Women in AI

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Recently, a woman whose article had been accepted for *IEEE Expert* asked us to use her initials rather than her first name in her byline. She believed that if the readers knew a woman had done the research, they would question the validity of the work.

We were surprised. Although we were aware of recent studies that showed how much women are underrepresented and sometimes undervalued in science and engineering, we had thought that AI — as a relatively young subfield of computer science — might be an exception.

After looking at the proportion of women authors in *IEEE Expert* over the last four years (about 13 percent), we decided to take a closer look at the field.

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Most of us acknowledge a perceived underrepresentation of women in science and engineering, whether or not we agree a problem really exists. Ellen Spertus started her 1991 report "Why Are There So Few Female Computer Scientists?" with these statistics:

"In the most recent years for which statistics are available, women received a third of the bachelor's degrees in computer science, 27 percent of master's degrees, and 13 percent of PhDs. Not only do women make up just 7.8 percent of computer science and computer engineering faculties, only 2.7 percent of tenured professors are female. Even worse, these numbers seem to be improving only very slowly or even dropping."[1]

Other publications have also reported discrepancies in the treatment of women and men in computer science and engineering:[1...7]

- Women scientists earn less than men at every stage of their careers, and the disparity grows at the highest levels of experience.[2]
- Starting salaries are the same for men and women engineers, but the gap widens after about six years.[2]
- Women's colleges produce four times as many female research scientists and scholars as do coeducational institutions, and their graduates are twice as likely to earn PhDs.[3]

The Computing Research Association's 1989 Taulbee Survey[9] found that the percentage of female computer scientists decreases rapidly from high-school level to undergraduate, to graduate, to professorships, and that 13 percent of computer scientists are women and minorities. Only 4 percent of full professors and 10 percent of assistant and associate professors in computer science are women. Some schools have much higher percentages; at the University of Massachusetts at Amherst, for example, women account for 18 percent of the full professors.

We decided to see how women are doing in AI, a relatively young field.[8] We were deluged with offers by both senior and junior AI women to talk about their problems and successes, but while everyone was happy to talk openly about their interests and achievements, no one wanted to be quoted about gender-related obstacles they've met. A few said they'd lose their jobs if they spoke on the record; the discussion of individual problems is therefore anonymous. However, we also highlight the work of a handful of the dozens of scientists interviewed, who communicate their excitement about the future, their commitment to quality work, and their desire to encourage more women to choose AI as a career.

Is AI Different?

We started by looking at at the representation of women in AI publications and conferences. While these statistics do not necessarily indicate what proportion of AI scientists overall are women, they do provide a context for examining how women are faring generally in AI. Women represented

- 10 percent of the program committee members at 25 AI-related conferences over the last three years;
- 8 percent of the invited speakers at seven AI-related conferences;
- 9 percent of the principal presenters at AAAI '91 and '92, and 11 percent at the Canadian AI '92 conference;
- 9 percent of the editorial-board members of 17 AI journals and magazines.
- 9 percent of the authors in *IEEE Expert*, *Artificial Intelligence*, and *AI Magazine* combined over the last four years;
- an average of 9 percent of the authors in five other domain-specific journals and transactions, ranging from 4 percent (in pattern analysis and machine intelligence) to 37 percent (in user modeling);
- about 25 percent of AAAI's executive councillors; and
- about 8 percent of AAAI fellows.

The representation of women in academic institutions varies tremendously, and the numbers mean different things at different institutions (0 out of 4 isn't the same as 0 out of 40). Many computer science departments have no female professors, while one has more women than men. It was impossible to count the percentage of women among AI graduate students, since schools handle these numbers differently. However, a few reported that around 10–15 percent of their computer science graduate students are women, and that the number of female applicants has decreased in the last two years.

The women we interviewed pointed to a particular aspect of AI that might have reduced the number of women in the field. A necessary part of early AI research was Lisp. Working with Lisp required Lisp machines, which were only found at the first and few schools involved in AI, expensive schools like the Massachusetts Institute of Technology, Stanford University, and Carnegie Mellon University. A small group of men at these institutions were thus the first members of AI's "inner circle." AI has recently been applied to other, less expensive platforms, and the inner circle's proteges (and their students) have begun to spread out to other private and public schools across the country. Yet many still feel on the outside of the circle.

One senior interviewee characterized these early years of AI as "far out" and its adherents, struggling to earn credibility, as arrogant. "It was like a frontier atmosphere: it drew people who could compete and go out on a limb without being right. This usually isn't women. The women who 'made' it were the ones who had advisors in the original inner circle. Besides, early on, more women than men were horrified by the idea of building a machine as intelligent as people."

But as AI has since developed, some women now see it as a "natural" place for their research: "AI has more cognitive aspects than does computer science. Since women are generally more introspective, attuned to psychology, and more verbal than men, AI has a natural draw." Another woman who believes there are more women in AI than in computer science said it's because AI is a newer field "with less baggage," so it offers good careers with fewer stereotypes. Other women noted the "scruffiness" of AI and its connections to "softer" sciences like education and psychology. On the other hand, the stereotypes often break down: One woman noted that her female natural-language colleagues come from heavy math and linguistics backgrounds.

Obstacles

So what do these AI scientists say about their careers and the environments they've worked in?

Small numbers

One woman likes the unbalanced percentages between genders. She is used to working with men and admits the ratio gives her more visibility, with more positive than negative repercussions: "People remember me much more than if I were a man." On the other hand, she noted that some men claim reverse discrimination, where women have received what they consider undeserved awards.

She also said, "The women in the department are not particularly close, partly because there is such a small selection of us...The chances are small that we will find other women that we really want to be close with...Also, I think that most of us women are pretty strong and have learned how to survive without a support network. That's not to say it wouldn't be nice to have one, but I don't think there's a lot of interest — as long as life is not terrible for women, [we] might as well just get science (or one's private life) done, instead of meeting about being women in science."

Another woman commented, "During my many years of study, I came in contact with one female professor – first-year music. I had no role models. In fact I was often the only woman in my class. I was the only female PhD in my program and for many years the only female faculty member in my department."

From another: "I had few female peers and fewer female professors in graduate school. The ones who 'made it' didn't have the time nor often the inclination to help younger female precolleagues."

And from a leader: "I have a selfish motivation in wanting more women to participate in the field. When a group wants a woman to give a speech, I am often the one called. I need to have others share the work load."

Many women raised the issue of tokenism. "I don't like being the sole person fighting a battle...There is a critical mass needed in both race and gender: You need about one-third representation before you escape from tokenism. Lower than this, it's hard to keep good female workers."

Stereotypes

Women talked about experiences with stereotyping throughout their educational years, at work, in the texts they read, and in gender-biased reviewing.

In education When a male researcher sent us names of potential interviewees, he commented, "It is unfortunate that more women don't enter the field, a failure I attribute to poor, gender-biased education in our secondary schools."

One woman described her all-girls' high school and the stereotyping that its all-female staff passed on to their students: "My math teacher, who had a master's degree in mathematics, advised me against majoring in math in college, saying the subject was too difficult for girls."

Another woman commented, "My graduating class in undergraduate school had 300 men and three women. This environment taught me to be independent and stand up for myself. Since gender discrimination, when present, was rather open, I could talk about it to my teachers and argue that I ought to be given a chance. Most of them reconciled themselves to the situation (which broke their stereotype of women) by not acknowledging the fact that I was a woman. I was promoted to being an 'honorary man.'"

Another talked about the stereotype she was subjected to while in graduate school. "I had this 'Mom' feeling, that I didn't belong there. Three of us were in our 30s with children. Most of the others were younger, with no families. My adviser called me 'Mom' the whole time I was there. And people tended not to talk to me about substantive issues when I had to have my baby with me at school."

Another said, "I cannot remember receiving support from anyone as a student. In fact I remember quite the opposite — discouragement. About half way through my PhD, I became pregnant — obviously not a common occurrence among my costudents, who were all male, or the all-male faculty. They assumed I would drop out of the program. I also had little support from my family, none of whom had gone through college and could not understand my desire to continue my education. Fortunately, I try all the harder when people assume I cannot do something."

In publishing One interviewee's experiences seem to correlate with the *IEEE Expert* author who was worried about her byline: "I've had two papers rejected — I used my first name in both. I've had three accepted, and I used only my initials in those. So now I submit papers with initials only; it doesn't hurt, just in case."

Gender-biased language annoys several of the people we spoke to. While it may seem trivial to some, these women said it distracts them from their work. One said, "In the AI linguistics class, we found sexism in all the example sentences. For example, the active person was always male: 'John kicked the ball.' Women sometimes appeared in the passive role: 'Bill threw the book at Jane.' The one exception was 'Mary mended the sock.' Many of the women in the department were incensed at this, because it is blatantly sexist, totally unnecessary, and easily avoided. If AI is to attract and keep women's respect and interest, this sort of thing should be tackled first."

At work Two women mentioned problems at work with "wallpaper" backgrounds in graphical user interfaces: "My colleagues just don't get it — why I'm uncomfortable with seminude Windows displays." In a similar vein, another said, "I'm fed up with the alias 'gradstuds' on the network, and nongender-neutral language. This kind of politics saps my energy away from my research."

One professor described a contentious work environment. When she disagreed with some of her male colleagues, they told her she doesn't know how to be a wife or a professor. She believes they would never talk to her like that if she were male, or shout at her as they have. Taking any disagreement with a woman very personally, they get angry easily.

Two-body problems

Interviewees often raised dual-career issues, often called "two-body problems," which are no different for people in AI than in any other field. "When I was in grad school, my husband was a postdoctoral fellow at another university, so we met on weekends. When we got jobs in the Northeast, we were still 180 miles apart. Finally, after three years of separation, I got a job near him and will be moving there. All dual-career couples have to face this problem."

Another feels both insecure in her job and "stuck," since her husband has tenure: "If I were not happy, I couldn't do anything about it." They have both compromised their careers and personal lives: After living apart for years, they left good jobs and had to build new careers.

A leader in the field said she has benefitted from the fact that her husband is also in AI. He not only understands what she is doing but supports her efforts and values her achievements. Many women don't have the male support she does.

Parenting

Many of our interviewees are mothers as well as scientists. One has three children, and twins on the way. Having worked in industry, she recently finished her PhD. She has found both supportive and unsupportive advisors and managers of both sexes; those with children understood parental pressures and therefore were more supportive. Despite her busy schedule, she is involved in local professional-society activities as well as Girl Scouts.

Another said she had her child by Caesarean section and was back at work in two weeks, because her employer would not allow any more time off.

Asked about her daily schedule, a well-known researcher said, "I work every waking hour." 60- to 80-hour work weeks occur regularly in all scientific disciplines, she said, and she expects this pattern holds for many people through the tenure and promotion years. Science and parenting leave no time to do anything else, such as sports or exercise. She said she feels like a field marshall handling logistics and replanning, or a juggler with plates in the air.

Another interviewee has to contend with long commutes. She said, "I live three hours from my graduate school so that I can live with my husband and child. I put up with many hours of travel and expensive child care."

"There is no good time to have a family," commented another researcher. "Life never gets easier (well, maybe during retirement...) Few women who get pregnant in the middle of their studies finish their PhDs, but plenty of men get PhDs while their wives have children. Many women have children first and then go for a PhD...I doubt whether there is much chance for a close family life if both parents are in academia."

One woman with small children advised other mothers to accept the fact that work comes before family sometimes and that family comes before work sometimes. Unfortunately, the children always get sick just as some deadline is looming at work.

On the other hand, one woman said that having two children did not interrupt her career at all. She was able to continue to work full time, getting adequate support at home and at work.

Social interaction

Candy Sidner, a AAAI fellow and a member of the research staff at Digital's Cambridge Research Laboratory, talked on the record about the differences between working in a place with few female peers and a place where women comprise a sizable proportion, a "critical mass." Her lab has six women among 22 principal researchers, enough to change the environment, including how people interact and treat each other. She explained, "I think men have a hard time collaborating with women (in either research or general lab activities) until there are enough women around that they feel comfortable and have productive expectations of women colleagues. When you have a bunch of women colleagues, you usually find more than one you respect, and it changes your perception of the whole group!... When enough women are around, the fraternity atmosphere becomes a society, a community." Sidner also believes that women value consensus more than do men, and that they compete with and critique others differently. She attributes such differences to socialized skills learned in childhood, and she sees the same forces at work today in her nine-year-old daughter's experiences.

Another woman said, "When I first started, my research group consisted of older students, including two women. Later, younger men joined, and I was the only woman. The character definitely became much more of a 'male banter' style of interaction — which I really disliked."

Another woman commented on the banter: "It has grated more and more on my nerves to hear some of the stuff guys think they can dish out. Many of the male TAs joke (or even say seriously) that they make female students go out with them for grades. Male friends tell me about jokes they make with male professors about women in or out of the department...I have heard many guys make comments like 'The women on the faculty are technically far below the males,' which is patently not true by any objective measurement...Male friends think that in the name of friendship they can be as coarse or vulgar or make as outrageously sexist statements as they like; I think they do this more for shock value than anything else. None of this is particularly terrible, but can get annoying after the first 50 times it happens. As a woman in science, I have had to develop a thick skin and decide what is worth fighting about and what is not."

Disproportionate male-female ratios made it difficult for several women to interact socially with other students, sometimes being the only woman present. "As a grad student, I used to feel self-conscious about joining my male peers for a pizza. Now that I'm older, I don't care what other people think. I know I'm not doing anything wrong." Another added, "Being a single woman is the hardest. Heterosexually coupled social events are very important for making contacts."

Naturally, AI conferences are generally male events. A few women referred to their discomfort dealing with the conference cocktail party syndrome. One said, "When I used to go to conferences, some man would approach me, at first seeming like he was interested in talking about AI. I couldn't get rid of him. My fellow graduate students (all male) laughed at me, and gave me advice: Be really rude to people, wear crummy clothes, and look as ugly as you can. Eventually, I stopped making eye contact or being very friendly with anyone at conferences. That's not very helpful for making connections in the field, but better for staying safe. Over the years, I've developed an air of control around myself and I don't have to hide so much, but I remember how annoying it was at the time. And I realized where all the jokes about conferences come from. Somehow, I did not think it would apply to 'intelligent' men."

Invisibility

Women at various career levels mentioned invisibility: "I'd say something in my group, and no one heard me. When the person next to me repeated my idea, everyone complimented him. This happened several times. Maybe it's female tentativeness, looking for agreement before standing up for what you believe. After a few times, I said to the person repeating my idea, 'Yes, that's exactly what I was trying to say earlier. Thank you for rephrasing my idea.' The group slowly got what was happening, and it has stopped."

A well-known woman said, "When I interact with industry, I am often ignored in favor of my male colleagues, even when I am the senior scientist and principal investigator. One experience remains in my mind, a visit from a granting committee: A colleague and I, as coinvestigators, were up for a grant renewal. We had invited a junior member of the department to participate in the new grant. While the funding agents, all men, spent three to four hours questioning us, they did not address one question to me. Instead they asked my coinvestigator and the junior man, who had not even participated in the previous grant."

Finally, another leader in AI said, "Companies are worse than universities. A company is much more structured; you have to 'fit in.' They tolerate me because I bring in money and do my work. I'm never given credit or asked my opinion. I feel personal invisibility here...it's an emotional drain. I never felt that in academia. Other companies have significant equal-opportunity efforts. You won't find token minorities there."

Competition

Several people talked about the issue of power rather than gender, of being in the "in" group. One person described the "self-selecting good-old-boy network" based in well-known, large universities. People with "new" ideas, like fuzzy processing or neural networks, could not break in, so they left mainstream AI and started their own "clubs." Several people emphasized that problems with uncooperative or unsupportive advisors can happen to anyone; the difference is that women with lower self-confidence sometimes fault themselves for such problems, and leave programs rather than fight for a new advisor.

Several people talked about personality issues, not necessarily tied to gender. In their early years of education, women are often encouraged to be quiet and not respond to criticism, cultivating bad habits for a successful science career where researchers must sometimes get into the intellectual fray. Quiet, retiring men have similar problems. One woman suggested picking a school that fits one's personality; some schools have a reputation of being more nurturing than others.

One woman feels especially isolated: "It has not been easy as a faculty member here — it makes the situations in undergraduate and graduate school seem trivial. I do not have a mentor in the field or in this department. This makes it incredibly difficult to publish or get funding. It is difficult to get the respect of one's peers because they assume you were hired on the 'woman track' and therefore are not quite in their league. It is difficult to get the respect of the graduate students for very similar reasons: If they perceive that the other faculty have no regard for you, they see no reason why they should either. For instance, I was abused by an ex-student of mine who tried to publish my paper under his name, and the department and the university offered no help... I am considering a job in industry. If I leave academia, it will be with a great sense of personal failure. The fact that I have survived thus far is mostly due to my 'never-say-die' attitude fostered by my super-supportive parents as well as my super-supportive husband."

Another said, "The attrition rate of female faculty here is nearly 100 percent. The environment is survival of the fittest: You have to compete to get an advisor, compete to get an account on a machine. If the university creates an environment in which people must struggle and claw to get basic resources to do their work, it ends up selecting a population for those skills and not necessarily for academic ability. And on average, this process takes a higher toll on women. This wastes a lot of human resources."

"We women have been taught to put ourselves down," another interviewee said. "We're more objective in describing our projects and results, and not willing to play the hype game. Over time, history will give women credit for not hyping their work. The problem is, we're competing with 'hypers,' and at any given time a good sales job can determine who gets funding. Of course, most men aren't willing to hype their results, either. Hypers represent a small piece of the AI community."

An ex-AI person also addressed the question of hype: "I was involved in AI three different times. Each time I had to deal with people who felt they had to oversell what they were doing to get funding. Often they were young, eager men with little sense of perspective, and no experience in marketing. At the first site, a company, we began with six female managers out of 20. The women seemed to be more reasonable, with more sense of balance. It's a question of research versus production: You can promise you'll do research, but you can't promise you'll produce. By the end of one year, all six had left [and] another woman had been hired."

Two women talked about peer competitiveness: "My biggest gripe is that my fellow female students, rather than being timid and unassuming, were fiercely competitive. Most of the science students I knew were unwilling to have any kind of intellectual conversation about anything for fear of sharing information. The close friends I made were those who could get past this barrier. We studied together and shared insights — these were my most fulfilling times at school."

Regarding access to granting agencies, one woman said, "The senior people were reluctant to let us junior researchers have any contact with the funding people who came to our site. Everyone was out for themselves."

The glass ceiling

As far as promotions go, several women attested to the glass ceiling: "I don't think it's due to any malevolence on the part of management, but simply because most of management is male and feels more comfortable dealing with other men."

A senior researcher believes that a woman's gender-related experiences depend a lot on her generation. "The greatest change has come at the bottom of the pyramid; junior faculty members have so far not encountered obvious obstacles. It's different at the top." While she sees herself in the vanguard, the only woman in many situations, she does not consider herself part of the "in" group. She believes women can go further in industry than in academia. Evaluations are more structured and above-board, and depend on more objective criteria.

Others also mentioned the pyramid effect: "I'm almost uniformly the only woman on a program committee, the only woman among a list of invited speakers. Men make up the reviewing committees, and they choose mostly men. There are women in the audience, but not where I am; there is no one ahead of me to fight for me."

Recommendations

So what can women in AI, their male counterparts, and their employers do?

Be good at what you do

Many gave this advice: "The most important thing is to believe in what you're doing, do a good job, and don't be shy about talking about it and advertising it."

"Never think in terms of gender where work and ability are concerned."

One person put it succinctly: "Be good, hungry, driven, and aggressive."

Get good training

Several people advised going to a graduate school with a good reputation: "Don't compromise. You'll meet contacts that will help you for the rest of your career."

One recommended a women's college: "It's an excellent environment for academic women. At a small school in a big university, you get individual attention and mentoring, but have access to all the resources you need. My school has an official policy of being sensitive to many needs — those of women, minorities, the disabled — without being patronizing or lowering standards. And since it is a women's school, women have to be trained to take leadership positions."

Be aggressive

"Men have what it takes to run large research groups: aggressive, dominating attitudes. You have to be egotistical. You can be egotistical and still act like a woman."

"Look at yourself and what you do, and see that it's great. Convey that in your proposals. 'I'm great, and I'm the only one in the world who can do this.' If you show doubt, you don't get funded. Look at the large, funded programs, and what they claimed when they asked for funding. Yes, this is egotistical, but it's necessary to win funding."

"As a graduate student, you'll be fighting for space, fighting with other graduate students. And most of them will be men. You don't have to be calm and quiet about it."

"Almost from day one I have been a fairly visible person in my department. I took some nontrivial courses from the beginning and audited others (good for getting to know more faculty and expressing interest). I attend a lot of the department parties. I go to talks presented by visiting scientists, even those not in my field. I talk to students in all areas of research, just to find out what goes on in the rest of the field. In my second year, I was on the executive board of our department graduate student organization, and then became coordinator of the graduate student talk series. I'd advise any new student to do these kind of things — not so much for visibility, as for his or her own intellectual benefit."

Be productive

Many of those we talked to pointed to volunteering in various ways to get oneself known: Call a technical-committee member, send your resume to a book reviews editor, volunteer to give conference talks for your colleagues, write conference papers and book chapters, run workshops, or organize new workshops. One woman said, "Write papers for workshops. They're small, you'll meet people in your field, names become faces, you'll feel a part of a community. National conferences can be enormous and intimidating. Also, workshops are meant for preliminary work. They are a good forum for graduate students. Getting a paper accepted is real validation — it can be a big boost when you need one. Rewards in research can be few and far between."

"It's best if you're the sole author. Second best is to be the first author in a group-authored paper."

"Write a textbook; if possible, one of the first in an area. In fact, just write a lot. This is especially good for shy people."

Another added, "It's better to have something worthwhile (a finished project of some sort, such as a good dissertation) to support your claims to fame."

Be political

Start up new databases of potential candidates where there are none. Use and support the databases that are growing. For example, the Computing Research Association's Committee on the Status of Women is compiling a database of female computer scientists in the US and Canada.[9] Joan Feigenbaum, a researcher at AT&T Bell Laboratories, has finished the first round of data collection and is now constructing the database with information on 500 PhDs and women enrolled in PhD programs. The database will be updated regularly. The committee would like to increase coverage but needs more resources from other groups.

"Nominate women for awards. Invite or request that specific women be invited to give talks at your school or workplace."

"I made a deal on women hires... I agreed to pay the salary of one woman out of my grant money if the dean hired two women (and of course one had to be in AI or it wouldn't work to pay her from my contract). As a result of my challenge, we made offers to two women. One is coming. The AI person turned us down because of a two-body problem."

"Don't get romantically involved with a professor, on or off your committee. People will say you graduated only because of his influence."

"Try not to let the nonsense get you down-people say and do a lot of stupid sexist things, and most of them will have zero impact on anything except possibly your self-confidence. Don't let them have even that impact."

Be professional

"If you have a disagreement with someone, and his anger gets out of control, discuss the issues in private. Always bring another person in the room with you. Tell him calmly that his behavior is unprofessional. If he is still yelling, leave the room. Women must have professional standards of behavior; for instance, they need not allow anyone to yell at them. Always evaluate the professional role you're in at the moment, and what the best course of action is for that role, rather than how a woman would react."

Find a mentor

Having a mentor certainly isn't a new idea, but it is an important factor. A few people mentioned the value of male versus female mentors. One person said, "You have to have a male mentor — mostly because there aren't many female ones around to wait for. I was lucky to have had two excellent male mentors. They made sure I survived, and they shared their network with me."

A number of professors said they want their own mentor, not necessarily female, who understands the biases that exist and could help them find creative ways to deal with situations.

A few women pointed to their parents or their mothers as having mentored them: "My parents were both medical-school professors. I had role models to follow."

Be a mentor

"Work with all your advisees, not just an inner circle. A star might be lurking quietly in the background."

"Teach those you mentor about politics and business, as well as AI."

"To be a good role model, be the best woman you can. Be a good researcher, and display this to others. Under the current momentum, historical underrepresentation will persist."

"We need more women who are visible at the top."

"My advisor supports a self-directed advising style. He prefers a 'hands-off' approach. This teaches independence, which you'll need later."

"Encourage women to develop and build independent computer systems. Having to demonstrate one's system repeatedly gives a student good exposure and visibility."

A graduate student recommended that faculty members help or talk about things with women students: "It is really good to be working for my [advisor]. She is very outspoken about women's issues and likes mentoring and encouraging women."

Having talked about organizing graduate women's support groups, one professor discussed the need to support and encourage female undergraduates. She suggested having more luncheons and other meetings directed toward them.

Find a support network

Several of the women we interviewed heard of our work on this article through Systers, a network of 1,100 female computer scientists, which one woman called "immeasurably helpful." (For more information, see the accompanying sidebar on Anita Borg, Systers' originator.)

Many people recommended various forms of seminars, lectures, and lunch meetings for women only; subjects included how to write a curriculum vitae, how to give a research talk, how to write a cover letter, the pros and cons of teaching at four-year colleges, and what it's like to be a new faculty member. One said, "The women's group kept my morale high during the arduous trek through graduate school." And another: "These group meetings gave me an idea of who I could talk to about various issues and problems. They provide a reality check: Is it just me, or is some other issue involved?"

"Go to conferences for the feeling of community, even though women are always outnumbered."

"This [university] atmosphere is very supportive for everyone. There are so many streams of AI work that no two people here work on the same thing, so we can afford to help each other."

"Travel with another woman and get rooms next to each other. Plan ahead when you know you'll be arriving at your destination at odd hours."

"Take other women's ideas as seriously as men's ideas."

"Share information about how to get articles written, reviewed and published; how to find a good job; networking; how to train your advisor."

A leading researcher attributes part of her success to collaborating with very good people. She and her colleague were able to build the costs of travel to work together into their funding request. If money is tight, she suggests new means of communication, such as videoconferencing.

Two-body solutions

"Companies that have multiple locations should be sensitive to this issue and facilitate internal transfers for employees in such situations."

"Get your name established before you have children."

"Take turns with your partner on making the hard choices. It's my husband's turn now — he's quitting a great job to move with me, and take a leap into the unknown. We've decided we'd rather compromise our careers than our personal lives. But right now, we have no idea if this is the right decision..."

One mother takes advantage of creative scheduling. She and her husband each work four days a week; she stays home on Mondays, and he on Fridays. They use child care three days a week. Describing her career as on "the outer periphery of the inner circle," she said, "I feel like I'm treading water, but I like my life...We'll keep this schedule until both kids are in school, about eight to 10 years. This is a rewarding option for both of us, but we must work efficiently and schedule carefully." Asked about travel, she said each spouse goes to only one or two conferences a year. Another mother recommends not working past 5 p.m. or on weekends.

One interviewee wants to see more programs like Boston's Parents in a Pinch. Many working parents need emergency child care now and then but have difficulty finding it.

Suggestions for managers and institutions

A number of people suggested more flexible work environments. One woman said, "Employers should acknowledge the demands that come from combining career and family goals...For example, a woman should be able to choose to work less than full-time without sacrificing all employee benefits. It is often difficult for women to find appropriate positions that will let them work less than full-time under any conditions. If women are kept out of the work force by inappropriate conventions, everyone loses." Another woman chided, "Don't punish men who decide to spend time with their families."

Most people would like institutions to foster new and existing mentoring programs. Several schools, such as the Stevens Institute of Technology[3] and the University of Texas at Austin,[10] have been taking the lead, along with the Association for Women in Science.[4] Hosting female-only meetings and seminars was a common suggestion (although one woman objected to these groups as sexist).

Another participant suggested, "Encourage study groups. Successful people in science work in groups. We experimented with this, introducing students to each other for group work, and they continued (meeting voluntarily). It was very useful and did not cost a lot of money. We also schedule mentoring labs after class."

In terms of family life, many want increased child care spaces for the staff's children, and more baby-sitting services offered at conferences.

Eliminating bias Participants made these suggestions regarding various kinds of bias: "Examine policies and procedures for possible bias in reviewing, hiring, and promotion." "Clarify and publicize policies requiring nonsexist language usage in all published material." "Give your junior people access and exposure to the funding process."

Dealing with critical mass Institutions need to take responsible actions to change the persisting percentages. Here are some suggestions: "Sometimes, once one or two women are involved in something, others get involved too. They feel more comfortable, not so alone (the snowball effect)." In a similar vein: "Hire three or four women at a time, to get beyond the critical mass. Grant additional postdoctoral slots along with hiring new faculty, so that peers can support and mentor each other." "Examine organization-sponsored activities for an 'old-boy network' style of doing things, and make an effort to include new blood. Actively solicit from a wider spectrum of candidates." "Make sure qualified women get the scholarships and research posts that tend to keep students in the program longer and eventually do PhDs."

One professor talked about the importance and difficulty of hiring and keeping women and minorities. "The dean challenged his department units: If any of them hired one woman or minority, he would use his discretionary funds to pay the salary of a second woman or minority hired into the same unit. His rationale is that, since keeping them seems to be very difficult in a white-male-dominated culture, it is important not just to add tokens, but to add real critical mass and create the culture that's necessary for women and minorities to flourish."

And finally, one woman offered a perhaps obvious but especially important piece of advice: "Small gestures toward inclusion mean a lot. Make women feel welcome. But this is not just about women: Any underrepresented group needs to feel like they are first-class members of the community."

Some women we spoke to had never experienced overt sexism. Perhaps the "old-boy network" is more historical than real, as one woman put it. Another reported that women are being promoted faster than men at her site. No doubt some problems are due to individual rather than to societal quirks and inadequacies. In any case, individuals and groups are making changes. Some organizations and committees go out of their way now to look for balance.

The underrepresentation problem does not derive from the fact that female scientists are consciously ignored, but that

1. unconscious biases drive some women to quit science, and
2. not enough women (and minorities) are entering scientific fields in the first place.

One woman believes strongly that we must "improve primary and secondary education, especially in mathematics, the basis of all science. Today's children don't know math or the fun of it."

Since AI is a relatively young science, and the number of women is small to start with, there are not enough women at the necessary career levels to reach "critical mass." Several women talked about being deluged with requests to speak at meetings or sit on committees; since it is "politically correct" these days to appear unbiased, those women who are qualified and have established names are asked to do much more than they have time for.

The interviewees emphasized the need to encourage people, and especially women and minorities, to pursue AI and other scientific careers, and then to find ways to keep these people involved.

Of course, there were many positive comments, too, especially how much these women are enjoying their research endeavors. Not surprisingly, the most common suggestion we heard was to do high-quality science. Women are clearly doing their part, for themselves and for the field.

References

1. E. Spertus, "Why Are There So Few Female Computer Scientists?" AI Tech. Report 1315, Publications NE43-818, Massachusetts Inst. of Technology Artificial Intelligence Laboratory, Cambridge, Mass., 1991.
2. "Women in Science First Annual Survey," *Science*, Vol. 255, Mar. 13, 1992.
3. A. Reyneri, "Shaping the Future," *Engineering Horizons*, Women's Edition, 1991-1992, Stevens Inst. of Technology, Hoboken, N.J., 1992, pp. 42–45.
4. L. Friedmann, "More Women in Science: A Goal for the 1990s," Nat'l Research Council New Report, Vol. 42, No. 2, Feb./Mar. 1992, pp. 11–13.
5. V. Dahl, "How to Attract More Women to Computer Science," Tech. Report 91-11, Computing Sciences Dept., Simon Fraser Univ., Burnaby, B.C., Canada, 1991.
6. G. Gruman, "Getting Women and Minorities into Computer Science," IEEE *Software*, Vol. 7, No. 4, July 1990, pp. 87–89, 92.

7. *Women into Computing: Selected Papers, 1988-1990*, G. Lovegrove and B. Segal, eds., Springer-Verlag, New York, 1991.

8. C. Metselaar, "Gender Issues in the Design of Knowledge-Based Systems," in *Women, Work, and Computerization*, I.V. Eriksson, B.A. Kitchenham, and K.G. Tijdens, eds., Elsevier Science, New York, 1991.

9. Computing Research Association, Suite 110, 1625 Massachusetts Ave., N.W., Washington, D.C. 20036.

10. "UT-Austin Engineering College to Encourage Women to Meet Technical Workforce Demands," *UT Engineering News*, Univ. of Texas, College of Engineering, Austin, Tex., 1992.

Further Reading

- *Computing the Future: A Broader Agenda for Computer Science and Engineering*, National Research Council, National Academy Press, Washington, D.C., 1992.
- C. Leighton, "Women: Scarce at the Top," *Computerworld*, Mar. 23, 1992, p. 33.
- C. Marenghi, "There Are Cracks, but Glass Ceiling Is Still Mostly Intact," *Computerworld*, Feb. 3, 1992, p. 85.
- A.M. Russell, "Packaging Your IQ: Women Engineers Take the Wraps Off Their Stereotypes," *Graduating Engineer*, Feb. 1992, pp. 92–94.
- *Women in Science and Engineering: Increasing Their Numbers in the 1990s*, Committee on Women in Science and Engineering, Office of Scientific and Engineering Personnel, Nat'l Academy Press, Washington, D.C., 1991, ISBN 0-309- 04595-9.

Profiles

Eva Hudlicka
Senior scientist, Bolt Beranek and Newman
Eva Hudlicka is a two-field scientist, working in both AI and cognitive science. Her overriding interest is in human information processing and human cognition. Her goal is to build systems that enhance human use of information and knowledge.

Her AI work deals primarily with model-based reasoning and its applications to expert systems, training and tutoring, and information management. She emphasizes one central idea in this work: By representing the domain of interest in terms of a model that is consistent with a person's mental model of that domain, an expert system could provide better explanation and support training.

She was a project manager for a NASA-funded project to develop an expert, model-based aiding system for commercial aircraft pilots. One of the outcomes of the project was a development environment for constructing causal model-based systems. Now Hudlicka wants to find funding to apply these techniques to other domains, particularly to biology and medicine, and eventually to extend the techniques into multimedia environments.

Hudlicka earned her PhD in AI at the University of Massachusetts at Amherst. Afterwards, she began shifting toward cognitive science and computational psychology. She is now building computational models of human information processing, focusing on such models as planning, decision making, and complex, skilled behavior. She is particularly interested in the memory structures that produce intelligent behavior and the processes that operate on these structures. She and her colleagues are looking at the existing "unified theories of cognition," such as SOAR and Act*, and are building a testbed that will let researchers experiment with various models of human information processing.

Hudlicka says she never felt discriminated against because she was female. The University of Massachusetts was a fairly nonsexist environment, and the presence of "quite a number of female grad students" certainly helped. On the other hand, the general "female" characteristics, such as lack of confidence in one's own ideas, did affect her. "I remember many times talking to people who were so self- assured about their work and just 'knew' they were right — and early on in my career I was only too ready to assume that indeed they were and I was wrong. This hurt me during the selection of my dissertation topic. I think I might have focused on the type of work I do now much earlier if I had had more confidence in my intuitions-which turned out to have been right most of the time!"

Suggestions:

1. Look for supportive people; when you find someone who isn't, don't assume it's your problem, go look for someone else.

2. Trust your ideas and intuitions — and, of course, be technically good so that the intuitions don't come out of thin air.

3. Don't ignore politics. Having your ears open and being somewhat politically aware is essential to "getting ahead." I don't mean winning a Nobel prize — I mean simply being able to get the money to do the research you are interested in doing.

4. Mentoring programs are great, a good way to ease difficult transitions.

Janice Glasgow

Associate professor of computer science, Queen's University, Canada

Mental imagery has been an active area of research in cognitive psychology for a number of years, but Janice Glasgow is one of the first people to consider imagery as a reasoning paradigm in artificial intelligence. Computational imagery involves the ability to generate, transform, and inspect visual and spatial representations of images to retrieve and reason with information not explicitly stored in long-term memory. For example, a spatial image of a chess board could be reconstructed and then analyzed to determine if a particular motif is a subimage in it.

Glasgow is developing a knowledge representation scheme for imagery. This scheme represents knowledge in terms of a semantic network in long-term memory, organized according to the structural and conceptual hierarchies of the image domain. She has two working-memory representations for visual and spatial reasoning, corresponding to distinct components in human cognition. This research evolved out of her earlier work on programming languages for AI. She was involved in the development of Nial, a high-level programming language based on the mathematics of array theory. The mathematical basis of this language now provides a metalanguage for specifying the representations and primitive functions for computational imagery.

One of the most exciting aspects of this work is an application she and her colleagues are developing with an international team of crystallographers: a knowledge-based approach for molecular reconstruction. The long-term memory model for molecular images is being constructed using crystallographic databases containing over 100,000 previously determined scenes. The researchers are integrating the tools and techniques of computational imagery with aspects of earlier work on Crysalis, recent theoretical advances in protein crystallography and AI, and a more case-based approach to reasoning. This is an ambitious project, with the potential to greatly assist in the determination of protein structures. Currently, a lab may take several years to determine a single structure. Glasgow's group hopes to have a prototype knowledge-based assistant system within a year or two.

Glasgow also believes that imagery is an important alternative reasoning paradigm. According to her recent studies in machine learning and database discovery, this knowledge representation scheme may provide powerful tools for classification based on spatial reasoning.

Glasgow was the program cochair of AI '92 and is now president of the Canadian Society for Computational Studies of Intelligence, one of the oldest national AI societies in the world. She is also a principal investigator in the Intelligent Robotics and Intelligent Systems Federal Center of Excellence and the principal researcher on an AI project for the Canadian Space Agency.

Regarding career development for women, she said, "I think things have improved in the last 20 years. There is a greater awareness among both men and women...Only in the last few years have I been able to find female scientists at similar career points to me. It has been very supportive to talk to them and share experiences." Glasgow believes more women need to hold positions that make a difference-on granting committees, program committees, as senior administrators in academia and industry, on boards of directors.

Suggestions:

1. Younger women should seek out peers as well as role models. They can be especially supportive.
2. Take a leading role: Present a paper if you are a coauthor, organize conferences and workshops, act as principal investigator on grants and contracts, get involved in activities that bring you to the forefront. This means you have to sometimes get aggressive, which is difficult for most of us.
3. Women on program committees need to nominate other women as invited speakers. There are a lot of supportive men who are also willing to help promote women, but sometimes just need a bit of awareness. I have had mainly positive experiences on committees when I suggest bringing more visibility to deserving women.
4. Women need to educate one another on how to react when obstacles arise. The Systers network has helped a lot.

Janet Kolodner
Professor, computer science, Georgia Institute of Technology

As one of the coinventors of case-based reasoning (and a recently elected AAAI fellow), Janet Kolodner is applying her research in several real domains. Most importantly, she wants to make case-based reasoning do something; that is, make it work in real situations.

First, she is asking what it means for computers or people to be creative. She and her students have worked on a program that plans meals for people with dietary restrictions. Such software must remember cases, suggest nutritious but not boring meals, be aware of correct textures and how real food should taste, and come up with various possibilities. The program was able to come up with breakfasts that matched what human dieticians were doing, but the meals were not very creative. In another program, Kolodner and her group added brainstorming and evaluative components and got far more creative solutions. They are now looking at creative problem solving across several different design domains: lesson plan creation, meal planning, software design, and architecture.

Kolodner is also using what she's learned about case- based problem solving to build interactive systems that can help people solve problems. The systems provide three major services:

1. They help people identify what they should be paying attention to as they solve problems.

2. They point out the challenges that people are likely to encounter when they try to carry out solutions in the world.

3. They suggest solutions to problems posed by the user.

They do this by presenting cases (collected from experts) that teach an appropriate lesson and that the user has probably never seen before. The systems augment the memories of people, allowing them to do case-based reasoning even though they themselves don't have a store of their own cases.

One part of this project aims at helping elementary- school teachers teach science. Kolodner's group is collecting the experiences and lesson plans of experienced and novice teachers. With help from the novices, they are identifying the sorts of problems teachers need help with; from experienced teachers, they are collecting solutions to those problems. This information is then made available to the teachers who need it. She is also looking at the use of this technology in design, and in particular, architecture.

As a senior woman in her field and on her campus, Kolodner is asked to take on a lot of extra responsibilities. There are more senior men to share similar requests, so each one's burden is less. Kolodner said it will greatly help the current batch of female scientists to have more women around.

Suggestions:

1. If you're not sure of yourself, pretend! Act self-confident.

2. Go to conferences, get on panels; create your own new forum, start a new journal.

3. More than just a few people need to suggest names for speakers, panels, and committees, so that a broad range of candidates are considered.

4. Grit your teeth and go after funding. To open doors, invoke the name of someone known in your field.

5. If you are one of those known researchers, tell your junior colleagues to use your name to help them get funding.

Lori Pratt
Doctoral candidate (scheduled to graduate this month), Rutgers University

Lori Pratt had the advantage of a strong role model at home: Her mother is a PhD who is very active in the women's movement and who has always supported her daughter's interest in science. Pratt has tried academia and industry, operating systems development, symbolic AI, and neural networks. She has always been interested in evolution and biological self-selection-ideas that have led her to study problem solving, learning, and questions about how new knowledge can be integrated into existing systems. She's particularly intrigued by the novel computational properties that emerge when massively parallel systems are used to solve problems. Pratt's most active current research explores the relationship between AI and neural networks — two fields that she believes have a lot to learn from each other.

Pratt discussed the insights she's gained from AI: "Knowledge is power, and you learn better on the thresholds of what you know." In her doctoral research, she applied this idea to neural networks. She studied how a neural network that's been trained for one task can be mined for information to be used in a related problem. For instance, information from a neural network used for speech recognition in a general population might be used to help train a new network for a specific speaker. Or a medical diagnosis neural network built using information about patients in one geographical location might be used to help train a network for a different patient population.

Pratt's research has also explored more fundamental questions, such as how to obtain a neural network that uses a small amount of storage, how to visualize network learning dynamics, and how to construct large networks modularly.

She is just beginning a new job as an assistant professor in the math and computer science department at the Colorado School of Mines, where the computer science faculty women will outnumber the men. And two of the three women are in AI.

Suggestions:

1. Go to high-quality conferences where you can get inspired by colleagues' work and the sense of community.
2. Husbands and wives should take turns when one is offered a positive career move.
3. Be a good role model: Do good research, and display this to others.

Luqi
Associate professor of computer science, Naval Postgraduate School
The emerging problem of the 1990s, according to Luqi, is software quality, in addition to the continuing battle of the 80s to solve productivity problems. Software failures sometimes have serious consequences, including death, injury, and financial losses. These problems are often caused by people failing to understand and communicate system and resource requirements. Huge amounts of resources are wasted each year building elaborate systems that do not solve the right or the entire problem. Luqi is particularly interested in software automation, since it can improve software productivity and reliability.

Her work in computer-aided prototyping involves automating development tasks currently carried out by engineers. She and her Prototyping Research Group are trying to

- use specifications and abstractions to make prototypes easier to construct, understand, and analyze,

- use advances in software modeling to produce tractable formal models of problems, criteria for evaluating solutions, and solution methods, and
- experimentally construct computer-aided prototyping systems (CAPS) to demonstrate the feasibility of automation in software development.

Once she and her colleagues have formulated domain models using software-engineering techniques, they apply AI technology to automate the solution processes in relatively narrow areas of tool development.

The prototyping approach uses prototype demonstrations to determine and update the requirements of a proposed system during both requirements analysis and the evolutionary life cycle. Such demos expose misunderstandings and enable software developers and their clients to converge to an accurate formulation or a reasonable estimate of the system's goal. Prototyping tools provide decision support for formulating a design and establishing system feasibility; for example, evaluating hard real-time deadlines for software functions relative to proposed hardware configurations.

This research started a new area of investigation, combining general software engineering for system modeling with AI automatic-programming techniques to achieve software productivity and quality. Luqi initially had trouble convincing people that the problems had substance and that solutions were possible until her prototyping systems started to work. Progress depended on her maintaining confidence in what made sense in the face of initial discouraging comments by peers; such criticism actually motivated her not to quit. To prove that these new ideas could work, Luqi invested a great deal of effort and long hours to fill in her students' steep training gaps and to manage the bureaucratic processes for establishing a lab. A system that can demonstrate the effectiveness of new ideas is a very strong argument about the importance and significance of a scientific contribution.

Suggestions:

1. Set high professional standards (no difference for men or women) for your job. Focus on the research, and ignore irritations caused by people with handicapped personalities.
2. Choose research topics with important long-term effects on society. Though important, theoretical papers are valuable only if they can be applied to real problems.
3. Do not submit to unreasonable pressures. Actions motivated by gender discrimination will not stand up under public scrutiny. Most people are professionals, but when you encounter one that is not, stick to your position and defend it using rational methods. Professional success is the best defense.

4. Work with the people around you and the people from professional societies such as the IEEE Computer Society. Warmth, help, and support can only come from good people. Seek administration support when needed.

5. Think of the role of the traditional mother: The lifetime efforts of a large portion of the population are taken for granted. We are lucky to have the chance to follow Madam Curie's footsteps.

6. Remember the words of Albert Einstein: "In the middle of difficulty lies opportunity," and "Imagination is more important than knowledge."

Devika Subramanian
Assistant professor of computer science, Cornell University
Subramanian is interested in both theoretical computer science and AI; having begun her graduate work in parallel program correctness and design, she found the questions of AI more intellectually appealing. She became tantalized, in her words, by "the long-term scientific goal of understanding intelligence through computation and the shorter term goal of making machines smarter than they are today."

In her doctoral research, Subramanian noted that today's systems, intelligent or otherwise, are limited by the conceptualization of the world given to them by their designers. When computational constraints on a task change, people have to reprogram the system. She constructed a theory of how an intelligent system faced with new computational pressures from the environment can automatically abstract its knowledge to solve its goals faster. This saves human designers from the tedium of reprogramming and allows systems to adapt to their environment by reprogramming themselves.

With one of her students, she has applied this theory to the task of optimizing functional programs. They have shown that the suite of optimizations discovered by people over the last 20 years can be automatically discovered by a machine in a few days.

Suggestions:

1. Speak up for what you want, despite others' stereotypical attitudes.

2. Join "women in computer science" groups for peer support.

3. Working independently in graduate school will serve you well in your career.

Jill Crisman
Assistant professor of electrical and computer engineering, Northeastern University
Jill Crisman is researching biologically based robotic systems as well as computer vision techniques for intelligent robotics. She is working with a biologist

to understand how a lobster's central nervous system controls walking, and then implementing this control strategy in an ambulatory robot. They have simulated the central pattern generator, and the command and coordination systems that generate muscle control signals for stable walking gaits.

A second project, building a user interface to a robot wheelchair, involves computer vision and intelligent control. The user would point to a location on a video screen and issue a command such as "go there" or "track that." The robot would then go to the location or follow the target while avoiding obstacles along the way. Crisman plans to extend this interface to control manipulation tasks as well.

Crisman's doctoral research at Carnegie Mellon University dealt with a computer vision system that could detect roads for a robot van. Her system could track difficult roads that had potholes and degraded road edges but no lane markings. CMU's Navlab robot (see *IEEE Expert*, Aug. 1991, pp. 31–52) successfully drove on many of these roads in a variety of weather conditions using Crisman's computer vision system.

Suggestions:

1. Find a mentor. Older and more experienced mentors can often explain the "rules" of your discipline and specialty. A female mentor can provide first-hand advice, although a male mentor might still be able to provide much of the same advice from a different perspective.

2. Find female friends. They can offer great moral support, since they might have encountered many of the same issues.

Beverly Woolf
Research scientist, computer science, University of Massachusetts at Amherst

Because Beverly Woolf's research interests span several fields, the students she attracts come from varied backgrounds, including computer science, education, and the physical sciences. Together, they are designing knowledge- based tutoring systems for subjects ranging from high school physics to emergency cardiac treatment.

About 100 paper mills now use Woolf's tutoring system for recovery boilers. Operators used to have many accidents; Woolf's system was so successful at showing operators how to avoid accidents that insurance companies now require mills to use it in the control room. And the system did not cost a lot of money to develop. Woolf sees a great need in industrial and technical societies for one-on-one training and alternative teaching systems. She would like teachers to have a repertoire of tools at their disposal, including tutoring systems.

A key to building these systems, Woolf says, is involving educators who know their discipline. These domain experts are invaluable during design and testing, because they quickly find gaps in the software. Woolf used a high-school physics teacher over a long period of time to test and refine the physics tutor. Now she and her colleagues are testing their cardiac-arrest tutoring system. Recently, they found that doctors using the program quickly forgot it was a simulation and began acting as if they were handling a real emergency. She expects this system to be ready in about a year.

Now Woolf is ready to take the field to the next level: to create shells that can get more systems produced and installed, helping to teach in multiple domains. One of the exciting things about knowledge-based tutoring systems is that it is "AI-complete" — that is, almost all the subareas of the field, even machine learning, will be involved as applications are developed.

As a woman and a leader in the field of knowledge-based tutoring systems, Woolf finds she is often the only woman on a program committee, the only woman on a list of invited speakers. She's looking forward to the day when she won't be the only one.

Suggestions:

1. Collate and make available lists of qualified female candidates, so that colleagues can use them to recruit speakers and committee members.

2. Encourage group sharing and support: Successful people in science work in groups.

3. Believe in your own work, don't manifest doubt.

4. Break stereotypes: Women don't have to be placid and nourishing.

5. Cultivate a strong personality: Good science is often supported by a powerful and committed personality.

6. Get a male mentor: If your environment has few female teachers, find a man who can be helpful.

7. On the other hand, research shows that female graduate students do better if they work with a female researcher.

Yumi Iwasaki
Research associate in computer science, Stanford University
When engineers develop new designs, they have to get to a fairly detailed stage before they can apply CAD tools to refine and evaluate the model. However, the decisions made during the early stages of conceptual design are very important, and have already shaped the process and the product significantly. Yumi Iwasaki is working on a project that will help designers make these early decisions. In the "how things work" project, she and her colleagues are working on a prototype that can access an abstract design, generate a model, and simulate the behavior of the product, so that designers can get quick feedback as to whether the design is likely to accomplish an assigned goal. She is also refining the representation

of functions-what needs to be accomplished and how. If she can make functional representation more rigorous, she can apply it to evaluate a design by verifying whether the predicted behavior accomplishes the function.

The big question is deciding how to model the design. Deciding on an appropriate model depends a lot on what questions the designer asks. How do we find the relevant piece of a knowledge base, perhaps just one percent of it? How do we build just the right model? Part of Iwasaki's work concerns reasoning about the relevance of knowledge to formulate the right model. Answers to these questions will do much to further the field of design.

As a shy person and often the only woman, Iwasaki was uncomfortable in her undergraduate physics classes and ended up switching to math. In graduate school, she was more comfortable in her research groups because they were small, even when she was the only woman. She also got extra encouragement from her graduate advisor, building her self- confidence.

Suggestions:

1. Shy students need extra support. With encouragement, they might produce the same quality of work as an outgoing student.
2. Smaller groups of students might make the few women present more comfortable.

Ritu Chadha
Member of technical staff, Bell Communications Research
While the title of Ritu Chadha's doctoral dissertation is daunting — Applications of Unskolemization — the ramifications of that research are far reaching. Unskolemization is the process of replacing certain functions by existentially quantified variables in logic formulas, which is useful for deducing facts about collections of logical formulas. As a doctoral student at the University of North Carolina at Chapel Hill, she developed an algorithm for performing unskolemization and applied it to several areas, including the automation of program verification.

"The foremost problem in software development today is ensuring the correctness of software," according to Chadha. Much research has been devoted to mechanizing the verification process, but no one had been able to devise a general method for mechanically deriving program loop invariants — until Chadha developed an algorithm based on her thesis work. This opens up the possibility of building systems that will mechanically prove the correctness of software. "There is still a lot of work to be done to make such systems commercially viable," she said, but this could dramatically cut the cost of software development since laboratories typically budget as much as 50 percent of their cost for software testing.

She also applied her thesis to machine learning, developing another algorithm based on unskolemization that deduces certain facts about collections of objects or statements. For example, given examples of a class of objects, the algorithm can generate a general description of objects in that class. This method can be applied in program verification as well as other fields.

Chadha spent most of her adolescent years in a highly respected high school for girls in India. The teachers (all female) warned the students that science and math were not "for girls." While she believes this discouraged many talented girls, she persisted, going on to major in mathematics at Delhi University and earn the highest grades ever obtained there in any subject. During her undergraduate and graduate school years, Chadha never encountered any discrimination due to gender. However, the disproportionate male-female ratio in computer science departments did make it difficult for her to interact socially with students.

Suggestions:

1. Don't lose confidence in yourself despite any discouragement or discrimination you may encounter.

2. Never think in terms of gender where work and ability are concerned.

3. Don't be afraid to point out any discrimination if and when you encounter it.

4. Companies with multiple locations should be sensitive to the "two-body problem" (where both members of a couple need to work) and facilitate internal transfers for employees in such situations.

Susan Lander
Doctoral candidate in artificial intelligence (scheduled to graduate this month [August 1992]), University of Massachusetts at Amherst
Are women more interested in conflict resolution than men? Whether or not this is true, Susan Lander is looking at this area from an interesting point of view — one might even say from a woman's perspective.

In her work with multiagent systems, Lander investigates different methods for resolving conflicts, especially those in which agents don't act with hostility. Rather than competing for resources, these agents interact cooperatively. Either all agents win, or they gradually and equitably relax their requirements until they come to an agreement. She has developed systems in two domains: the design of steam condensers, and buy-sell contract negotiation. As an example, an agent negotiating a buy-sell contract in Lander's cooperative system will look for the fairest price, not just the best price from its selfish perspective.

Lander's evolution to become a scientist is unique. She came to the university as a secretary in the Computer Science Department, but knew she wanted to do more. She has been at the university for 14 years in various capacities: first as a secretary and then as a student, earning her BS, MS, and soon to receive her PhD there — along with adopting two children.

Suggestions:

1. Be aware of your priorities. "Having it all" is only realistic if you accept that you can't be the "perfect" mother, wife, student, and researcher all at the same time. Find the balance that works for you.

2. Universities should extend tenure decisions to give women with families a more reasonable amount of time to produce valuable work.

Anita Borg and the Systers network

For Anita Borg, a consultant engineer at Digital Equipment Corporation's Western Research Lab, the Systers network combines 23 years of computer work with 25 years of feminism. Systers started almost five years ago, when about 25 women got together for dinner at an operating-systems conference and decided to stay in touch. It now has 1,100 members in 15 countries representing more than 150 colleges and universities and 75 companies. There are also a few subject-related sublists, including one for AI. Despite its size, Systers continues to work well, according to Borg, because of the social mechanisms in place and the "serious, concerned, and sophisticated people" who use it. She is working on automating some of the administrative tasks involved; for instance, users will eventually be able to remove themselves from the list during vacations and then reinstate themselves.

Since all messages go to all members, the social culture of the network had to evolve as Systers grew. When there were about 200 members, the network was getting unwieldy with too many messages and too much conversation. Borg developed a number of rules; for instance, when someone sends a question to the entire list, individuals respond directly to the asker, who compiles the responses and broadcasts a summary back to the list. Borg sets the tone, encouraging members to think hard about what they send to the list. The network is not moderated, but Borg corrects things if they go off track. Almost no arguments have occurred. She believes that the network's existence proves that electronic mail can be used ethically. "There is something quite incredible about the way women interact and the seriousness with which they take this resource."

"An essential element [of the network's success] is that it has created a global community of women who would otherwise have very little opportunity to interact with others like themselves. Systers provides both role models and mentoring; it is a sounding board when one feels alone, isolated, that she might be the only person in the world who ever experienced something. Finding that you are not alone is empowering and encouraging.

"As a geographically dispersed and often individually isolated minority in computer science, women rarely have the opportunity to interact in person with other women on any subject in the field. Systers exposes women to the full range of significant professional interactions among women without the perception of help by or input from men. This serves to bolster self-esteem and independence.

"Systers has helped us realize that computer science is not a men's club in which we each in isolation are the freakish exception. There are many of us. We have much in common. And we have much to offer and to gain by staying in the field."

Borg certainly enjoys her work, and appreciates the freedom DEC gives her to pursue research of her own choice. Her latest project supersedes her previous interests in operating-system and performance analysis. She is working on creating a database of Systers users, who would each control the contents of her entry and the accessibility of each field. Users could direct e-mail through the database to dynamic subsets within the list. The public part of the database could also help people identify qualified female candidates for appointments. This project has implications far beyond Systers for enriched communication among groups with common interests.

Female computer scientists with e-mail facilities can contact the network at Systers-request@wrl.dec.com

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