraduate courses and graduate courses in their specialty.

Send by Feb. 1 your resume, a select subset of your best papers and the names of three references to Professor David Patterson, Chair for Computer Science, EECS Department, University of California, Berkeley, CA 94720.

In addition, please ask your references to send their letters directly to the same address. Applications submitted after the deadline will not be considered.

The University of California is an equal opportunity, affirmative action employer.

University of Illinois at Urbana-Champaign

Department of Electrical and Computer Engineering

The Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign anticipates possible tenure and tenure-track faculty appointments in computer engineering. Applicants must have outstanding academic credentials and an ability to teach effectively at both the graduate and undergraduate levels.

Selected candidates will be expected to initiate and carry out independent research and perform academic duties associated with our bachelor's, master's and doctoral programs. A doctorate is required. Salary is open and based on qualifications. The starting date is negotiable.

Send resume and at least three references to T. N. Trick, Head of the Electrical and Computer Engineering Department, 1406 W. Green St., Urbana, IL 61801. Tel. 217-333-2301.

The University of Illinois at Urbana-Champaign is an affirmative action, equal opportunity employer.

Purdue University

Department of Computer Science

The Department of Computer Science has more than 38 faculty members in operating systems, networks, programming languages, database systems, robotics, software engineering, solid modeling, supercomputing, theory and numerical analysis. We invite applications at all professorial levels in any area of computer science.

The department affords great opportunities for people who want to get involved in exciting research. Each faculty member has access to the departmental computing facilities (many Sun file/compute servers, a 64-processor nCUBE 2 and many workstations), to the computing center's Cyber 205, ETA-10 and Intel iPSC/860 supercomputers, and to national computer networks.

Candidates must have, or be about to receive, a doctorate (or equivalent experience) in computer science or a related discipline. Salary is competitive and depends on background and experience. Submit resume and names of references by March 1 to Chair, Personnel Committee, Department of Computer Science, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity, affirmative action employer.

Colorado State University

Computer Science Department

The Computer Science Department solicits applications for tenure-track and visiting faculty positions at all levels (subject to funding). Candidates for assistant professor need a doctorate in computer science (at time of appointment) with promise for excellence in research and teaching. Applicants for senior ranks must possess distinguished research records. The department has approval for significant growth over the next few years and has identified selected areas in parallel computing, artificial intelligence and software engineering for special attention. Salary is commensurate with rank and experience. New and visiting faculty will enjoy duties especially conducive to productive research.

The department offers bachelor's, master's and doctoral degrees. We have excellent cooperative research relations with industrial and government laboratories, and their people form a significant portion of our graduate student population. We operate numerous multiuser systems (HP, DEC and Sequent) and many workstations (HP, IBM, Sun and AT&T), all networked. University operations include IBM RS/6000 servers and a visualization laboratory. Department personnel work in a pleasant, smoke-free environment.

Fort Collins is a growing community of 92,000 located along the foothills of the Rocky Mountains, 60 miles north of Denver. The climate is moderate—about 15 inches of precipitation and 290 days of sunshine per year. There are many cultural opportunities and year-round outdoor activities.

Send your curriculum vitae and names of at least three professional references to Faculty Search Committee Chair, Computer Science Department, Colorado State University, Fort Collins, CO 80523. Applications for August will be considered March 1. The search may be extended if suitable candidates are not found.

Colorado State University is an equal opportunity, affirmative action employer. EO Office: 21 Spruce Hall.

State University of New York at Stony Brook

Computer Science Department

Applications are invited for junior- and senior-level tenure-track positions in computer science. We are particularly looking for people interested in graphics, user-interfaces and visualization, or in some aspect of information systems, but will consider all applications.

The Stony Brook Computer Science Department consists of 25 faculty members with a variety of research interests including computer architecture, databases, distributed systems, software engineering, logic programming, automated reasoning, computer graphics, visualization, image processing and artificial intelligence. The department currently graduates about 100 students with bachelor's degrees each year and has about 60 master's and 60 doctoral students.

The department has an excellent networked computing environment including numerous SPARCstations, HP and Silicon Graphics workstations, graphics equipment, a Sequent S27, an Intel iPSC/860 and undergraduate laboratories with Apple Macintoshes and HP workstations.

Stony Brook is located about 50 miles from New York City on the historic and attractive north shore of Long Island, with easy access to the recreational activities on Long Island and the excitement of New York City.

Candidates should have a doctorate in computer science or a related engineering discipline. Please submit a detailed vita and the names of at least five references to Professor Arie Kaufman, Chair, Faculty Recruiting Committee, Computer Science Department, State University of New York at Stony Brook, Stony Brook, NY 11794-4400. Tel. 516-632-8471; E-mail: ari@cs.sunysb.edu.

Applications from women and minorities particularly are sought. Stony Brook is an affirmative action, equal opportunity educator and employer.

University of North Carolina at Chapel Hill

Department of Computer Science

We invite applications for one or more assistant (or possibly untenured associate) professor positions to begin in August.

Candidates must hold (or expect to hold) a doctorate. We will give highest priority to those who have strong research credentials in the theory or practice of algorithms, especially distributed, geometric or parallel; distributed systems; hardware systems; or parallel scientific computation.

The department operates extensive computing facilities and well-equipped laboratories for computer graphics and image processing; communications, networking and collaboration research; software packaging and distribution support; and VLSI- and microtechnology-based system prototyping. Our new building is extensively wired for video and integrated voice and data communication. The university is one vertex of the Research Triangle, a rapidly growing center of technology.

Apply either by electronic mail to search@cs.unc.edu or by postal mail to Faculty Search Committee, Campus Box 3175, Sitterson Hall, Chapel Hill, NC 27599-3175. Advise us of *your* electronic address.

Minorities and women are encouraged to apply. The University of North Carolina is an equal opportunity, affirmative action employer.

Cornell University

Computer Science Department

Applications are invited for tenure-track positions beginning in August. These positions are at the assistant professor level, although appointments at the associate and full-professor level will be considered for highly qualified applicants. Applicants should have a doctorate in computer science or in a closely related field. The department requires demonstrated research accomplishment at a very high level, as well as teaching ability and leadership qualities.

The Department of Computer Science at Cornell University encompasses a wide range of research areas, including algorithms, applied logic and semantics, artificial intelligence, computing theory, concurrency and distributed computing, databases, information organization and retrieval, numerical analysis and scientific computing, programming environments, parallel systems, programming languages and methodology, and robotics and vision. In a number of these areas, the department is especially interested in connections to parallel systems.

Research positions in software systems also are available.

Applicants should submit a vita and the names of at least three references to Chair, Faculty Recruiting Committee, Department of Computer Science, 5146 Upson Hall, Cornell University, Ithaca, NY 14853-7501.

Cornell University is an equal opportunity employer and welcomes applications from women and ethnic minorities.

Kent State University

Department of Mathematics and Computer Science

Applications are invited for a tenure-track faculty position in computer science at the assistant professor level beginning fall 1993. Applicants must have completed all requirements for a doctorate in computer science or a closely related field. Preference will be given to candidates in performance evaluation of distributed systems and in distributed operating systems software, to interface with the existing faculty in a major initiative in heterogeneous computing systems. Other research areas of interest are parallel processing, compilers, networking, graphics, scientific visualization and database theory. Salary is competitive and negotiable.

The department operates a computer laboratory consisting of nearly 100 Sun and HP workstations, including several high-end color graphics stations; HP Apollo 9000 Series 705s, 720s and 730s; a four-processor Sun 4/670 server; a Wavetracer DTC 4096 processing element SIMD computer; a GE Warp Systolic array processor; a 26-CPU Sequent Balance; a 12-CPU Encore Multimax; and miscellaneous laser printers and other peripherals. All systems within the department run

Professional Opportunities

Unix and are connected to a local area network, as well as to OARNET (Ohio Academic Research Network) and Internet. University facilities include an IBM 3090/2005, an IBM 4381R (on BITNET) and two DEC VAX 11/780s running VMS. Access through OARNET to the Cray YMP-8/864 at the Ohio Supercomputing Center in Columbus also is available. The department recently moved to a new building and expects to increase its equipment holdings considerably in the near future.

Applicants should submit a resume and arrange to have three letters of recommendation sent to Professor Kenneth Batcher, Chair of the Search Committee, Department of Mathematics and Computer Science, Kent State University, Kent, OH 44242; fax: 216-672-7824. The deadline for receipt of applications is Feb. 1, but may be extended if suitable candidates are not found. Kent State University is an affirmative action, equal opportunity employer.

Brandeis University

Michtom School of Computer Science

Brandeis University announces an opening for a senior tenured position in the Michtom School of Computer Science, starting in the fall. This position carries the title of Michtom Chair, made possible as part of the endowment provided by the late Benjamin and Hadassah Michtom. We seek an individual with a national reputation in research and teaching. Furthermore, the candidate should have administrative skills and be willing to chair the department on a rotating basis.

The Michtom School of Computer Science presently conducts research in artificial intelligence, languages, algorithms and parallel computing. The candidate should have a strong interest in experimental computer science and be able to establish interactions with the existing groups. The school currently has 11 faculty members with a strong record of research publications and external funding, a total of 30 doctoral students and 25 undergraduate majors per year.

The Michtom School is part of the National Center for Complex Systems, which congregates researchers in neural, computational and cognitive sciences. A new building housing the Michtom School and the center is under construction and scheduled for completion in the spring of 1994.

The candidate's area of interest should relate to those of the Center for Complex Systems, including very large databases, computational biology, neural computing, simulation of complex systems and massively parallel and distributed computing.

Please send nominations or applications (with names and addresses of references) by March 1 to Search Committee, Professor Jacques Cohen, Computer Science Department, Brandeis University, Ford Hall, Waltham, MA 02254. Tel. 617-736-2702; E-mail: jc@cs.brandeis.edu.

Brandeis University is an equal opportunity, affirmative action employer. We particularly encourage applications from women and minorities.

Georgia Southern University

Department of Mathematics and Computer Science

Applications are invited for a tenure-track position as either an assistant or associate professor starting Sept. 1. Requirements include a doctorate in computer science or closely related field with training and experience in more than one of the following four areas: operating systems, parallel and distributed systems, networking and data communications. Candidates also must provide evidence of dedication to outstanding teaching. Duties include teaching graduate and undergraduate courses in computer science and supervision of research projects for master's degree candidates concentrating in computer science.

Qualified applicants should send a letter of application, curriculum vitae, unofficial transcripts of all college work and three letters of recommendation by Feb. 15. to Dr. John A. Rafter, Landrum Box 8093, Georgia Southern University, Statesboro, GA 30460-8093. The letter of application or vita must specifically address all requirements listed above. The names of applicants and nominees, resumes and other general non-evaluative information are subject to public inspection under the Georgia Open Records Act.

Georgia Southern University is an affirmative action, equal opportunity institution.

Brown University

Department of Computer Science

Applications are invited for a faculty position commencing Sept. 1 at the assistant professor level. Candidates must demonstrate high research and scholarship potential and significant teaching ability. Applicants are sought in all areas of computer systems (including, but not limited to, distributed computing, operating systems, environments and graphics). Successful applicants will find at Brown a stimulating environment conducive to professional growth, with state-of-the-art equipment and excellent undergraduate and graduate students.

Candidates must hold a doctorate in computer science or related discipline, or show evidence that the doctorate will be completed by the end of the first year of appointment. Applicants should send a resume and have at least three referees send letters of recommendation to Professor Paris Kanellakis, Computer Science Department, Brown University, Box 1910, Providence, RI 02912. All application materials must be received by Feb. 15 for full consideration.

Brown University is an equal opportunity employer and encourages applications from members of protected groups.

University of Chicago

Department of Computer Science

Junior and senior positions are available in the Department of Computer Science. Our preference is for candidates with expertise in one of the areas of experimental computer science, such as programming languages or distributed systems, but we will consider exceptionally strong applicants from all areas.

Send curriculum vitae and three letters of reference to Professor Janos Simon, Chair, Department of Computer Science, University of Chicago, 1100 E. 58th St., Chicago, IL 60637. Inquiries can be directed to chair@cs.uchicago.edu.

The University of Chicago is an equal opportunity, affirmative action employer.

University of Colorado at Boulder

Department of Computer Science

The Computer Science Department at the University of Colorado invites applications for faculty positions. The department is most interested in candidates in the areas of databases and numerical and parallel computation, although exceptional candidates in other areas also may be considered. Preference will be given to candidates at the assistant professor level. Applicants should show strong promise in both research and teaching.

The department has 24 faculty and about 180 graduate students. It has strong research programs in artificial intelligence, databases, numerical and parallel computation, software systems, theoretical computer science and user interfaces. The computing environment includes a multitude of computer workstations and a variety of parallel computers. The department is the recipient of two consecutive five-year National Science Foundation Institutional Infrastructure (previously CER) grants that support its computing infrastructure and collaborative research among its faculty. The department is a major participant in a new NSF Grand Challenge Applications Group grant that includes research in both databases and numerical and parallel computation.

Applicants should send a current curriculum vitae and the names of four references to Professor Robert Schnabel, Chair, Department of Computer Science, Campus Box 430, University of Colorado, Boulder, CO 80309-0430. One-page statements of research and teaching interests would be appreciated. Review of applications began Jan. 1, but all applications postmarked before March 1 are eligible for consideration. Earlier applications will receive first consideration. Appointment can begin as early as August.

The University of Colorado at Boulder has a strong institutional commitment to the principle of diversity in all areas. In that spirit, we are particularly interested in receiving applications from a broad spectrum of people, including women, members of ethnic minorities and disabled individuals.

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area and make their results more relevant to practical problems.

• Find ways to evaluate researchers whose work spans more than one area. University promotion policies encourage researchers to do concentrated work in a single field. The former Bell Laboratories ranking system is an exception, although it is not clear how it could be applied in other settings. Until recently, all researchers in the laboratory were ranked in a single list. This was accomplished by a type of merge sort. Line managers ranked their own people, then the lists were merged to give a ranking for the next level in the hierarchy. Because managers could be expected to support their own people, moving ahead in the sort requires support from other managers. Such a system strongly encourages interdisciplinary work.

Effective research

A session on large-scale systems and experimentation focused on finding ways to increase the effectiveness of research in this area. The group identified two reasons for undertaking large-scale projects: the size itself may be the research, or a large-scale system is needed to enable further research. Participants agreed that effective systems people are the scarcest resource, and they examined ways to increase their numbers and enhance their usefulness.

The panel identified six ways to attain leverage in large-scale systems research:

• Sharing a common infrastructure was identified as the most important way to attain leverage. Rather than building everything from the ground up, systems should build on top of a common base. To effectively share infrastructure, subareas need to clearly identify what constitutes infrastructure and what is sharable.

• Standard interfaces can be a source of tremendous leverage. Conversely, standards also can unnecessarily constrain research, especially when they are imposed by the funding agencies. Subareas need to clearly identify which interfaces make sense to standardize and which should be left unspecified.

• To enhance sharing, we need to make tools widely available. Such tools will be more useful if they are parameterizable, such as a parallelizing compiler that allows experimentation with optimization techniques.

• Cooperating with industry, particularly in hardware prototyping projects, almost is a necessity. Identifying the limitations of university researchers and exploiting the talents of industry professionals is key to the success of large hardware projects.

• Large-scale projects must build upon previous work as much as possible. Researchers should focus their intellectual efforts and resources on the novel aspects of their systems. This includes building on previous research projects and commercial systems.

• Researchers should reduce the scale of the research project by raising the level of abstraction whenever possible.

A way to evaluate people who work on large collaborative projects is needed. And the infrastructure, which computing researchers claim should be shared, often is the competitive advantage of the research group that developed it. Mechanisms are needed to encourage and reward researchers for sharing and supporting the infrastructure.

Barbara Liskov is a professor of computer science and engineering at the Massachusetts Institute of Technology and was chair of the workshop's program committee.

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standing the diversity and character of these interfaces, which are required to make many systems usable, rests in understanding the way people and groups organize their work and computing expertise. Appropriate theories of the diverse interfaces that make many computer systems truly useful must rest on theories of work and organization that characterize these phenomena.

Improving performance

The foundations of the NRC's report go beyond interface design to claims that computerized systems will improve the performance of organizations. The report argues that the United States should invest nearly a billion dollars a year in CS research because of the economic and social gains that must pour forth from CS research. These are important claims, for which critics can ask for systematic evidence. For example, one can ask about the evidence that 20 years of major computing R&D and corporate investment in the United States has helped provide proportionate economic and social value.

The report includes many examples where computer-based systems

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Conference News

Computing researchers to meet at federated conference in May

The first Federated Computing Research Conference, FCRC '93, will be in San Diego May 15 -21. The conference will bring together nine conferences and workshops that represent a variety of computing research disciplines.

Two years ago, CRA received a National Science Foundation grant to explore the feasibility of a major research conference for computing and make the initial plans for such a meeting. Although many members of the research community were reluctant to give up the benefits of the smaller, more specialized meetings, they believed the field was intellectually mature enough to benefit from a larger, more diverse research meeting. However, the community did not want to create another conference, which is why the hybrid, federated approach was explored.

By providing a common time and meeting place for several established meetings, FCRC '93 is retaining the intellectual benefits and research identities of the smaller constituent meetings, while providing greater visibility for the field. FCRC '93 also is providing the opportunity for researchers to meet with their peers in other specialties. Because of the unified nature of the conference, researchers will be able to learn about important findings in other specialized subfields.

Each participating conference will be independently administered, and each organizing group will be responsible for their meeting's structure, content, proceedings and special events. All FCRC '93 attendees will register for at least one participating conference and will be able to buy proceedings from the other meetings. During their "home" conference—to the extent facilities allow—attendees will be free to sit in on other meetings.

Each morning will start with a plenary lecture on a topic in computing research. The conference features two plenary social events.

The plenary speakers are Richard Karp of the University of California at Berkeley, Maurice Wilkes of Olivetti Research Ltd., Guy L. Steele Jr. of Thinking Machines Corp, and László Babai of the Universities of Chicago and Eotvos. A yet-to-be-selected federal policy-maker also will deliver an address.

In planning FCRC '93, CRA received financial help from NSF and support and assistance from other sponsoring organizations. The Association for Computing Machinery has been particularly active in providing support and planning expertise.

Contact Phil Louis at CRA to request a registration package. Tel. 202-234-2111; fax: 202-667-1066; E-mail: plouis@cs.umd.edu. Anyone who previously received information on any of the participating conferences automatically will receive the registration package.

Participating research meetings

• 25th Annual ACM Symposium on the Theory of Computing (STOC)
Sponsor: ACM Special Interest Group on Algorithms and Computation Theory
Contact: David S. Johnson, AT & T Bell Labs, dsj@research.atl.com

• Ninth Annual ACM Symposium on Computational Geometry
Sponsors: ACM SIGACT and ACM Special Interest Group on Graphics (SIGGRAPH)
Contact: Chee Yap, Courant Institute, yap@yap.cs.nyu.edu

• Fourth ACM SIGPLAN Symposium on Principles and Practices of Parallel Programming (PPoPP)
Sponsor: ACM Special Interest Group on Programming Languages (SIGPLAN)
Contact: Marina Chen, Yale University, chen-marina@cs.yale.edu

• Eighth Annual Conference on Structure in Complexity Theory
Sponsor: IEEE Technical Committee on Mathematical Foundations of Computing
Contact: Steve Mahaney, University of Arizona, srm@cs.arizona.edu

Workshop on Parallel Algorithms (WOPA '93)
Sponsor: University of Maryland Institute for Advanced Computer Studies (UMIACS) and the Defense Advanced Research Projects Agency
Contact: Uzi Vishkin, University of Maryland, vishkin@umiacs.umd.edu

• 20th Annual International Symposium on Computer Architecture
Sponsors: ACM Special Interest Group on Computer Architecture, IEEE Computer Society and the IEEE-CS Technical Committee on Computer Architecture (TCCA)
Contact: Lubomir Bic, University of California at Irvine, bic@cj2.ics.uci.edu

• Seventh Workshop on Parallel and Distributed Simulation (PADS)
Sponsors: ACM Special Interest Group on Simulation (SIGSIM), IEEE Computer Society, IEEE-CS Technical Committee on Simulation (TCSIM) and the Society for Computer Simulation (SCS)
Contact: David Jefferson, University of California at Los Angeles, jefferso@cs.ucla.edu

• ACM/ONR Workshop on Parallel and Distributed Debugging
Sponsors: Office of Naval Research, ACM SIGPLAN and the ACM Special Interest Group on Operating Systems
Contacts: Bart Miller, University of Wisconsin, bart@cs.wisc.edu
Joan Francioni, University of Southwestern Louisiana, jf@cacs.usl.edu

• CRA Workshop on Academic Careers for Women
Sponsor: CRA's Committee on the Status of Women
Contact: Cynthia Brown, Northeastern University, brown@corwin.ccs.northeastern.edu

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have provided value to people and organizations. The tough question is whether the overall productive value of these investments has been worth the overall acquisition and operation costs. In the last few years, economists have found it hard to give unambiguously affirmative answers to this question. The question has been termed "The Productivity Paradox," based on a comment attributed to Nobel laureate Robert Solow who said, "computers are showing up everywhere except in the [productivity] statistics."

There are many potential slips in translating high-performance computing into cost-effective technological support to improve organizational performance. Some technologies require extensive technical support that provides hidden costs. Some technologies are superb for well-trained experts, but are difficult for less-experienced people or "casual users." A significant body of empirical research has shown that the social processes by which computer systems are introduced and organized makes a substantial difference in their value to people, groups and organizations.

Most seriously, some computer applications do not fit a person or group's work practices. While the applications may make sense in a simplified world, they can complicate or misdirect real work. The computing research community graduates about 30,000 computer scientists every year, and many of them find employment on organizational information systems projects. Unfortunately, few of them have developed an adequate conceptual basis for understanding when information systems actually will improve organizational performance.

The NRC report anchors the value of CS research on the belief that interesting new technologies certainly will yield significant economic and social value. These assessments rest on social analyses. Unfortunately, the CS academic community is not organized (or funded) to provide a significant body of trustworthy research to help answer these kinds of questions.

Organizational informatics

The report places dual responsibilities on computer scientists. One responsibility is to produce a significant body of applicable research. The other responsibility is to educate a significant fraction of the CS students to be more effective in conceiving and implementing systems that will enhance organizational performance. Most of the thousands of people who earn bachelor's and master's degrees in computer science have no opportunities for systematic exposure to reliable knowledge about the value of computing in a social world.

A substantial fraction of these students go on to work for organizations attempting to produce or maintain systems that improve organizational performance. Yet these people do not have a good conceptual basis for their work. Consequently, many of them develop systems that underperform, and sometimes are even counterproductive, in organizational terms.

Organizational informatics includes studies of the usability of computerized information systems and communication systems in organizations. It also includes studies of their effective implementation, use, organizational value and consequences for people and an organization's clients. It is an intellectually rich and also practical research area.

In the last 20 years, a substantial body of scientific research in organizational informatics has developed. The best of the research is conducted by faculty in the information systems departments in business schools and by scattered social scientists. But the body of research and teaching cannot be left to business schools or "sociologists." They rarely ask questions with attention to fine-grained technological variations, which are important for computer science, and they do not teach CS students.

The report is permeated with interesting claims about the social value of recent and emerging computer-based technologies. While many of these observations are of a kind that should rest on an empirically grounded scientific footing, computer scientists have deprived themselves of access to such research. Consequently, many of the obvious claims about the value of various computing technologies that we computer scientists make are more akin to the lore of home remedies for curing illness. Some are valid; others are unfounded speculation. More seriously, the theoretical basis for recommending home medical remedies and new computer technologies is not advanced without having sound research programs.

What is needed

The report sets the stage for a broader appreciation of the value of organizational informatics within computer science. It bases the expansion of the discipline on a rich array of applications in which many of the effective technologies must be conceived in relationship to plausible uses to provide attractive social value for multibillion-dollar public investments.

The CS community needs an institutionalized research capability to produce a reliable body of knowledge about the usability of computerized systems and the conditions under which computer systems improve organizational performance. The CS curriculum must include opportunities for students to learn the most reliable knowledge about the social dimensions of systems development and use. While the study of organizational informatics builds upon both the traditional technological foundations of computer science and the social sciences, it is not a sustainable topic within the social sciences at most universities.

Other disciplines will not do our important work for us. Mathematics departments may be willing to teach graph theory for CS students, but the analysis of algorithms would be a much weaker field if it only could be carried out within mathematics departments.

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