Defining an Agenda for Human-Centered Computing[1]

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Two workshops sponsored by the National Science Foundation (NSF) were held in September 2006 at NSF headquarters in Arlington, Virginia, with the goal of identifying important and emerging research areas and trends in Human-Centered Computing (HCC). In this article we report on these workshops, each of which was attended by about 30 prominent researchers in the area.

About the NSF HCC Cluster

According to the National Science Foundation Act of 1950 (Public Law 81-507), NSF's mission is to initiate and support basic scientific research and research fundamental to the engineering process, programs to strengthen scientific and engineering research potential, science and engineering education programs at all levels and in all the various fields of science and engineering, programs that provide a source of information for policy formulation, and other activities to promote these ends. As part of this mission, NSF recently established a new cluster, referred to as Human-Centered Computing, within the Division of Information and Intelligent Systems. The core of this new cluster was formed by combining what had been three separate programs: Human-Computer Interaction, Universal Access, and Digital Society and Technologies. As a result, this cluster addresses a diverse set of research themes "which are united by the common thread that human beings, whether as individuals, teams, organizations or societies, assume participatory and integral roles throughout all stages of IT development and use" (National Science Foundation, 2007).

The workshops were designed to accomplish the following:

- educate active researchers in the areas of human-computer interaction, universal access, and digital society and technology about the new HCC cluster and the related solicitation (NSF 06-572);
- provide guidance to young researchers regarding areas for future research and issues to consider when developing research proposals for submission to NSF; and
- provide feedback to NSF from the affected research communities regarding topics that are considered particularly important.

The majority of the workshop attendees were principal investigators on grants funded by one of the three merged programs. Other individuals were invited to ensure a broad perspective. The following sections summarize the structure of the workshops and some of the significant outcomes.

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Workshop Structure

Both workshops were two-day events. Two breakout sessions in each one allowed smaller groups to explore specific issues in depth. Combined, the two workshops included six breakout groups that discussed continuing and emerging research opportunities, three groups that focused on interdisciplinary research opportunities, and two groups that explored issues related to HCC education. At the conclusion of each session, all groups came together to share their insights.

Outcomes: Continuing and Emerging Research Opportunities

Below are some of the many areas discussed by workshop participants.

1. *Privacy, security, e-government, and HCC*. These questions were seen as fundamental for the HCC community to address in the areas of privacy, security, and e-government: How can we provide usable tools and interfaces to enable individuals to remain in control of their personal information? What tools and policies can help organizations and institutions more effectively manage and secure their data?

   Participants discussed the role of regulations and directives, the integration of usability-related concerns into security and privacy issues, and the need to address these issues in e-government-related projects. Electronic voting was noted as an area for additional research.

2. *Intelligent user interfaces*. Workshop groups highlighted the need for additional research on multimodal interactions, adaptive user interfaces, artificial intelligence-supported interactions, and other related methods of interacting with information technologies, including interactions that leverage speech, eye-tracking, and electrophysiological data.

3. *Universal access*. Children and older adults were identified as being appropriate targets for additional research in universal access. Foci include cognitive impairments in general, autism and illiteracy, and visual, physical, and hearing impairments. Brain-computer interfaces, which can provide interaction opportunities for individuals with severe impairments, may offer interesting possibilities for a broader range of users than has been studied in the past, including individuals without disabilities.

4. *Research with child participants*. Several efforts are ongoing to integrate technology into children's lives in a positive way, including educational technology and other aspects of design. Related HCC research can also involve design ideas specific to younger users.

5. *Needs of an aging population*. Older adults are becoming more familiar with information and communication technologies that enable them to stay connected with family and friends, pursue education, and shop online. Ongoing HCC research for this population involves the provision of an engaging and safe environment for the elderly through technology, especially for adults in assisted-living facilities.

6. *Ubiquitous computing*. This category includes mobile, embedded, and location-aware technologies. There is an increased emphasis on smaller multifunctional devices, such as those that combine the functionality of mobile phones, cameras, digital music players, and personal digital assistants. The workshops focused on embedding these devices in the environment (e.g., integration with home-monitoring systems). This convergence in computing was noted as a research area of great interest.

7. *Mobile computing*. Information and communication technologies are becoming smaller, more mobile, and more connected. There was significant interest in research that would address a broader range of computing environments.
8. *Nomadic computing* (computing on the move) is an area of interest because it leads to more dynamic environments and additional challenges for information technology users. Location-aware technologies are on the rise and enable mobile computing tools to support social connections, e-commerce, and a number of other socially engaging activities.
9. *Social computing*. Of great interest were online communities that support daily tasks and work-related activities (e.g., jobster.com and monster.com), as were the factors that influence the success of such communities. One specific question concerned the usefulness of online communities in engaging children and women in science and math.
10. *Health care applications*. Telemedicine has a potentially far-reaching impact to improve delivery of health care to remote areas. User-centered design of sensor technologies to support home health care could allow for greater independence and better treatment. Information technology can greatly improve disease management and patient safety.
11. *Healthy computing and long-term effects of technology*. Prolonged computer use is associated with such repetitive strain injuries as eye strain and carpal tunnel syndrome. Two areas highlighted for additional research were the relationship between repetitive-stress injuries and mobile devices and other, less-traditional information technology interfaces. Also of interest are potential social and psychological problems stemming from excessive computer use.
12. *Theory and evaluation methodologies*. The groups suggested that greater emphasis must be placed on developing underlying, foundational theories as the HCC area moves forward.

Outcomes: Interdisciplinary Research Opportunities

Research can address issues related to electronic medical records, emergency care, security, privacy, and mobile interactions. Other possible domains include space industry, neuroscience, the humanities, philosophy, and urban computing. With these opportunities come numerous challenges, which include:

1. *Understanding the disciplines*. Effective interdisciplinary research requires an understanding of and appreciation for the various disciplines involved in HCC research. Interdisciplinary experts may not be fully accepted by the various discipline-specific experts.
2. *Promotion and tenure*. The issue of acceptance is particularly important for new faculty members who are seeking tenure and interdisciplinary Ph.D. students who will be pursuing faculty positions. A "tenure home" must be defined for the interdisciplinary faculty if they are involved in a discipline-specific promotion and tenure process. Additionally, finding funding sources may be more difficult for individuals with an interdisciplinary research focus.
3. *Administrative overhead and where to publish*. There were concerns with regard to the most appropriate venues in which to publish interdisciplinary research results as well as the additional administrative overhead that is often involved in such activities.

4. *Different approaches to science*. It can be difficult to identify methodologies that are considered acceptable by all individuals involved in a specific project. Learning and applying new methodologies can also be a challenge for a new faculty member who has limited time.
5. *Interdisciplinary Ph.D. students*. Relatively few doctoral students plan to pursue a faculty career and conduct interdisciplinary research. Some challenges include a lack of mentors engaged in interdisciplinary research, concerns regarding future employment opportunities, and additional work involved to obtain appropriate breadth and depth of knowledge in more than one discipline.

Outcomes: HCC Education

In each workshop, one breakout group discussed HCC education. Their discussions produced a list of curriculum recommendations and a number of ways to enhance the education of future HCC practitioners and researchers. Workshop participants suggested that HCC education would be improved by additional coverage of issues related to the tools used, iterative development techniques, methodologies, theoretical frameworks, and various application domains.

With the establishment of the new Human-Centered Computing Cluster, new opportunities will emerge with regard to the nature of the research that is funded and the types of educational activities that are supported. In these workshops, a diverse set of established researchers, as well as individuals who are still developing their research programs, outlined a variety of important topics for human-centered computing. Researchers and educators interested in the future of this field are encouraged to explore these issues and to watch for future developments within the HCC Cluster at NSF.

Reference

1. National Science Foundation. (2007). Human-centered computer cluster, synopsis. Retrieved January 29, 2008, http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=500051&org=IIS&from=home.

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