An Agenda for Human-Computer Interaction Research:

Science and Technology Serving Human Needs

Building Partnerships and Infrastructure

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ABSTRACT

As policymakers and technology planners respond to the growing activity in human-computer interaction, a broad perspective may be helpful. This article offers a top-down view of current activities and suggests opportunities and challenges for the continued growth of HCI. Partnerships among universities, corporations, government agencies, and professional societies are proposed. Infrastructure needs to support this new discipline are outlined.

Insert A

Trade magazines are beginning to appear such as Ergonomics in Design and the Usability Magazine (working title for ACM's recently approved offering).

Insert B

The major report of the US National Research Council emphasizes applications of computing (global change, computational biology, commercial computing, and electronic libraries) which are to be supported by six core subfields, including user interfaces (Hartmanis & Lin, 1992).

1 new and 1 missing reference

Hartmanis, J. and Lin, H., editors, 1992, Computing the Future: A Broader Agenda for Computer Science and Engineering, (National Academy Press, Washington, DC).

Peter Denning, P., Comer, D., Gries, D., Mulder, M., Tucker, A., Turner, J. & Young, P., 1989, "Computing as a Discipline", Communications of the ACM, Vol. 32(1), 9-23.

1 Introduction

Human-Computer Interaction (HCI) is emerging as a major area of research, education, industrial application, international competition, and national policy (Marchionini and Sibert, 1991; Shackel, 1991). To ensure continued growth, healthy interaction with related and supporting communities is necessary. Since research and education through universities play key roles, adequate infrastructure should be built within the contributing disciplines.

We believe that research in human-computer interaction offers golden opportunities for computer scientists who will see their networks, hardware, software, and algorithms applied in ever widening circles for continuously growing communities of users. The novel challenges of user interface design and implementation inevitably lead to advances in the state-of-the-art. Psychologists can explore human problem-solving at a level of complexity rarely attempted in the past. Perceptual, cognitive, and motor models of human performance take on new significance because of their widespread application to interface design. Not only can psychologists make a contribution to an important, pervasive, and socially constructive technology, but they can refine their theories and learn much about human problem-solving, learning, memory, attitude formation, social psychology of small group interaction, organizational behavior, and other components of psychology. Similarly researchers in information science, education, management, etc. can all contribute to and benefit from the growth of HCI research.

This growth is recognized internationally with conferences, journals, national plans, and international cooperation. Several national policy documents (Alvey Committee, 1982; Australian Science and Technology Council, 1990), reports on national projects (Hayashi, 1989; Nonogaki and Ueda, 1991; Curtis and Halbert, 1991), and reviews of regional cooperation (Bullinger, 1989) make clear that major efforts are underway to build infrastructure, support research, and develop advanced products. These diverse and multiple efforts provide some examples of how universities, government agencies, businesses, professional societies, and workers in related disciplines can all participate in HCI research.

This report expands the discussion by proposing a variety of ways in which partnerships can be built among these communities and by suggesting what infrastructure is necessary to support such partnerships. Section 2 covers potential partnerships for HCI researchers to establish closer cooperation with workers in other disciplines. Section 3 concentrates on specific infrastructure needs in the university research and education arena.

2. Building partnerships

2.1 Universities

Within the university community, HCI research is still a new domain. Although there are five research journals (International Journal of Man-Machine Studies, Interacting with Computers, Behaviour and Information Technology, International Journal of Human-Computer Interaction, and Human-Computer Interaction), an abstracting journal (Human-Computer Interaction Abstracts), several related journals (e.g. IEEE Systems Man and Cybernetics, Hypermedia, Journal of Visual Languages and Computing), and several emerging journals (e.g. Telepresence, User Modeling and Adaptive Systems) academic acceptability is still varied.

While many departments of Computer Science, Psychology, Business, Library and Information Science, and Education have strong programs of research and teaching in HCI, many departments

do not. Members of the HCI community need to tie HCI work into traditional mainstream concerns in these fields so as to build support for HCI within departments where it is lacking. Research projects that bring HCI people into partnership with researchers in other fields are important, as are ways to incorporate HCI concepts and methods into the traditional curriculum. Partnerships between senior HCI people and junior faculty in HCI could also help young faculty establish themselves at institutions that are beginning programs in HCI.

Productive steps include:

- hiring new faculty
- promoting junior faculty and granting tenure
- acceptance of interdisciplinary programs of study
- addition of undergraduate and graduate courses
- infusion of HCI ideas into courses, even freshmen level
- inclusion of HCI topics in colloquia & seminars

Faculty members with HCI interests need to be encouraged and supported by current leaders of the field. The Doctoral Consortium at the SIGCHI Annual Conference is a constructive effort, but further gatherings of junior faculty and senior faculty might be useful too. The Denning Report included 'human-computer communication' as one of the nine areas of computer science education (get ref??). While the number of universities listing a course on human-computer interaction is steadily growing, such universities are still in the minority. Adequate textbooks are appearing and the number of competent faculty are also increasing.

2.2 Government

Since HCI work has a strong impact on government projects and since government policies can influence HCI directions, a durable relationship needs to be developed. Certainly recognition and support from the U. S. National Science Foundation (NSF) is an important step and we are pleased about the improving connections between the NSF Interactive Systems Program and the HCI community.

Many government agencies could benefit from HCI research and development and therefore stronger links should be made. For example, the Library of Congress's Online Public Access Catalog, called ACCESS and the National Library of Medicine's online search of medical research literature called Grateful Med, both apply current HCI techniques and influence many developers in the information retrieval community. National Aeronautics and Space Administration (NASA), Nuclear Regulatory Commission (NRC) and the Federal Aviation Authority (FAA) have a long history of internal research and external research support for human factors and HCI issues. The Office of Technology Assessment has already prepared research reports for Congress on issues such as office automation, robotics, and intellectual property protection for user interfaces.

In addition to these agencies, workers in many Departments such as Commerce, Education, and Defense (AFOSR, NRL, ARI, DARPA) are part of the HCI community. We should explore how to increase the connections, seek additional research support, and expand the impact of current research on these and related government offices.

While direct contacts between researchers and members of Congress are rare, some consideration might be given about how to promote awareness of HCI issues on the part of Senators and Members of the House of Representatives.

State, local and city governments should also be considered as sources of collaboration, joint research, and education projects.

To pursue these directions, SIGCHI might appoint a Government Affairs representative to keep members informed about relevant legislative, executive, and judicial activities. ACM is a professional society engaged in science and education, not a lobbying group. But SIGCHI members need to know about policy issues affecting their field. A Government Affairs representative could also establish liaison with groups with related interests, such as the Computing Research Board and Computer Professionals for Social Responsibility. Trade associations and lobbying groups such as the Electronic Industries Association, Electronic Mail Association, Computer & Business Equipment Manufacturer's Association, Computer & Communications Industry Associations, Software Publishers Association, etc. can be influential in developing awareness of HCI issues in government and industry. The main report of this workshop might be sent to leaders of these groups, and presentations might be made at their meetings.

A final community is the National Academy of Sciences, National Academy of Engineering, and National Research Council whose Commission on Behavioral and Social Sciences has an active Committee on Human Factors that has produced valuable reports such as the 1983 document on 'Research Needs for Human Factors.' The NAS/NRC is not a government agency, but advises government agencies under the authority of its Congressional charter as a 'private, non-profit, self-governing membership corporation.'

In Europe, the ESPRIT project devotes approximately 150 person-years of effort per year to HCI research (Bullinger, 1989). In 1988 in Japan, the Ministry of International Trade and Industry created the FRIEND21 project conducted by Institute for Personalized Information Environment (Nonogaki and Ueda, 1991). This consortium of 14 major computing, home electronics, and publishing companies is conducting basic human interface research (Curtis and Halbert, 1991).

2.3 Business

A fertile ground for HCI work is in the development of commercial products. More than three quarters of the 2300 attendees of the SIGCHI conference represented commercial

developers of hardware, software, and systems. This community has clearly recognized the beneficial impact of HCI on product quality and sales. The pressure for increased attention has often come from marketing and training staff who early on recognized the competitive advantages of improved interfaces. However significant numbers of designers, software engineers, advanced product developers, and managers have promoted awareness of user interface issues within their organizations.

The relationship between the HCI research and business communities might be built on:

- collaborative research with funding from corporations

- educational seminars within corporations

- TV and videotape presentations

- HCI conferences, awareness days, lectures

- product presentations within universities

- usability evaluations by universities for companies

- consortia for research, e.g. home automation, visualization, supercomputing

- participation of corporate leaders in academic boards

Good relations between corporations and universities can bring great benefit to both. Initial cooperation has been at a technical level, but increasingly corporate managers recognize the strategic impact of user interface technologies.

2.4 Professional Societies

Making connections in the professional societies closely related to HCI has already been successful in stimulating interest. The Association for Computer Machinery (ACM) with 80,000 members houses a variety of Special Interest Groups (SIGs) with

interests in the HCI domain. Primary among these is the SIGCHI (Computer Human Interaction) which has almost 6,000 members as of late 1991 and is the fastest growing of all the SIGs. Relationships with other SIGs could be strengthened through joint conferences, presentations at each other's conferences, and articles in each others Bulletins:

- Documentation (SIGDOC)

- Software Engineering (SIGSOFT)

- Information Retrieval (SIGIR)

- Computers and Society (SIGCAS)

- Artificial Intelligence (SIGART)

- Computers and the Physically Handicapped (SIGCAPH)

- Office Information Systems (SIGOIS)

- Hypertext (SIGLINK)

Outside the ACM there are strong bonds possible with professional societies such as:

- IEEE Computer Society

- Human Factors Society (especially the Computer Systems Technical Group)

- Society for Technical Communications

- American Educational Researchers Association

- American Psychological Association (especially Division 21 Experimental and Applied Engineering)

- American Association for the Advancement of Science

- American Society for Information Science (especially the Special Interest Group on Human-Computer Interaction)

The annual SIGCHI conference already carries co-sponorship from many of these groups.

Potential projects include:

- Conferences, seminars, symposia, workshops
- Professional journals, informative newsletters, and commercial magazines
- Resource guides, membership directories, product sources
- Bibliographies, videographies, software guides
- Curricula, degree program listings
- Course outlines
- Speaker bureaus

2.5 Related Disciplines

Since the influences and impacts of HCI span many disciplines, it makes sense to reach out to other communities beyond:

- Computer science & engineering
- Psychology
- Business & management
- Library & Information Science

to include workers in:

- Medicine, optometry, health & safety

- Law, intellectual property protection

- Sociology, anthropology

- Engineering

- Education

- Art, graphic design, music

In addition, useful interactions might occur with workers in fields that might apply HCI work:

- Nursing, pharmacology, radiology

- Journalism, history, museums

- Environmental sciences, agriculture, meteorology

Of course, the pervasiveness of computing and user interfaces means that there is a potential for some contact with workers in every field of endeavor.

3. Building Infrastructure within & among Universities

The central goals are to promote HCI research and education within university departments such as Computer Science, Psychology, Business, Library and Information Science, and Education. Concerns include:

Hiring, Promotion, Tenure

Graduates, undergraduates, fellowships, courses

Laboratory resources: computers, software, media

Research grants: large, medium, small

Research centers: Regional, national, international

3.1 Resources for HCI Research

Much HCI research has special equipment needs.

Base-level support for HCI research includes workstations and some funds for software, not differing much from other areas of Computer Science. But many projects require significant investment in equipment beyond this base. Examples of technologies requiring special equipment that will play an increasing role in HCI research include virtual reality, teleoperations, groupware, image databases, data visualization, high resolution digital photography, and hypermedia. In addition, empirical user studies often require special facilities for collecting and analyzing data from groups of participants simultaneously, so that multiple networked workstations are needed, and video recording.

Staff support is a critical need.

Getting the necessary equipment, even for projects with special requirements, is not usually a major problem in itself. Getting staff support to operate, maintain, and adapt equipment and software is a much harder problem. Staff is expensive, but beyond that, good staffing requires a commitment of continuity of employment which is hard to establish. Universities have been willing to create and fund staff support positions for major externally-funded projects, but not for small ones such as have been typical in HCI.

There are opportunities for resource sharing between projects.

Staffing needs could be reduced to some extent, and overall research productivity increased, by pooling some kinds of work across projects. For example, research in i/o devices requires that prototype devices be designed and built; one laboratory could do these jobs and make multiples of the devices available

to other groups. As another example, researchers doing cognitive modelling could share models more effectively if resources were available to produce distribution versions of software and provide some level of consulting and support.

"Virtual center" project structures could provide useful support for HCI research. Large-scale projects such as NSF's Engineering Research Centers and Science and Technology Centers could of course make an important contribution to HCI research. But looser arrangements, requiring smaller up-front commitments and offering more flexibility, could also be valuable.

The community of researchers who have developed the SOAR cognitive model have successfully developed a kind of "virtual center" in which a high degree of sharing of work, information, and ideas has been achieved without any collective funding arrangement. SOAR researchers raise funds separately for their own projects but then participate in well-organized community-wide workshops and share software development.

Such "virtual centers" could be created in a number of areas of HCI research, including cognitive modelling, input/output devices, user interface software, home automation, and others. Proposals for funding individual projects would be considered on their own merits, but proposals could show greater strength by showing how the facilities of the virtual center would be exploited, and how the overall research thrust of the center would be advanced by the proposed work.

A virtual center structure could also promote ties between HCI research and applications. Some projects within a center could focus on application partnerships, undertaking to apply the ideas and products of other center projects to specific problems in science, engineering, or other spheres. Industrial cooperation could also be promoted within the center structure. Such arrangements could provide the "use pressure" that is needed to encourage researchers to push their work far enough to be really useful.

If virtual centers in more than one area of research came into operation cooperation between centers would be desirable. As

with application partnerships this could be encouraged by considering possible contributions to inter-center cooperation as a positive attribute when reviewing proposals.

Hub projects within virtual centers could provide infrastructure support.

Virtual centers could include one or more hub projects funded at a higher level than other projects. Such projects would undertake to perform hardware and software development as required for the center as a whole, to distribute devices and software, and to provide support. The higher funding for hub projects could be used to leverage university staff support at the hub sites.

3.2 Resources for HCI Education and Training

The ACM SIGCHI curriculum recommendations (soon to be published) call for single course offerings at the undergraduate and graduate levels. These courses are clearly desirable, but further curriculum work would also be valuable. Introducing ideas and methods from HCI into undergraduate introductory courses is important; more generally, joint curriculum development with other areas of CS would serve to integrate HCI better into the overall field. For example, HCI material would be very appropriate in database and software engineering courses.

Good teaching materials in HCI are still scarce. No widely accepted textbook has emerged. Video and software materials could also be developed and shared effectively. Much useful material already exists in videos produced by SIGGRAPH and SIGCHI, but it is not well packaged for instructional use.

Library resources in human-computer interaction are often thin and funds to acquire journals, videotapes, and books are scarce. Specific funding to increase information resources for HCI would improve education and research. Access to diverse software

packages for analysis, critiquing, experimentation, etc. is an important resource. In addition, the emergence of user interface management systems, toolkits, prototyping tools, and development environments, means that a heavy investment will have to be made to acquire and maintain these tools and the appropriate hardware.

4. Conclusion

HCI is a growing field, but there are many limiting factors that restrain growth. We believe that the benefits of accelerated growth of HCI research warrant special treatment from national funding sources. The opportunity seems compelling because we believe that even modest investments will produce large benefits. Creating a new discipline, shifting existing research paradigms, and overcoming resistance to change are anticipated challenges, but the potential benefits for academia, business, and users of new technology are sufficiently attractive.

References

Alvey Committee, A Programme for Advanced Information Technology: The Report of the Alvey Committee, HMSO, London, UK, (1982).

Australian Science and Technology Council, Your word is my command: Towards an Australian capability in human-computer interface design, Australian Government Publishing Service, Canberra, ACT, Australia (June 1990).

Bullinger, H.-J., Fahnrich, K.P., and Ziegler, J., Human factors in information technology - Results from a large cooperative European research programme, In Smith, M. J. and Salvendy, G. (Editors), Work with Computers: Organizational, Management, Stress and Health Aspects, Elsevier Science Publishers B. V., Amsterdam, The Netherlands, (1989), 3-12.

Curtis, Bill and Halbert, Alan, Japan's research focus shifts to interfaces, IEEE Software 8, 6 (November 1991), 70-77.

Hayashi, Yoshio, Research trends of human interfaces in Japan in the past decade, In Smith, M. J. and Salvendy, G. (Editors), Work with Computers: Organizational, Management, Stress and Health Aspects, Elsevier Science Publishers B. V., Amsterdam, The Netherlands, (1989), 13-20.

Marchionini, Gary and Sibert, John, An Agenda for Human-Computer Interaction Research: Science and Technology Serving Human Needs, ACM SIGCHI Bulletin 23, 4 (October 1991), 17-32.

National Research Council Committee on Human Factors, Research Needs in Human Factors, National Academy Press, Washington, DC, (1983).

Nonogaki, Hajime and Ueda, Hirotada, FRIEND21 Project: A construction of the 21st century human interface, Proc. CHI' 91 Human Factors in Computer Systems, ACM, New York, NY, (1991), 407-414.

Shackel, Brian, Whence and where - A short history of human-computer interaction, In Bullinger, H.-J. (Editor), Human Aspects in Computing: Design and User of Interactive Systems and Work with Terminals, Elsevier Science Publishers B. V., Amsterdam, The Netherlands, (1991), 3-18.