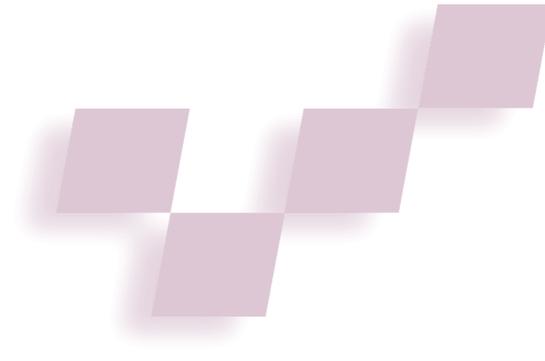


Human-Centered Computing, Online Communities, and Virtual Environments



Judith R. Brown, Andy van Dam, Rae Earnshaw, José Encarnação, Richard Guedj, Jennifer Preece, Ben Shneiderman, and John Vince

The Joint European Commission/National Science Foundation Strategy Group first met in September 1998 as a result of a joint collaboration agreement between the EC and NSF in August 1998. The collaboration aims to facilitate the

joint development of knowledge and applications in key emerging science and technology areas of mutual interest. Successful cooperation holds the promise of more cost-effective investment of research funds in the United States and the European Union.

The group recommended a series of research workshops to enable early identification of key research challenges and opportunities in information technology. Each workshop should bring together eminent scientists and technologists in the area addressed, and the themes

would emanate from the research community.

The Strategy Group identified a number of possible themes. These included human-centered computing and virtual environments (VEs), large-scale scientific databases, and intelligent implants. Scientists in this Strategy Group included Andy van Dam (Brown University, USA), Paul Messina (California Institute of Technology, USA), Rae Earnshaw (University of Bradford, UK), Giorgio Baccarani (University of Bologna, Italy), Rolf Eckmiller (University of Bonn, German), and Gilles Kahn (Inria, France).

The group agreed that the first joint research workshop should concentrate on the themes of human-centered computing and VEs. Human-centered computing is perceived as an area of strategic importance because of the move towards greater decentralization and decomposition in the location and provision of computation. The area of VEs is one where increased collaboration should speed progress in solving some of the more

intractable problems in building effective applications. Further workshops should follow, either on separate topics or on specific issues arising out of this first workshop.

Objectives of the workshop

The workshop concentrated on the research frontiers of human-computer interaction and VEs. Of particular relevance are the desires that interaction center more around human needs and capabilities, and that the human environment be considered in VEs and in other contextual information-processing activities. The overall goal is to make users more effective in their information or communication tasks by reducing learning times, speeding up performance, lowering error rates, facilitating retention, and increasing subjective satisfaction. We believe that improved designs can dramatically increase effectiveness for users ranging from novices to experts, of diverse cultures, with varying educational backgrounds. Their lives could be made more satisfying, their work safer, their learning easier, and their health better. Research areas to address included

- High-level content descriptions and their access, such as metadata and MPEG-7
- Reduced cognitive load and more scope for creativity
- Cross-disciplinary interaction and how to make it work
- Interaction in specific social contexts and with cultural differences
- Universality and the problems of the differently abled
- Interaction styles and their implications
- Consistency of cognition models across information appliances
- Paradigms for emerging new kinds of interaction, beyond WIMP (Windows, icons, mice, and pull-down menus) interfaces: multimodal and perceptual user interfaces
- Challenges for VE technology and interfaces
- Usability issues and measuring the effectiveness of symbiosis

This report summarizes results of the first EC/NSF joint Advanced Research Workshop, which identified key research challenges and opportunities in information technology.



1 Attendees at the first Joint EC/NSF workshop. Front row, left to right: Karine Iannelli (Secretariat), Ute Fahrholz (Secretariat), Emilie Monferran (Secretariat), Richard Guedj (INT, France), Co-Chair Margaret Denison (Secretariat), Judy Brown (University of Iowa, USA), Rae Earnshaw (University of Bradford, UK), Co-Chair Françoise Simon (host). Second row: Lisa Manekofsky (Brown University, USA), Bertram Herzog (Fraunhofer CRCG, USA), Junji Yamaguchi (independent researcher, Japan), Larry Rosenblum (Naval Research Laboratory, USA), Ben Shneiderman (University of Maryland College Park, USA), Jenny Preece (University of Maryland Baltimore County, USA), Wendy Kellogg (IBM T.J. Watson Research Center, USA), John Thomas (IBM Research Hawthorne, USA). Third row: Toshiyasu Kunii (Hosei University, Japan), Andy van Dam (Brown University, USA), Co-Chair Debbie Van Dam, Jo Vranesh, Matthew Turk (Microsoft Research, USA), Charles Koelbel (NSF, USA), Jürgen Schönhut (Fraunhofer IGD, Germany), Mikael Jern (AVS and Linköping University, Sweden), David Leever (VERS, UK), Christoph Busch (Fraunhofer IGD, Germany), Tom DeFanti (University of Illinois at Chicago, USA). Fourth row: Hartmut Chodura (Fraunhofer IGD, Germany), Sudhir Mudur (National Center for Software Technology, India), Thomas Kirste (Fraunhofer Institute, Germany), Deb Roy (MIT Media Laboratory, USA), Turner Whitted (Microsoft Research, USA). Back row: Tom Furness (HIT Laboratory, University of Washington, USA), Bill Buxton (Alias Wavefront/Silicon Graphics, University of Toronto, Canada), John Vince (University of Bournemouth, UK). Also attending but not shown: Victor Abrash (SRI International, USA), Daniel Andler (University of Paris X, France), Jehan Bing (SRI International, USA), Ole Bernsen (Odense University, Denmark), José Encarnação (Fraunhofer IGD, Germany), and William Newman (Xerox Research Center Europe, UK).

- Design and evaluation of online communities for intranets and the Internet
- Scaling of online communities to support millions of people
- Universal access, social and ethical issues

The workshop invited international researchers and key actors in the fields of VEs and human-centered computing. Each workshop participant produced a position paper on a selected topic, used to feed the discussions. The participants then formed working groups to discuss in detail the research issues in particular domains that arose from the position papers. Figure 1 shows the attendees.

The workshop's results and recommendations will inform the collaboration between the EC and the NSF on developing mechanisms to support collaborative research

and to identify optimal areas in which cooperation could take place. We're also circulating these results to the community in journals and newsletters for discussion and comment. The formal "Report to the European Commission and the National Science Foundation on the Workshop" (<http://www.eimc.brad.ac.uk/news/>) will be joined by a book published by Springer-Verlag containing the material considered at the workshop.

Principal workshop results

The position papers submitted to the workshop determined the first cut at possible research priorities. Following the initial review of the areas, they were combined into the following:

- VEs, augmented reality, and mobile computing
- Applications and tools

- Devices and future interfaces
- Online communities
- Collaboration among industry, academia, and government

Working groups in these five areas further considered the detailed research issues.

VEs and human-centered computing

Although VEs and human-centered computing differ substantially, it proved useful to consider the issues together. VEs face challenges, especially in the areas of display technology, interaction methodologies, update rates, and collaboration among users in different geographic locations. A mobile augmented-reality environment faces issues involving portability, devices, interfaces, and communications. It's difficult to make computing human-centered with standardized technology such as keyboards and mice, impedance mismatches, and the current shift towards ubiquity.

As a result of this ubiquity, the computation will become incorporated in mobile devices or embedded in the infrastructure or the environment, rather than in a particular desktop device with which the user can interact. We see challenges in steering technological innovation to meet human needs, in ensuring that the results of empirical research prove useful to designers, and in orienting the system developer to think more in terms of the human user. Output devices can range between the two extremes of light-emitting polymers for coating wallpaper (for large-scale, wall-sized displays) and small-scale retinal displays, where the image is focused directly on the retina.

Diversity of technology and users

The current diversity of the field, such as in displays, offers both a challenge and an opportunity. Current developments in technology and content generation, and the rapid rise of new uses and applications, require diverse interdisciplinary expertise to exploit the technology effectively. We see a diversity of technology (hardware, software, and networking), a diversity of users (especially in areas where technology has not yet made significant inroads), and an increasing gap between what users know and what they need to know to use current systems effectively. All this bears testimony to tools and systems being technology-driven rather than user-driven. Much more attention needs to go into end-to-end design and integrating the needs of the user from the very beginning. Critical parameters in the design and evaluation process need to be much more firmly identified, quantified, and rigorously upheld. This area needs research.

Research integration

The wide range of expertise available at the workshop enabled us to recognize the challenge of diversity and seek to address it. We agreed that current research doesn't consider the breadth of the field. The experts in converging areas don't work together, and research programs don't get the right kind of interdisciplinary expertise or support to give added-value integration. Indeed, the need for a greater degree of integration and

greater attention to scalability pervaded many of the research issues highlighted at the workshop.

Multiple disciplines

One important area of future work is the behavior of individuals and communities in their relationship to each other and to the world. Despite a long history of educational, psychological, social psychological, and sociological studies, we need methodological innovations to capture and understand the complex nature of individual and group behaviors that occur while using technology. Analytic and descriptive studies can provide useful insights, but there's a strong need for more prescriptive outcomes that can guide designers of new technologies.

Although guidelines are available for basic user interface design, they need to be extended to accommodate new technologies. In addition, validated metrics, user surveys, task taxonomies, ethnographic methods of observation, participatory design methods, usability testing strategies, expert review techniques, and software development methodologies would all help produce more orderly development processes for new technologies. Social impact statements prepared in advance of implementations could facilitate broad discussions of critical technologies and thereby minimize the number and severity of unanticipated side effects.

Understanding community relationships becomes even more critical for a community of users interacting in a shared world or information space, such as on the World Wide Web. The interface needs to be appropriate to the task performed, the social behavior of the user (or groups of users), and the maintenance of relationships. Research programs should be developed in this area.

Universities should be strongly encouraged to support multidisciplinary activities and to reform traditional computer science departments so that they include a human-centered approach throughout their research and educational programs. A specific suggestion for moving the center of gravity in this direction would be to fund graduate fellowships in human-centered systems.

Pure and applied research

We felt that resistance to full recognition of the value of interdisciplinary research resides in both funding bodies and academia. Academia prefers promotion criteria that emphasize "pure" science, with elegant solutions derived for somewhat arbitrary intellectual problems. Funding bodies promote research areas recommended by scientific peer groups in the same tradition. This roadblock to interdisciplinary research must come down.

Currently academia loses many valuable people to industry simply because industry pays them to do the kind of exciting and meaningful research they can't do in academia and get tenure. We see a lack of synchronization among academia, the changing nature of the world, and the research needed to shed light on important current issues.

In addition, we believe a stronger emphasis must be placed on evaluation and empirically testing systems in the context of work. This evaluation and testing should

be both controlled and ethnographic, in the laboratory and in the field. Needs, requirements, and behavior of the users, as well as the range of problems they need to solve, should be considered. Progress in VR, online communities, universal usability, and other user-centered areas will increase dramatically if the funders insist on some form of assessment.

Key application drivers

Problems needing solutions can be key drivers in the domain. In some sense these represent pull requirements from users that need consideration alongside the more normal push technology from vendors. The working group that considered the agenda for collaboration among industry, academia, and government proposed the “content” age as the key driver for the year 2010. Human media technology, augmented reality, digital storytelling, interactive broadcasting, and multimedia workspaces all need content. Indeed, the whole nature of the human-computer interface may move away from one operating on a model of sequential task definition and processing. The new human-computer interface could operate on a model of behavior, context, cultural background, information awareness and imagination, namely storytelling at the interface, thus drawing on its own values of context and history.

The Content Age needs a working model and methodology. The technology should be user-centered and mobile, with new types of interaction technology and information display. Three key application domains have requirements for this technology:

- Health and continuing medical education (both doctors and patients)
- Environment
- Cultural heritage

We propose organizing a follow-up workshop on this theme with content experts, perceptualization experts, and representatives of potential funding sources from governments and industry. The objective would be to stimulate and integrate government and academic research agendas in this area.

The networked community

Current developments in online communities present a major strategic opportunity for the information technology community, providing another key application driver. Although the nature of these new communities is not well understood, because of their rapid growth they have the potential to change the world, especially in developing countries.

As the online community moves toward the million-person interface, what will its needs and requirements be, and how should they be supported? How can multicultural and multilingual requirements be handled and represented? These are complex and difficult challenges, offering an opportunity to make a significant impact on the world stage.

Universality need not imply a loss of functionality for particular domains and applications, nor should it be seen necessarily as lowest-common-denominator information

technology. However, the global nature of the online communities phenomenon presents a major strategic opportunity for governments to collaborate on research in this area. They would thus benefit from pooling expertise from different cultures, backgrounds, and countries.

Taxonomy of human-centered systems

Workshop participants produced an initial taxonomy for human-centered computing in the context of VEs. This provides a framework for understanding multi-channel input and output, the user’s skills, the particular technology selected for a task, and the task to be performed (whether simple or complex). We proposed a foreground and background task model, which highlights two key issues for the future:

- How to get foreground and background to assist each other
- How to increase the background’s effective contribution (to make the computer more aware of the user’s context, needs, and requirements at any time)

Summary of recommendations

This section lists the recommendations of the five working groups.

General

- Give more research consideration to human needs and requirements, rather than technology functions per se.
- Conduct research to identify the critical parameters involved in the design and evaluation of technology to meet user needs.
- Develop mechanisms and procedures for facilitating interdisciplinary research collaborations.
- Put a greater emphasis on quantitative and predictive methods for analyzing user behavior and user requirements that can inform the technology design process and its user interface.
- Develop research programs on interfaces for tasks, social behavior of users, and the maintenance of relationships.
- Provide practical and political support for multidisciplinary approaches by making funding available for graduate fellowships in human-centered systems.
- Overcome current roadblocks to interdisciplinary research, especially those caused by the research grant proposal review process and faculty tenure considerations.
- Funding agencies should insist on evaluation and testing of systems in the context of their intended domain of use.
- Content should be a key driver for the next phase of developments. This will open up new interface requirements.
- Define a working model and methodology for content.
- Arrange a workshop on the theme of a working model and methodology for the Content Age, with content experts, perceptualization experts, and representatives of potential funding sources.
- Perform an analysis to determine the needs and requirements of the emerging online community.

- We must take advantage of the strategic opportunity, available through the online community, to collaborate on R&D issues with potential global significance.
- In the context of an overall framework for human-centered computing, we should create a classification of user tasks into foreground and background activities in order to understand how to get technology to assist the user, both directly and indirectly.

VEs, augmented reality, and mobile technology

- Effectively using technology requires reducing the complexity of the user's task(s).
- The report sets areas for future research in VEs, augmented reality, and mobile technology.

Applications and tools

- Conduct research into applications and tools that lead to better methodology.
- Long-standing, independent organizations, such as Fraunhofer IGD in Darmstadt, Germany, should be invited to take responsibility for maintaining industry-standard platforms as they emerge. Large organizations like the EC and NSF may have a role in funding to cover this type of work.
- The VE community should build stronger relationships with the commodities and large-scale solutions sectors.
- Increase emphasis on performance metrics.
- We need to take steps to ensure continuity of infrastructure environments to protect the current investment in toolkits, component sets, and platforms.
- We need to consider the effects of commoditization of technology.

Foundations of future interfaces: devices, hardware, and software

- Human-centered computing is increasing in complexity as the number of interacting users increases and their environments increasingly integrate real and virtual worlds via technology. Future research must take this complexity into account.
- Recognizing these rapidly developing wider horizons to user interfaces is important in formulating steps to increasing their applicability and effectiveness. In addition, it has already been demonstrated that design strategies which facilitate use by the differently abled often increases the usability for all classes of users.
- The report details essential research issues to do with displays, interaction methodologies, and interaction environments for us to move forward with more intelligent devices, hardware, and software.

Online and networked communities

- Conduct research with teams of social and technical scientists to inform the design of all kinds of online communities.
- We must understand and develop software that considers the ethical issues and universal access.
- Theories from sociology, psychology, social psychology, linguistics, communications research, and psychotherapy can help inform research and devel-

opment of online communities. Before this happens, we must research how such theories relate to technology-supported communities.

- We need considerable research on on-line behavior as it occurs, as well as histories of behavior, stored communication and knowledge, nature of the communication, the number of people participating, and relationships between participants.
- Conduct research to develop participatory, community-centered design and evaluation techniques that consider different user and access needs.
- Two crucial areas require substantial research to develop a powerful electronic market and eliminate lack of trust in online transaction: copyright protection and conflict between identification and privacy or anonymity.
- Scalability is a research priority for online communities. We must consider how we develop software and guide social processes to support very large communities.
- We advocate funding for case study and ethnographic research that will enable us to better understand the needs of online health and education communities and networked communities in which online resources are integrated with physical resources to support community life.

Business, academia, government

- We propose developing an international R&D collaboration to define a working model and methodology for content based on a common working platform, Univiz (a content, perceptualization, visualization, and networking platform.)
- Three pilots of test domains based on selected applications were written up in the report. Health and continuing medical education, the environment, and cultural heritage are increasingly important application areas world-wide. Funding should be provided for international, interdisciplinary collaborative projects in these application domains.

These recommendations should give the EC and NSF a clearer outlook on the areas that would benefit from future collaborative research. ■

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This report results from amalgamating the reports of the working groups at the workshop, and we'd like to fully acknowledge the contributions of all the participants.

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