The Human–Computer Interaction Handbook

Fundamentals, Evolving Technologies, and Emerging Applications

Second Edition

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FUTURE TRENDS IN

HUMAN-COMPUTER INTERACTION

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Human-computer interaction (HCI) continues to evolve in terms of educational approaches, employment opportunities, and issues that are explored. After careful consideration, we decided to close the second edition of the *HCI Handbook* by posing a series of questions to five well-established members of the HCI community:

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- Katsuhiko Ogawa was named the Director of Research Planning within the Department of Research and Development at Nippon Telegraph and Telephone Corporation (NTT) in 1995. He has served as the Director of NTT Cyber Solutions Laboratories since 2004. His areas of expertise include human interaction, media design, and home appliances. He has published more than 80 articles, is a member of Human Factors and Ergonomics Society, The Institute of Electronics, Information and Communication Engineers, and Information Processing Society of Japan.
- Gavriel Salvendy is a professor of Industrial Engineering at Purdue University and Chair Professor and Head of the Department of Industrial Engineering at Tsinghua University in Beijing. He is the author or coauthor of over 420 research publications and is the author or editor of 27 books. His research focuses on the human aspects of design, operation, and management of advanced engineering systems. He is the founding editor of the International Journal on Human-Computer Interaction and Human Factors and Ergonomics in Manufacturing. In 1995, he received an Honorary Doctorate from the Chinese Academy of Science. He is an honorary fellow and life member of the Ergonomics Society and fellow of Human Fac-

tors and Ergonomics Society, Institute of Industrial Engineers, and the American Psychological Association. In 1990, he was elected to the National Academy of Engineering.
- Professor Constantine Stephanidis is faculty at the Department of Computer Science—University of Crete. He is also the Director of the Institute of Computer Science—FORTH, and Head of its Human-Computer Interaction Laboratory and the Centre for Universal Access and Assistive Technologies. He is the President of the Board of Directors of the Science and Technology Park of Crete. His research interests lie in the fields of Human-Computer Interaction and Universal Access and many of his activities have focused on user interfaces self-adapting to user requirements and context of use. He has published more than 300 articles. He is the Editor-in-Chief of the Springer journal *Universal Access in the Information Society*. He is the founding chair of the ERCIM Working Group "User Interfaces for All" and of the International Conference "Universal Access in Human-Computer Interaction." He is actively involved with the European Commission's Research and Development Policy on Information Society Technologies with particular focus on issues related to e-Inclusion.

We began by asking about grand challenges in human-computer interaction (HCI). While others have asked about grand challenges in information systems, information technology, e-Science, and other specialized fields, we felt it was time to answer this question in the context of HCI. While the grand-challenges question looks toward the future, we also felt it was appropriate to reflect upon the accomplishments of the field. To do this, we asked about important results that have emerged from HCI research during the last decade. We concluded with a series of additional questions the future, with the goal of gaining insight into important application domains, interaction innovations, and the education of future HCI researchers who will address the grand challenges and produce future innovations. Lastly, we explored the future of HCI as a discipline and profession. While the length of the responses varies, we believe you will be able to identify common themes among the responses. We hope you will find useful suggestions to guide your research, ideas that may help shape educational programs, and ideas that will guide you in practice.

WHAT ARE HCI'S THREE GRAND CHALLENGES?

John M. Carroll

To broaden the question a bit, I think HCI faces different kinds of challenges. Since this interview is for a technical book, I assume you are most interested in engineering and scientific challenges. However, HCI also faces organizational/political challenges at several levels. These latter challenges are very important, since they embody threats to the whole enterprise of HCI. For example, consider the challenges of research funding. Nonmilitary funding and funding for basic research has significantly declined in recent years. Funding from industry, and even in-house industrial research funding, has significantly declined. National Sci-

ence Foundation research, and what research there still is in industry are more applied and more narrowly focused than in the past. None of this is good for HCI, and the solutions lie beyond anything technical theories and empirical results can provide.

The HCI community also faces many organizational challenges in constituting itself. There has been a persistent tension in product development organizations about how to organize usability functions. This is more complicated now because usability is not a single function and is frequently addressed by 3–4 different professional perspectives for example, user-experience analysis, graphic design, user interface and application development, and usability evaluation. All of these perspectives and professional skill sets are integral to HCI. This differentiation is a natural and very positive development; it shows again how important usability is to effective product development. But, now, instead of the simple battles between virtuous usability guys and lunkhead developers, we can have disputes between different kinds of HCI perspectives. It raises the question of how HCI is or will be a profession or discipline.

The engineering and scientific challenges are actually far less daunting, though a good deal more exciting. One is the emergence of ubiquitous computing—I prefer the European term "the disappearing computer"—as the reference paradigm for HCI. Of course, computing has been moving off the server, off desktop, and into personal devices for many years. And there is no shortage of attention to these developments, or interesting discussions of what they mean for research, development, and education in HCI. However, it is likely that we have only seen the very beginning of the diffusion of computing into the objects and experiences of everyday life. What will HCI become without the computer?

The second engineering and scientific challenge I would mention is "end-user programming." Ironically, some of the earliest work in what became HCI addressed the psychology of programming. In that work, early HCI researchers investigated how people understand and can use conditionals, how they can use Boolean logic to express queries, etc. This thread has never died completely, but at times it has appeared a somewhat arcane focus in HCI. I think it is more urgent than ever. As computing moves into the personal realm, it is essential for people to be able to exert more direct and wide-ranging control. It's not just nice to configure a web server, it's essential; indeed, it may soon be essential to have one running on your wristwatch. This challenge interacts with, and perhaps is compounded by, the disappearing computer: If manipulating explicit Booleans and other formal expressions in the relative calm of a desktop interaction is problematic, how will people get along drawing specifications in the air as they cross the street?

My third "grand challenge" is collaboration. I know we've had 20 years of computer-supported cooperative work (CSCW), and maybe 30 years of computer-mediated communication (CMC), but I think we still have only scratched the surface. One of the main functions of computers now is to give us access to e-mail, wikis, and blogs, so that we can interact with other people. The sophistication of collaborative systems is developing rapidly. Many project groups routinely employ collaborative infrastructures that a just few years ago would have been gems of the U.S. National Science Foundation's collaboratories initiative. A modern frontier is collaboration that never stops: Distributed global teams working in several time zones.

Katsuhiko Ogawa

In the next 10 years, we will likely see the emergence of three integrated services: (a) telecommunications and broadcasting, (b) fixed and mobile, and (c) telecommunication and information. The first challenge for HCI relates to the integration of telecommunication and broadcast services. In television, major changes in HCI will bring about TVs you can watch wherever and whenever you want, TVs with which you can watch broadcasts from all over the world via the Internet, and TVs where you can choose whatever picture you want from those being sent in. The next challenge will be HCI for mobile appliances. These will include cameras and music players, of course, and HCI for portable devices with an electronic money function will also become very important. Finally, there will be the challenge of HCI for cyberspace. Communication tools tailored to the individual will be designed to enable websites, communities, and chat rooms for the individual.

P. L. Patrick Rau

The first challenge is to make effective contributions in business, particularly in emerging markets such as China. In many companies, HCI people have successfully demonstrated their importance on product/service development. However, the contribution of HCI on the profit of a business is difficult to see. The second grand challenge is to develop and validate new methodologies. The pressure for improving HCI methodologies is increasing because of the rapid growth of Internet and telecommunication industries. The development lifecycle and the product lifecycle of handheld devices are decreasing. In addition, the importance of fun and emotional satisfaction for computers is growing, but current HCI methodologies are mostly designed for goal-oriented tasks. The final grand challenge is to develop new technologies that impact user experience. There will be some killer technologies that can change the way people use computing devices.

Gavriel Salvendy

The first challenge is to develop the science base of HCI. We also need to develop a comprehensive educational program for HCI, so that all computer-science and information-technology students would be exposed to HCI. Finally, HCI must to push the needed technology rather than respond to the emergence of technology.

Constantine Stephanidis

Computing technology evolves rapidly, and each new generation of technology offers new opportunities to improve the quality of human life. HCI is one of the key factors toward ensuring social acceptability of computer-based products and services and is therefore continuously called upon to face new challenges, by adapting, or better anticipating, new requirements for technology acceptance. Several recent trends in the direction of improving acceptability can be observed. Universal access aims at preventing the exclusion of users from the Information Society, while at the

same time increasing the quality and usability of products and services. Additionally, there are approaches to design that emphasise the need to better reflect users' everyday goals by providing more natural and activity-oriented, rather than application-oriented, forms of interaction, and by breaking down computing into specialized devices that are designed specifically for everyday activities. Other factors related to user acceptance include the need to provide self-explaining interfaces that limit the learning process to a minimum, as well as user interfaces that increase user trust and confidence. Another perspective is that of moving beyond usability and efficiency in design toward a more emotionally pleasant user experience. Consequently, a first grand challenge is that HCI must now explore new areas to understand and formalize the knowledge of what makes a design more acceptable, appealing, and fun to users, and to overcome the social, cultural, and organizational barriers that may limit acceptance of technological breakthroughs.

A second grand challenge, which is also related to the first, is the need to establish HCI theories and methodologies that are defined at a fundamental, more abstract level. HCI is a dynamic field, and the nature of interaction changes dramatically as time goes by. New technologies and trends emerge too often to be able to apply specific guidelines and practices to all of them in an equally successful manner. This is evident from the history of computing, which has started with command-line interfaces and has gone through a series of successive developments, from the graphical user interface, to mobile computing, virtual reality, and ubiquitous computing. In order to be prepared for new evolutions, a more fundamental approach to interaction needs to be elaborated. Human-centered design was a first attempt toward this direction. Although manifestations in design guidelines and interaction paradigms change along with technology, the basic principle remains the same: putting the human user at the center. Similarly, current approaches toward universal access transcend specific technological manifestations.

The third grand challenge concerns computer-based support and "digitization" of HCI practices. Today, most work in the design and evaluation of user interfaces is still being conducted "on paper." This is clearly becoming impracticable, as the task of HCI practitioners becomes increasingly complex due to the diversity of parameters involved and the need to design interactive environments that are entangled with the physical world; rather than simply designing user interfaces to single applications. In this respect, appropriate methods and tools are required.

WHAT ARE THE THREE MOST IMPORTANT RESULTS THAT HAVE EMERGED FROM HCI RESEARCH IN THE LAST 10 YEARS?

John M. Carroll

The last 10 years have been full of important results, factoring them into three bullets is the hard part!

One of the three would have to be *interactive-information visualization*. The past 10 years established the "spotfire" paradigm for allowing people to drive visualization toward the in-

formation they want. One classic example is the University of Maryland's real estate finder. The visualization is a map of the District of Columbia and its surrounds. A set of sliders is provided, allowing the user to specify a price range, as well as indicating locations to which they will commute or frequently travel to, and how far from these locations, they are willing to live. As the user tunes these sliders, spots appear/disappear on the map indicating currently available homes that meet the current search specification. This project utterly transformed how people think about information visualization. The basic direction is now being most dramatically pioneered in virtual environment work.

My second candidate would be *collaboration via the Web*. The original web itself is barely 10 years old, and was a huge HCI result: usable ftp (file transfer protocol). The important lesson I see in this is how a relatively modest enhancement in functionality can trigger a revolution in the use of technology. Subsequent refinements to the web, like forums, wikis, and weblogs are even more important than the original web. New web technologies dissolve the old distinction between synchronous and asynchronous collaboration. They have made web-based collaboration so easy, so flexible, and so powerful that—like e-mail—we now use it just to work with folks in the next office. Anyone can now create and manage a sophisticated collaboratory environment. It is difficult to imagine managing a project without these tools.

Thinking more broadly about social interaction, many of these same tools for web-based collaboration have changed the fabric of society. Sixty million people are cultivating weak ties on myspace.com, while 30 million are developing strong ties on facebook.com. This is a nice validation for Mark Granovetter, who originated the distinction between relatively more intimate (strong) ties to those we regularly interact with, and relatively more casual (weak) ties to those we merely know, but who can provide specific and critical help in specific areas, such as advice in a job search.

I'm starting to hate this "top three" thing! My third important result is *powerful information retrieval tools*. This is a bit of a cop-out, since I am using it to aggregate a whole bunch of now-paradigmatic mechanisms that are quite distinct, but generally help us find stuff—latent semantic analysis (LSA), which represents information structures by patterns of co-occurrence and social recommendation, as employed by Amazon, which allows us to make use of the prior searches of ourselves and others in streamlining current searches, and Google's search algorithms, which make searching the entire web easier and more successful than looking for information on your desk.

Katsuhiko Ogawa

One important result is universal designs for aged and disabled persons. Another is interaction between portable devices and users, such as that in portable phones, portable computers, iPods, and digital cameras. And another is interfaces for the dispatching of individual information, such as blogs and homepages. To be sure, these did not surface directly from HCI research, but it is certainly true that the merits and advantages of HCI were the deciding factors in enabling these to become widely available.

P. L. Patrick Rau

Website usability is clearly one of the most important advances in the last decade. Many HCI researchers have been working on improving user experience on the web. I would also include advances and significant progress in the area of user interfaces for handheld devices. Handheld devices such as cell phones and MP3 players have drawn attention of many HCI researchers.

Gavriel Salvendy

The first would have to be the broad area of concepts, methods, and tools, which have been developed to accommodate all segments of society. I would also include developments and methods relating to visualization and the development of adaptive-interface methods.

Constantine Stephanidis

The user-centered approach to design is probably one of the most important benefits arising from HCI research in the last decade. Moving from a technological perspective of design to placing the user as the first priority has fundamentally changed the way we design artifacts in all domains. In the computing world, we have seen the impact of this process most prominently in user interfaces, ranging from software applications and services to operating systems and web pages. The result has been an increase in the usability of computers and the quality of users' experiences. Furthermore, having the user at the center of the design is a perspective that is most likely to encourage the advancement of HCI as a discipline. For example, there have been steps forward in understanding the complexities of human cognition, emotions, and needs because the focus of investigation has shifted from technology to the human being: Pervasive Computing seeks to hide the technology; Emotional or Experience Design seeks to make interactive products not only more efficient but also more pleasant, and Universal Access aims to provide the means for all humans to benefit from information technologies. A related result has been the development of methods to evaluate the usability (and hence efficiency and quality) of designs and products. The past decade has seen considerable research in developing reliable and substantial ways to determine if a product suits the real requirements of users (as opposed to the perceived requirements). Appropriate heuristics and empirical evaluation methods conducted in the laboratory have started to become the norm in the industry, although there is still much room for improvement in this respect. Work on usability has also been consolidated in a wide range of standards that bring design knowledge nearer to wider practice.

Recently, considerable advances have also taken place in the domain of computer accessibility, which is now recognized as an important prerequisite for technology acceptance and a fundamental aspect of universal access. There is now a considerable body of knowledge on how to make interactive applications and services accessible by people with various types of disabilities, but also of different ages and cultural backgrounds. A typical exam-ple of concrete advance in this domain is that of web accessibility, for which there are now universally recognized de facto standards, and, in many countries, also regulatory frameworks.

Another recent advance in HCI research, where considerable results have been obtained, although many issues remain to be explored, concerns user interface personalization. Adaptation methods and techniques have been investigated, and new forms of interaction have emerged through multimodality and multidimensionality of user interfaces. This area of research is one of the most exciting, as the adaptation of interaction depending on the context of interaction is crucial for universal access, not only for disabled users but also for the population at large. For example, nonvisual interaction is more generally useful beyond the case of blind users.

WHAT DO YOU SEE AS THE MOST EXCITING EMERGING DOMAINS FOR HCI RESEARCHERS AND PRACTITIONERS TO EXPLORE?

John M. Carroll

To me, the term "domain" is a bit problematic, but in an interesting way. System architectures define domains. Types of functions define domains. Applications define domains. And user experiences define domains. All these different senses of the term suggest exciting emerging domains for HCI.

New kinds of systems always entrain exciting emerging domains for HCI. The system infrastructures for the disappearing computer are obviously creating new domains for HCI in mobile interaction and distributed agency. One of the most important of these system-driven domains is security and privacy. In the mainframe and client-server worlds, these are central-system administration services. However, increasingly, they are end-user concerns. Security and privacy is already an important HCI domain, and will be far more important in coming years.

New types of functions also define emerging domains for HCI. One important area of this sort is universal accessibility. Not everyone wants or would tolerate a user interface with extra-large text, but for some users, the possibility of large fonts makes the difference between having access to online services and not having that possibility. Identifying the critical functions to modulate user interface presentations and controls to better reflect the diversity of human competencies and preferences is a major ongoing focus in HCI. For example, there was a record-setting response to a recent special issue of the *ACM Transactions on Computer-Human Interaction* on accessibility. Another example of a function-driven HCI domain is web authoring. Wiki functions for linking, posting, and discussing on the web have enabled social computing to leap beyond the limitations of chat and instant messaging. Now users can have something to talk about, and can collectively build spaces and information structures. Like the original web itself, this shows how modest enhancements in functionality can trigger explosions in the appropriation of technology by people.

New application domains have always been a key driver for HCI, and this is still the case. For example, health care—medical

and health informatics—is a nexus of incredible need and incredible opportunity. Much of it is quite mundane technologically, but the potential social impacts are huge. This is probably the center court for HCI applications in the next decade, but there are lots of others. Community informatics is one that I have worked in over the past decade or so: The public and civic sector, particularly at regional and local levels, is literally where we live, but impoverished with respect to information technology, in generally, and HCI in particular. There are wonderful and inspiring cases of initiatives, some of which have also been very successful as public relations projects, but the broad state-of-the-art in regional and local community informatics is still fairly primitive. I believe that the rapidly growing demographic of educated and engaged elderly is going to be a key to a revolution in community informatics during the next decade.

The most exciting emerging domain with respect to user experience is affect. HCI started out worrying about whether user interfaces experienced as "easy to use" could also be experienced as "easy to learn," or whether there might be some sort of terrible tradeoff that would force designers to choose. Things turned out to be much more interesting than that! Now, when we speak of the experience of "usability," we are usually referring to an ever-growing complex of attributes: easy to use, easy to learn, challenging but tractable, consistent with prior knowledge, supportive of existing workplace roles and practices, just plain fun, and evocative of feeling of well being, creativity, collective efficacy, cultural identity, and social capital. I doubt that this is the end of the list.

Katsuhiko Ogawa

Portable devices that are easy for aged and disabled persons to use and services allowing access to information from the Internet using these devices. Search functions that allow users to find beneficial information are also very important.

P. L. Patrick Rau

My list would include emotional design, HCI in computer games, HCI in smart environment, and cross-cultural design. Design for fun is the design concept of many consumer products/services. Functions are no longer the only focus because of the maturity of some information technologies. Bringing more fun in use means value to business. Playing computer games has become a common life experience for many younger people. Many topics can be found about HCI in computer games. Customization is getting easier, which reduces the cost of addressing the special needs for different cultures.

Gavriel Salvendy

The first area I would list is the development of HCI theories and methods to enable the effective use of nanotechnology based computers. I would also include developing a comprehensive understanding of how individuals in different cultures make decisions; how the same input results in different decision outcomes across cultures; and how using this know-how to develop an automatic translation across cultures (not languages). Finally, I believe that HCI will emerge as a system science, whereby HCI will be studied as part of the overall job of the individual rather than as an isolated entity.

Constantine Stephanidis

The Information Society is anticipated to evolve toward the proliferation of computational systems that integrate a range of networked interactive devices embedded into a physical context (either indoor or outdoor spaces) to provide a host for a broad range of computer-mediated human activities and access to a multitude of general or specific services and applications. Such systems assume that computers and networks are distributed around physical environments, and are anticipated to exhibit intelligent and context-sensitive behavior. Although currently it is not yet clear how the vision for ambient intelligence is to be realized and shaped, its evolution is conceivable because of some general development trends that have already started to materialize. For example, services will be dynamic and can be reconfigured or recombined at run time to accommodate the different needs of different users in different environments. There will be no clear distinction between interpersonal communication and access to information; different components that use different media will be interconnected to allow a free intermixing of these functions. Services will be highly interactive; for example, interaction will be complex in terms of the functionality offered, input required, output provided, dialogue structure, and configuration capabilities. Most services will be inherently multimedia, providing information in multiple types of media (e.g., sound, graphics, video, text, animation, etc.) simultaneously and in an integrated manner. Additionally, interaction will often be multimodal; for example, different sensorial and motor abilities will be concurrently used, consciously or unconsciously, and based on more natural forms of dialogue. Cooperation will be an important aspect, communication and access to information will be concurrently used to solve common problems in a cooperative manner; moreover cooperation may be among human users themselves or among user representatives (agents and avatars), to whom variable degrees of trust can be assigned. Finally, computing will become progressively more social. Access to information and communications will no longer be the task of an individual but will be extended to communities of users, who have at their disposal common (sometimes virtual) spaces in which they can interact. This paradigm shift offers exciting opportunities for HCI research, as technologies are anticipated to have a much bigger impact on human life in the future, and raises an entire series of issues to be addressed, including interaction implicitness and continuity, distribution of input and output, appropriate exploitation of human perception and cognition abilities, user control over the intelligent environment, health, safety, privacy and social issues, and dynamic context awareness. It is clearly very important that such an environment develops proactively in a user-centered fashion, and comes to satisfy people's needs and improves quality of life, avoiding the risk of a technological nightmare. It is also very likely that new methods, techniques, and tools will be necessary for supporting the user interface development lifecycle.

In addition to human and computing devices, the intelligent environment will also be populated by robots. As a consequence, human-robot interaction will constitute a relevant domain of investigation, opening exciting new perspectives and offering significant potential improvements of the quality of life. In this context, the robot behavior and its autonomy with respect to the human user are important factors of acceptability.

Finally, we are witnessing a gradual fusion of computing with communications, learning, and entertainment. This also calls for new HCI approaches addressing appropriate design approaches and techniques, usability studies, theoretical and pedagogical foundations, analysis of nonbusiness human activities, as well as social and cultural issues.

WHAT ARE THE MOST INNOVATIVE CHANGES YOU ENVISION IN THE NEXT FIVE YEARS WITH REGARD TO HOW PEOPLE WILL INTERACT WITH INFORMATION TECHNOLOGIES?

John M. Carroll

My responses to the first three questions have already addressed this to an extent, probably to an extent just beyond my actual competence! My crystal ball is a lot like everyone else's, I suppose. The descendents of today's cell phones and other wireless devices will be far more powerful, more flexible, and more usefully connected to databases, to their own current locations in the world, and to the people we care about, work with, etc. How could it be otherwise?

I think we can look forward to some clarifications in the crystal ball during this period. For example, during the past five years, there has been debate about the feasibility and desirability of the agent paradigm. I'm not in the middle of it, but to a bystander, it echoes perennial debates about artificial-intelligence (AI) applications. I think it is likely that this latest instance of the AI debate will be resolved within the next five years; we'll either have pervasively integrated agents in our information interactions, or the agent paradigm will be gone, and AI will have made another strategic retreat to something analogous to expert systems. This is probably controversial enough to get me into big trouble!

Katsuhiko Ogawa

Agents will take the place of robots with moveable arms and legs. Agents will be incorporated into portable devices, and people can have their own agents incorporated into net space. These agents act as proxies for people, amassing information and making it available to others.

P. L. Patrick Rau

People will have wearable computers and ubiquitous computing. They will be able to access to information anywhere at any time. User interface of computers no longer means a display plus a keyboard and a mouse. Wireless network will bring information into people's pockets.

Gavriel Salvendy

My list would include additional emphasis on the disappearing computer, the emergence of miniaturized computing systems, and the revitalization of intelligent interfaces.

Constantine Stephanidis

There is a considerable trend toward mobile interaction. Mobile technologies are everywhere. Cell phones in particular have become a modern-day need and manufacturers have started to expand their capabilities. Like all new technological innovations, many areas are still in need of improvement, especially since cell phones have started to evolve into multifunctioning equipment, combining features such as personal organizers, web browsers, cameras, e-mail clients, and music players along with traditional telephone facilities. The main issue regarding mobile technologies is that users have already been using these applications in a very different environment and have not yet adapted to the cellphone device. Right now, it is a race of arms between manufacturers to be the first to include new innovations to their devices and not spending much time designing the existing ones to best do their job. The same holds true for PDA devices; although they seemed to have caught on well in in the business world, they did not manage to penetrate the general consumer market. The Information Society is not going to be confined in an office or at home. The convergence of communications and computing, in the form of cell phones, PDAs, and notebooks connected on a wireless network, means that quality experience on the move is going to be in high demand in the very near future.

A similar trend toward networked interaction can also be observed in the home environment, where technology is mature enough to support, for example, the fusion of the web and the digital TV, as well as the overall "connectivity" of various devices and controls in the home environment. As a consequence, we are already witnessing, for example, web navigation and interaction through a remote control, or using a PDA to set the fridge temperature.

Another field that is very likely to yield interesting applications in the near future concerns the exploitation of biometrics for interaction purposes, mainly for verification and identification purposes, but also, perhaps in the longer term, for the recognition of cognitive and emotional states.

WHAT DO EDUCATORS NEED TO CHANGE TO ENSURE THAT PHD STUDENTS ARE PREPARED TO ADDRESS THE HCI'S GRAND CHALLENGES?

John M. Carroll

The most important thing we need to change is our disciplinary bias. No one, not even the professors in our top HCI programs, can be masters of everything that is HCI. Experts are always narrow in some sense. HCI has matured as an academic focus in several disciplines—arts and architecture, cognitive science, communications, design, education, geography, information

science, industrial engineering, library science, and psychology. Like the blind men and the elephant, each of these has its own limited view of what HCI is, and produces students with these limited views perfected.

The obvious way to address this is for faculty and students to cross boundaries and expose their narrow expertise to broader discourses. Of course, this already happens in some places, but I think it is still talked about more than practiced. I guess one thing I would say to students is that if you think you are getting this narrow sort of training, don't settle for it!

The second thing I think we should change is our emphasis on practical skills. I love John Dewey; reading Dewey changed my life. However, I think that many pedagogical implementations of Dewey's ideas are too simplistic. The mere fact that students carry out "authentic tasks" in their classes is not a guarantee of anything, and in fact, can easily be gamed. One example of this is role definitions in project teams. A common approach is to create teams with a project manager, a lead designer, an information designer, and an implementer. However, these roles have only modest operational dependencies (which of course is why they are used in real work). Thus, they actually provide students with a gift-wrapped approach to divide-and-conquer; that is, to minimize overall group effort, which incidentally minimizes overall learning. Moreover, students sometimes specialize in these roles (which optimizes effort with respect to grading outcomes). After 5–6 courses in which a given student has repeatedly played the role of, say, information designer, how much has he or she learned about implementation?

I think that more attention has to be given learning objectives and outcomes, and not just to apparent authenticity. Another aspect of this, I think, is the erosion of emphasis on theory. HCI is a cornucopia of theory: Theories at different levels of philosophical, behavioral, social, cultural, economic, and technological analysis. Training students in usability testing or in the use of current development toolkits is appropriate, but not adequate. Such narrow skills will quickly become obsolete, they probably already are. Again, I would suggest to students: If you have learned how to write an interaction scenario, create a running prototype, and run a usability test, but you didn't learn about human-information processing, mental models, activity theory, small-group behavior, and ethnomethodology, you deserve a refund.

Katsuhiko Ogawa

It is important for them to learn not how to evaluate and analyze tasks, devices, software and so on, but to actively challenge the task of designing new and innovative things. They should also learn how to design new services as well as new things.

P. L. Patrick Rau

PhD programs should stress issues related to ubiquitous computing while providing basic knowledge to guide future research and development. Programs should also introduce new technologies, such as nanotechnology and cognitive science. Finally, HCI students need to understand developments in different areas. The development of HCI in Asia like Japan, Korea, Taiwan, and China will benefit the global HCI community by either sup-

plement investigations of Asians in previous HCI areas or inspiring new research issues from a different cultural perspective.

Gavriel Salvendy

PhD programs need to emphasize the science base of HCI and provide courses that prepare students with the know how on the science of the discipline.

Constantine Stephanidis

The foremost challenge in HCI education is addressing multidisciplinarity. A variety of diverse disciplines contribute to HCI, including ergonomics and human factors, social and organizational psychology, cognitive psychology, software engineering, design, artificial intelligence, semiotics and linguistics, philosophy, sociology, computer science, and anthropology. The leading experts of HCI come from all sorts of backgrounds, and the ability to widen scientific interests to address different fields is a key toward advancing the understanding of how humans interact with computers. An HCI expert must have solid multidisciplinary roots; he or she must be a scholar in more than one field and, more crucially, be able to merge the knowledge from each area into a heterogonous science. One of the problems today in HCI is that although everybody understands the multidisciplinary nature of the field, few have the level of in-depth knowledge that is required to push the boundaries further. Sometimes people work on preconceptions of what each discipline claims, and seldom take into account the most recent advances in each discipline. It is, therefore, necessary to adopt a more holistic approach to education, address multidisciplinarity more effectively in university curricula, and encourage students to cultivate a multidisciplinary mentality. The ultimate goal is that HCI researchers are able to evolve with, and anticipate, new and emerging technological environments and societal needs. Toward this direction, current efforts focus on examining educational curricula and practices from across the world, exploring the topics that are taught and the techniques used, discussing the foundations of HCI, examining how the curriculum is changing and the driving forces for this change, reviewing how students exploit their HCI education, and investigating employers' requirements for HCI curricula. Also from the perspective of HCI education, HCI theory is of particular importance, as it is an instrument to equip students with a "durable" background in a very dynamic environment.

WHAT IS THE FUTURE OF HCI AS A DISCIPLINE/PROFESSION? WILL IT CONTINUE TO BE SUSTAINABLE AS AN ACADEMIC ENDEAVOR THAT YIELDS MARKETABLE PRACTITIONERS/RESEARCHERS?

John M. Carroll

I'm glad you asked that question! I have changed my mind on this recently. Until a few years ago, I felt that future of HCI be-

longed to a new kind of technical professional—computer scientists with significant understanding of usability and design. I envisioned HCI as a major new focus within the discipline of computer science. I spent 10 years as a professor of computer science—five as a department head—trying to realize this vision in a sort of "best-case" situation with respect to like-minded colleagues and institutional support.

I changed my mind because I came to see that there is far too much to know and do in HCI professional activity for one-size-fits-all scenario. As I mentioned in an earlier answer, HCI is a constellation of professional roles, skills sets, and perspectives. This is a good thing, and it will surely provide richer and more meaningful careers for HCI professionals! However, it eliminates my earlier vision of a sort of super professional. Indeed, looking at contemporary trends in computer science and other computing-related disciplines suggests that the trajectory of HCI within computer science is destined to become narrower, not broader. As a former computer-science professor, this makes me sad, but it is clearly an opportunity for many other disciplines.

HCI academic programs are developing in arts and architecture, cognitive science, communications, design, education, geography, industrial engineering, library science, and psychology. One of the most important recent developments is the emergence of "i-schools"—schools of informatics, information studies, and information sciences and technology—as academic homes for HCI programs. The core construct for i-schools is information, not computation, as is the case for computer science. HCI ends up in the center of i-schools, instead of at the periphery of computer science. When I realized that the role of HCI within computer science was narrowing instead of growing, I moved to an i-school.

I think that HCI has a strong future both as an academic endeavor with respect to research and education and as a professional focus. As I look back over my 30 years in HCI, it seems that at every point the opportunities far outstripped the people power available, and the future looked more so. This is exactly how it looks to me today—an abundance of opportunities for contributions from HCI. Because the endeavor is increasingly multidisciplinary, I do see a need for creative constructivism in articulating a big vision that embraces and fully utilizes the diverse professional roles, skills sets, and disciplinary perspectives that constitute HCI. For example, we should start talking more about multidisciplinary teaching in HCI and about multidisciplinary HCI teams in product development. The greatest risk I see is not that HCI is going to flop or fade away, but that it is going to fracture into several pieces—each of which would be quite exciting and important in itself.

Katsuhiko Ogawa

If, like a doctor, we have the clear goal of curing disease and sickness, it is critical for us to always have the most up-to-date knowledge available when treating patients. As with doctors treating their patients, with HCI, too, in giant factories, aircraft, automobiles and the like, safety should be the first priority. In the area of consumer products, however, first priority is often given to the designing of functions and operations. Consequently, we should move away from the academic aspects stressed in the HCI of today and concentrate more on the practical aspects.

P. L. Patrick Rau

HCI will grow as the information technology (IT) industry grows. In China, the IT industry is now undergoing a rapid growth which North America and Europe experienced. This provides opportunities for HCI development. Especially after 2004, HCI has gained a lot of attention from the industry in China. However, there are also challenges. The development of such an interdisciplinary field such as HCI in academia will take more time and effort and will be strongly influenced by the industry.

Gavriel Salvendy

I view HCI in computer science as analogous to differential equations in mathematics. In the early stages, mathematicians went around engineering departments to help engineers solve their problems using differential equations. Over the years, differential equations became an integral part of engineering education and all engineers were acquainted with differential equations and no longer needed the mathematicians. Similarly, computer scientists and information-technology specialists will all be trained in HCI, and the demand for practicing HCI will significantly decrease over the years.

Constantine Stephanidis

HCI helps in the design and development of better products; i.e., more useful products that do what the users want them to do easily, efficiently and, in the best case, pleasantly. From the application of HCI methodologies throughout the development lifecycle, from analysis to design guidelines and practices to development strategies, and finally to evaluation and testing, there is clearly a major role that HCI plays toward improving interactive products and services. Evaluation of usability is perhaps the area of HCI that prevails, because it is permanently embedded in the business world. However, there is a clear need for wider HCI practice in industry, as only the major players have invested heavily in such direction, with clearly positive results, both product-wise and business-wise.

Thus, there is an ever-increasing need for HCI practitioners and researchers. However, in order to develop professionals to fulfil this need, enhance the practice of HCI in industry, and facilitate technology transfer, HCI teaching in universities should be rethought. First of all, the next generation of practitioners needs to be prepared for the business world, for example, by learning basic management and marketing skills. Additionally, HCI practitioners need to be better prepared to address the evolving situation in the context of the Information Society. A typical example in this respect is universal access and design for all. Although there is now wide recognition and a consolidated body of knowledge, one of the critical impediments to the adoption of universal design in practice is the lack of qualified practitioners

who understand diversity in the user-target population and in the technology and in the context of use and are able to integrate the related requirements in the development process. To overcome this, it is recommended that, in the short term, accessibility, usability, and quality in use are introduced as mandatory components of university education. Other similar challenges are very likely to emerge with the anticipated evolution of the information society toward an ambient-intelligence environment, where the complexity intrinsic in developing interactive applications and services will grow even further. As a consequence, HCI experts must be equipped to address diverse technological environments and changing needs in a dynamic way. It is likely that, in the future, "specializations" of HCI expertise in different subfields will arise.