The Many Facets of HCI

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ABSTRACT

In the last ten years HCI, the study and practice of usability, has emerged as a multidisciplinary, multifaceted field. HCI is an essential knowledge area that pervades the computing field and should be included in every computing professional's education. Computing professionals need to create software, and other technologies, so that users will want to use them and will be able to effectively use them.

User advocacy distinguishes the Information Technology discipline from the other computing disciplines. Graduates need to understand the many facets of HCI. These include not only understanding the design of the interface, but also the broader issues of the user experience, process and business concerns, challenges of distributed computing, the emergence of supportive technologies, and the impact of ubiquitous computing.

This paper will introduce the key HCI concepts, and discuss the challenges, issues and future developments of the field that will drive Information Technology curriculum development.

Categories and Subject Descriptors

H.5 [**Information Interfaces and Presentation**]: User Interfaces – *ergonomics, evaluation/methodology, graphical user interfaces (GUI), user-centered design.*

General Terms

Management, Design, Economics, Human Factors.

Keywords: Human-computer Interaction, usability, usability engineering, design methods, ubiquitous computing.

1. INTRODUCTION

Information Technology (IT) is a new and developing discipline that provides a unique perspective to the computing field. One area that distinguishes Information Technology from the other computing disciplines is that graduates are advocates for the user. They need to understand the users, who they are, what they do, how and why they do things, and the contexts in which they work. The area of study that contributes to the understanding of the user is human-computer interaction (HCI).

There are several overarching themes that contribute to the IT discipline. Programming is the most basic foundation skill for any computing professional; without it, graduates would not be able to understand and/or interact with other computing professionals, or to develop or modify software. As user interfaces have become more visual, it is even more important to not only be able to write programs that present data but also to do so in an effective manner. Information is presented to users in a variety of ways and might be accomplished through a variety of media (e.g., multimedia and web). IT professionals will also need to be able to access and organize data (e.g., through databases). An understanding of certain technologies such as networking is essential; graduates must know about the principles of how computers communicate with one another and the implications of wireless devices. They need to know about creating the user experience and designing effective products that are guided by sound principles (e.g., HCI).

HCI has become an essential component for all computing professionals. Computer scientists and software engineers, the primary developers of sophisticated and complex software products, also need to understand the principles and concepts of HCI. They may not be the professionals primarily responsible for the analysis of user requirements and interface design, but they will work with those who are (the IT graduate). While computer scientists and software engineers are concerned with good component and architecture design, they are also concerned with testing. This testing is primarily in the area of software quality, however, not usability. The information technologist will need to be able to work in all phases of a user-centered software development lifecycle as well as in teams with other computing professionals. Today's IT graduate needs to understand not only the traditional usability concepts of HCI, but also the implications of the technological developments that are impacting the computing field, the business concerns, and the overall user experience. Thus, HCI is more that just understanding usability and interface design.

2. BRIEF HISTORY OF HCI

HCI already has enjoyed considerable success by providing solutions for problems brought about by the increasing

CITC4'03, October 16–18, 2003, Lafayette, Indiana, USA.

complexity of computing systems and their impact on people's lives. Moreover, the commercial importance of HCI recently has come to the forefront with the recognition that applications and interfaces make up the non-commodity value of computer products and services and that there is a clear return on investment in HCI [7][15].

HCI is a multidisciplinary field, which combines the theories and practices from cognitive and behavioral psychology, ergonomics, anthropology, sociology, computer science, engineering, and graphic design, among others.

As may be expected for an interdisciplinary field, it is difficult to pinpoint the exact beginnings of HCI, although its roots can be traced to research in the computing sciences, and applied social and behavioral sciences for at least 25 years and perhaps more than 50. According to Carroll, in his book *Human Computer Interaction in the New Millennium,* the foundations of HCI were primarily laid in the 1960's and 1970's along four (4) major threads of technological development, which remain the driving forces today. These threads are: prototyping and iterative development from the field of Software Engineering; psychology and human factors in computing systems; user interface software and computer graphics; and models, theories, and frameworks from Cognitive Science. Similarly, Preece cites the ACM SIGCHI model when describing the major topics of concern in HCI as the design and development process, the human, computer hardware, graphics and input output devices, and use and context [23].

There are several key individuals and landmark systems that illustrate the evolutionary path of HCI that developed as the essential concepts of desktop computing emerged. Early visions of personal, desktop access to information can be traced back to 1945 in the work of Bush [6]. The graphical and gestural interactions of the Sketchpad system developed by Sutherland [29] and synchronous collaboration through direct pointing and shared windows [11] have been cited as historically significant [7]. Other early influences came from Licklider [14] who visualized a symbiotic relationship between humans and computers [23].

In the 1970's new technologies, particularly advances in workstations and displays, led the way in advancing the areas that now fall under the HCI umbrella. At Xerox PARC the Dynabook was an early representation of ideas for a book-sized personal computer with links to a worldwide computer network. In the late 1970's the same group developed the desk-sized Star with several innovations, such as a high-resolution display, high-quality graphics, and point-and-click capability with a mouse. Then in the early 1980's Apple capitalized on Xerox developments with the Apple Lisa, which incorporated the graphical metaphor and marked the beginning of the graphical user interface (GUI). Usenet groups and e-mail that sprung up during this period sparked an interest in the social and psychosocial consequences of computing. Cognitive Science also matured as a discipline in the 1970's and HCI became one of its original domains with the vision of bringing Cognitive Science methods and theories to software development [7].

The convergence of these areas in the 1980's may mark the true beginning of HCI as a discrete field. Carroll cites the March 1982 National Bureau of Standards Conference called "Human Factors in Computer Systems" as a key event while groups such as SIGCHI also were formed during this period.

Not surprisingly, the balance of interest in the topics of HCI has shifted over time, as technologies advanced. In the 1970's and 1980's the emphasis was on the psychology of human information processing. The PC explosion in the early-mid 1980's drove a new focus on usability of single-user computer systems, followed in the next decade by a shift to multi-user workstations, multimedia, hypertext, virtual reality, and a recognition of the importance of group work, integration, use in home and society [23].

Social and cultural issues have been influential forces, molding the development of HCI. Early HCI in the United States was primarily concerned with how computers could enrich our lives and make them easier i.e. a tool facilitating creativity and problem solving. The emphasis was on building models of the interface, empirical evaluation, and psychology of programming. In Europe the early focus was on hardware and keyboard design, followed in the 1980's by theories and methods of design, and formalization of usability [23]. A post-war social movement in Scandinavia brought about the practice of participatory design that stresses that social objectives are sought in design [13]. The understanding that systems are used in a social context has been taken to another level by the Internet, which has motivated research into the concept of "community" and social software.

Trends in HCI research have also been influenced by practical experience. For example, an early focus on summative evaluation in usability engineering has been replaced with a formative process that emphasizes prototyping and iterative development. The crucial role of requirements analysis in the usability engineering process has been recognized and is now heavily influenced by sociologists and anthropologists who are skilled at the study of application domains and work practices. There is also a growing emphasis on design methods and on cost-benefit tradeoffs, with efforts on discount usability engineering methods, which are low cost inspection, and walkthrough methods [7].

3. KEY HCI CONCEPTS

The ACM's Special Interest Group in Computer Human Interaction (SIGCHI), the leading professional organization for this area, defines HCI as a discipline "concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [1]. Other definitions, such as that defined by John Carroll, specifically mention usability:

"HCI is the study and practice of usability. It is about understanding and creating software and other technology that people will want to use, will be able to use, and will find effective when used. The concept of usability and the methods and tools to encourage it, achieve it, and measure it are now touchstones in the culture of computing" [7].

These definitions provide a sound basis for the traditional view of HCI, but do not address the full breadth of the field. HCI is more than the traditional concepts of usability and interface design; it has several other facets.

3.1 Traditional HCI Concepts

Usability is the most traditional concept in HCI. A leading usability proponent, Jakob Nielsen, indicates that it is more narrowly concerned with system acceptability and more broadly concerned with how users can use a function. Does a system satisfy all the needs and tasks of the users of the system? The utility of a system is "whether the functionality of the system in principle can do what is needed" [20].

The implication is that a system not only works, but also does what it was intended to do. This "applies to all aspects of a system that the user interacts with, including the installation and maintenance phases" [20].

There are multiple attributes of usability. These are: learnability, how easy the system is to learn; efficiency, how quickly users can complete their tasks; memorability, how easy the system is to remember; control of errors, including prevention and recovery; and satisfaction, how much users like the system [20]. Usability is "a measurable characteristic of a product's user interface that is present to a greater or lesser degree" [17].

User-centered design is an organizing theme for software development and may be practiced through a process known as usability engineering, "a discipline that provides structured methods for achieving usability in user interface design during product development" [17]. Deborah Mayhew, a well-known practitioner in the HCI field, developed the usability engineering lifecycle, which is an approach that emphasizes the importance of involving the user throughout the entire process. The stages of the life cycle are: requirements gathering, user and task analysis, conceptual design, prototyping, usability testing, and deployment [17]. Each stage requires an appropriate level of feedback from the user.

During user analysis, users are studied and profiles and personas are developed for representative users. Alan Cooper, a leading proponent of personas, believes that software should be developed with specific users in mind [9]. This lends itself to a more focused product. In task analysis, scenarios are developed that will be used to understand what the user does and how they do it.

Personas and scenarios are integrated and used in design, as well as later during the usability testing phase. During the iterative prototyping phase, the interface is developed for usability as well as for functionality. Since most graphical user interfaces depend primarily on visual-based interaction, the developer needs to understand any potential impact of the users' cognitive processes. Cognitive psychology plays a very important role in HCI – it addresses the elements of human attention and perception as well as memory, learning, problem solving and decision-making [17]. An understanding of the abilities and limitations of human cognitive processes and the implications for interface design are essential knowledge areas for information technologists.

Usability testing does not "debug" the software or use blackbox testing strategies. Rather, usability testing is a process for determining what problems the user may have in using the system [28]. This iterative process involves varying levels and types of users at different times during the development of the prototypes. For example, in the beginning of the test, team members or colleagues may be used; later, various numbers and types of users such as novice or expert may be used. Results are analyzed and fed back into the development of the prototype for the next cycle.

3.2 Design Methods

There are a host of design approaches, each of which needs to be evaluated with regard to its appropriateness for the type of application being developed. These design methods are either a variation of the basic user-centered design approach or consider the user from a different perspective.

Gloria Gery, in her groundbreaking book *Electronic Performance Support Systems,* promoted the design of technology-based systems to improve human performance. This approach considered the support necessary for the user to perform a task. It included the evaluation of the number of steps in the task, what information was needed in its performance, and the identification of the actions required in the performance of the task [12]. Contextual design is a customer-centered approach to designing products. It is based upon customer data gathered in the field and models of how a customer works [3]. Learning-centered design (LCD) is an extension of user-centered design. LCD considers the user as a learner of a new domain [24]. The use of reusable interaction design patterns is a methodology that has gained a lot of momentum over the past few years and fits well into the usability engineering lifecycle. A design pattern is "a proven solution to a recurring design problem" (e.g. advanced search), and is expressed as part of a design language. [25] Lastly, scenario-based design is based upon the development of text stories or descriptions of how users interact in particular situations or in doing particular tasks [26]. This approach carries the use of scenarios throughout the entire software development lifecycle.

3.3 Designing for the User Experience

It has become clear that "two factors central to building usability into applications are interaction design and usability testing. Both practices seek to ensure that the user's experience with the software is consistent with expectations; that the use of the software is intuitive; and that there's no needless obstacle to successful completion of the transaction" [5]. As Alan Cooper points out "interaction design" means much more than just "interface design". Interaction design incorporates the end user and the objectives of the end user (and the organization) into the design process, whereas interface design, a subset of interaction design, refers to the look of the software and is not concerned with the user's overall experience and satisfaction [9].

As usability has become the defining standard for software quality it also has been a rapidly changing and expanding specialty [5]. In describing three waves of the usability evolution, Rubin [27] has emphasized the importance of the "user experience" in designs today. According to Rubin, the first wave of usability, started during World War II, was motivated by poor design of airplane cockpits. The major focus of this phase was on human physiology, information processing and performance under stress. The second wave came with introduction of the computer. The focus shifted to consideration of the hardware and software with the intent to improve usability so that users could perform tasks easily and efficiently. Rubin

refers to this phase as usability with a small "u", because the emphasis was on the product or service rather than the broader issues that affect user perception. With the emergence of the Internet there has been additional pressure for the design to be intuitive because often there is no opportunity to train customers to use the software and users easily leave a website for another if unsatisfied. Usability must extend beyond the issues of ease of use, ease of learning, and navigation. Rubin refers to the current phase as usability with a capital "U", which is more concerned with the user's experience as a whole rather than the user's interaction with the product. "In the broadest sense, usability involves every touch, every interaction, every phone call between an organization and user" [27]. This requires organizations to put the user experience at the forefront and may require new organizational practices.

4. PROCESS AND BUSINESS CONCERNS

The need for a focus on the user experience has major implications for businesses and their managers. The practice of separating responsibility for customer support, marketing, user interaction and other concerns into separate departments creates a "silo effect" and a fractured user experience according to Rubin [27, 28]. Breaking down such barriers may be necessary in many companies involved in software development and web design. Moreover, management often has balked at incorporation of usability engineering because of a previous lack of hard numbers on the savings that can be achieved with attention to usability. Most software and Web development managers view usability costs as added effort and expense, but the opposite is true. Many internal and external benefits (e.g., return on investment (ROI)) of the practice of usability have been identified in a study by Bias and Mayhew [4]. Marcus also provides many examples from the literature and cites statistics to provide evidence for ROI when usability is applied. General categories of benefits are reduced development costs, increased revenues from sales, and improved effectiveness. The first 10% of design process can determine 90% of a product's cost and performance. Applying usability techniques can help keep the product aligned with company goals and reduce those costs (Smith and Reinersten in [15]). For example, "the rule of thumb in many usability-aware organizations is that the cost-benefit ratio for usability is $1: $10-$100. Once a system is in development, correcting a problem costs 10 times as much as fixing the same problem in design. If the system has been released, it costs 100 times as much relative to fixing in design". (Gilb in [15]). There are also less tangible benefits of usability. Usability increases customer satisfaction and productivity, leads to customer trust and loyalty, and inevitably results in tangible cost savings and profitability. Moreover, usability affect's the public's perception and thus brand value and market share. Even court cases have resulted from poor usability [4] [15].

The observation that software developers rarely use the recommended usability engineering methods because they are seen as too costly, too time consuming, and too complex led Nielsen [22] to develop a simplified approach referred to as Discount Usability Engineering. Nielsen has also addressed another business issue: convincing clients to pay for usability. He suggests that "ultimately, the real answer to getting clients to pay for user testing and other user-centered design methods is to point out usability's astounding return on investment" [21].

5. SUPPORTIVE TECHNOLOGIES

According to Andrew Dillon, HCI can augment and enhance the design of technologies. These technologies will support the user in the performance of a variety of tasks that they would not otherwise be able to do. Dillon believes that HCI's contribution to technology advancement should be predictive rather than evaluative [10].

Supportive technologies can span the gamut of applications. For example, the design of digital libraries can and will have a profound effect on all users. The challenges of design include addressing interaction issues as well as other technical issues such as copyright and bandwidth. Other challenges such as the right mix of multimedia and instructional technology components need to be resolved. Digital libraries can be the main mechanism for bringing information to the user.

Developments such as wireless networking, mobile computing, and telecommunication technologies will allow the user to free themselves from their desk to perform a variety of tasks (some of which are not yet envisioned). Collaborative software and ubiquitous computing offer yet another look at how these technologies with an HCI perspective will impact the user.

5.1.1 Distributed Computing

Mark Weiser in his paper "The Coming of Age of Calm Technology" talks about the Internet and distributed computing as a transition between the PC (one computer, one person) and ubiquitous computing ("many computers sharing each of us") [31]. Distributed computing involves many computers in a client-server environment. These computers allow for accessing or sharing of information or activities.

Many applications have developed as a result of this type of environment. One such application is groupware or computer-supported collaborative work (CSCW). Groupware provides for group collaboration, cooperation and communication of a particular environment [8]. It has changed the way in which groups in a business, academic or social environment interact with each other. Not only does the design of the interface need to take into account the tasks to be performed, but also how the user will react and interact with them. For example, in a business environment, workflow applications may change what tasks are assigned to people, how work is reengineered, and how the work is supervised [8].

There are a wide variety of groupware applications. They range from the commonplace email to instant messaging (IM) to chat to interactive, multi-user, distributed games. The contribution of HCI to this area with such a wide variety of applications is to consider how users might interact differently (i.e., the development of a new language in the IM environment), what type of support and needs should be provided, how to appropriately visualize and provide awareness of the information within the interface, and how to represent the presence of the individual within the environment.

5.1.2 Ubiquitous Computing

The computer is destined to become invisible, that is, this technology as we know it will disappear into the background. Mark Weiser in his 1991 Scientific American article, "The Computer of the 21st Century," first proposed the notion of the

ubiquitous computer. His vision was one in which each person would share "thousands of highly distributed, interconnected, often invisible computers, blended into the natural environment, operating without engaging peoples conscious senses or attention" [30].

The PC is currently about an interface and a "hard" device that users might take with them. Ubiquitous computing (ubicomp) is the seamless integration and invisibility of the computer into our society. It will become second nature to use. Most of us already are not conscious of computers in cars and microwaves. However, given the problems with many so-called intelligent devices and appliances, the HCI problems of ease of use still have a long way to go.

Another concept, pervasive computing, is similar to ubiquitous computing. Pervasive computing is computing not bound to the desktop; it "goes beyond the realm of personal computer. It is the idea that almost any device, from clothing to tools to appliances to cars to homes to the human body to your coffee mug, can be embedded with chips to connect the device to an infinite network of other devices. The goal of pervasive computing, which combines current network technologies with wireless computing, voice recognition, Internet capability and artificial intelligence, is to create an environment where the connectivity of devices is embedded in such a way that the connectivity is unobtrusive and always available" [2].

On first pass, the two terms, ubiquitous and pervasive computing, seem similar. However we could distinguish them in the following manner: "Ubiquitous means everywhere. Pervasive means "diffused throughout every part of." … Pervasive computing involves devices like handhelds … [e.g.,] Web-enabled phones. … Ubiquitous computing, though, eschews our having to use computers at all. Instead, it's computing in the background, with technology embedded in the things we already use. That might be a car navigation system that, by accessing satellite pictures, alerts us to a traffic jam ahead, or an oven that shuts off when our food is cooked" [18].

This vision of computing is that the device (i.e., the computer) will come in many sizes and forms, each to suit a particular task, and be portable. It would not be uncommon to see post-it notes, smart sheets of paper (similar to the tablet PC), and larger devices much like bulletin boards [30]. Students would be able to download instructor's notes real-time in class and there would be no need for handouts. We already see this to some extent in such devices as PDAs, pagers, refrigerators, mobile phone, and other devices that are easy to hook up to the Internet. It allows us to be connected anytime, anywhere.

Several research laboratories, such as the MIT Media Lab, have been working on wearable computing. As the name indicates, wearable computing is a computer that is worn or implanted in an article of clothing. These devices are always on and are context-aware, that is they have the ability to track and retrieve various types of data about the user's environment. Such devices might include jewelry, eyeglasses, company badges, watches, and even the fabric of clothing.

6. FUTURE TRENDS

Several usability challenges have emerged as a result of the new technological developments that have taken place. As devices have gotten smaller and more portable, designers and developers need to think about how users will be able to use these many new devices and develop new metaphors for them. Usability issues are centered on the very limited input and output options that are necessitated by the small form factor of these devices. Research is being conducted, with the goal of defining some prescribed solutions or guidelines for small display devices, just as there are guidelines for normal display devices. Several user studies have shown that different user groups often have conflicting preferences, however, especially when it comes to small display devices [16].

Another challenge is interoperability. With the potential for a wide variety of devices being networked together, theses devices will not only need to be able to communicate with one another easily but information will need to be represented in many different formats. We see an example of this happening already with web site information being presented on traditional, full-sized monitors as well as on small mobile device displays.

We will see the computer become invisible with interfaces as we know them drastically changing – they may not be as visual but may become more physical (e.g., they will become an integral part of the device as discussed in the ubiquitous computing section). Creativity will need to be encouraged and supported if IT professionals are to think "out of the box" for new designs and metaphors [19]. Also in the case of distributed computing environments, an understanding of the social implications and the impact on social communities for many new applications will need to be understood.

7. CONCLUSION

As we have seen, HCI has become an integral and indispensable part of the computing environment. It encompasses a wide variety of elements. It is clear that the understanding of the field of HCI as well as the application of its principles will have a great impact on how users are able to interact with computing devices.

The burden to understand how the theories and practices of HCI may be applied will fall largely on the IT graduate as the advocate for the user. The IT graduate will need to understand all facets of the computing field as well as to understand not only the user's behavior and tasks but also the broader impact on the user's environment.

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