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Research Agenda in Human-Computer Interaction : Interaction Style

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Abstract— *This paper discusses the research that has been done in the field of Human Computer Interaction (HCI) relating to human psychology. A brief overview of HCI is presented. Specific examples of research in the areas of icons and menus are then reviewed. The results of these experiments and the predictions they make about general human psychology and specific human interaction with computers is discussed. Mental models of user interface interaction are discussed and compared to mental models of real world object. Finally, future directions for research are proposed. The past decade has witnessed an unprecedented growth in user interface and human–computer interaction (HCI) technologies and methods. The synergy of technological and methodological progress on the one hand, and changing user expectations on the other, are contributing to a redefinition of the requirements for effective and desirable human–computer interaction. A key component of these emerging requirements and of effective HCI in general, is the ability of these emerging systems to address* user affect*. The objective of this special issue is to provide an introduction to the emerging research area of affective HCI, some of the available methods and techniques, and representative systems and applications. "The question persists and indeed grows whether the computer will make it easier or harder for human beings to know who they really are, to identify their real problems, to respond more fully to beauty, to place adequate value on life, and to make their world safer than it now is".*

Keywords—*Affective HCI; Affective computing; Affect recognition; Affect expression; Affective user modeling.*

1 Introduction

Computers have become, for better or worse, integral parts of our lives in every respect. We use them to communicate with others, to write our papers, to monitor the arrival and departure of airplanes from a control room, and to play games, to select but a few of their many uses. Each of these uses requires us, as humans, to interact with these machines. This interaction requires a mode of communication that was generally unknown prior to the introduction of computers into our society. Indeed, this mode of communication was almost entirely nonexistent prior to the introduction of the Graphical User Interface (GUI) popularized by the Macintosh computer (Levy *1994)*.

The GUI works by using a representational form of communication to inform the user about the state of the machine and to allow the user to tell the computer which operations to perform. As Steven Levy (1994) succinctly states: "Metaphor, it turns out, is the key to making computers comprehensible." The truth of this statement is exhibited by the fact that so many computer users utilize this notion of metaphorical thinking without questioning its validity. One merely needs to listen to people discussing how a computer program works to realize this:

"How do I print my letter?"

"Open the letter, the select print, and hit ok."

Clearly these people are discussing a particular action to be taken at a computer.

However, their conversation doesn't hinge on the actual motions involved:

"Place your hand on the device next to the keyboard. Move that device, which causes movement of the black arrow on the bright TV-like device on your desk, so that the black arrow is on top of the white square, which has text below with the name of your letter, and click twice, in rapid succession, on the button at the top of the device in your hand."

Utilizing computers had always begged the question of interfacing. The methods by which human has been interacting with computers has travelled a long way. The journey still continues and new designs of technologies and systems appear more and more every day and the research in this area has been growing very fast in the last few decades.

The growth in Human-Computer Interaction (HCI) field has not only been in quality of interaction, it has also experienced different branching in its history. Instead of designing regular interfaces, the different research branches have had different focus on the concepts of multimodality rather than unimodality, intelligent adaptive interfaces rather than command/action based ones, and finally active rather than passive interfaces.

This paper intends to provide an overview on the state of the art of HCI systems and cover most important branches as mentioned above. In the next section, basic definitions and terminology of HCI are given. Then an overview of existing technologies and also recent advances in the field is provided. This is followed up by a description on the different architectures of HCI designs. The final sections pertain to description on some of the applications of HCI and future directions in the field. On the user's side, interactive system technology is constrained by the nature of human communication organs and abilities; on the computer side, it is constrained only by input/output devices and methods that we can invent. The challenge before us is to design new devices and types of dialogues that better fit and exploit the communication-relevant characteristics of humans.

2 HCI : Definition, Terminology

Sometimes called as Man-Machine Interaction or Interfacing, concept of Human-Computer Interaction /Interfacing (HCI) was automatically represented with the emerging of computer, or more generally machine, itself. The reason, in fact, is clear: most sophisticated machines are worthless unless they can be used properly by men. This basic argument simply presents the main terms that should be considered in the design of HCI: functionality and usability.

Why a system is actually designed can ultimately be defined by what the system can do i.e. how the functions of a system can help towards the achievement of the purpose of the system. Functionality of a system is defined by the set of actions or services that it provides to its users. However, the value of functionality is visible only when it becomes possible to be efficiently utilised by the user. Usability of a system with a certain functionality is the range and degree by which the system can be used efficiently and adequately to accomplish certain goals for certain users. The actual effectiveness of a system is achieved when there is a proper balance between the functionality and usability of a system.

"Place your hand on the device next to the keyboard. Move that device, which causes movement of the black arrow on the bright TV-like device on your desk, so that the black arrow is on top of the white square, which has text below with the name of your letter, and click twice, in rapid succession, on the button at the top of the device in your hand."

2.1 Overview of HCI

The advances made in last decade in HCI have almost made it impossible to realize which concept is fiction and which is and can be real. The thrust in research and the constant twists in marketing cause the new technology to become available to everyone in no time. However, not all existing technologies are accessible and/or affordable by public. In the first part of this section, an overview of the technology that more or less is available to and used by public is presented. In the second part, an outlook of the direction to which HCI research is heading has been drawn.

2.2 Existing HCI Technologies

HCI design should consider many aspects of human behaviours and needs to be useful. The complexity of the degree of the involvement of a

human in interaction with a machine is sometimes invisible compared to the simplicity of the interaction method itself. The existing interfaces differ in the degree of complexity both because of degree of functionality/usability and the financial and economical aspect of the machine in market. For instance, an electrical kettle need not to be sophisticated in interface since its only functionality is to heat the water and it would not be cost-effective to have an interface more than a thermostatic on and off switch. On the other hand, a simple website that may be limited in functionality should be complex enough in usability to attract and keep customers [1].

The focus of this paper is mostly on the advances in physical aspect of interaction and to show how different methods of interaction can be combined (Multi-Modal Interaction) and how each method can be improved in performance (Intelligent Interaction) to provide a better and easier interface for the user. The existing physical technologies for HCI basically can be categorized by the relative human sense that the device is designed for. These devices are basically relying on three human senses: vision, audition, and touch [1].

Input devices that rely on vision are the most used kind and are commonly either switch-based or pointing devices [8] [9]. The switch-based devices are any kind of interface that uses buttons and switches like a keyboard [10]. The pointing devices examples are mice, joysticks, touch screen panels, graphic tablets, trackballs, and pen-based input [11]. Joysticks are the ones that have both switches and pointing abilities. The output devices can be any kind of visual display or printing device [3].

The recent methods and technologies in HCI are now trying to combine former methods of interaction together and with other advancing technologies such as networking and animation. These new advances can be categorized in three sections: wearable devices [19], wireless devices [20], and virtual devices [21]. The technology is improving so fast that even the borders between these new technologies are fading away and they are getting mixed together. Few examples of these devices are: GPS navigation systems [22], military super-soldier enhancing devices (e.g. thermal vision [23], tracking other soldier movements using GPS, and environmental scanning), radio frequency identification (RFID) products, personal digital assistants (PDA), and virtual tour for real estate business [24]. Some of these new devices upgraded and integrated previous methods of interaction. As an illustration in case, there is the solution to keyboarding that has been offered by Compaq's iPAQ which is called Canesta keyboard as shown in figure 1. This is a virtual keyboard that is made by projecting a QWERTY like pattern on a solid surface using a red light. Then device tries to track user's finger movement while typing on the surface with a motion sensor and send the keystrokes back to the device [25].

Figure 1 : Canesta Virtual Keyboard [26]

2.3 Recent Advances in HCI

In following sections, recent directions and advances of research in HCI, namely intelligent and adaptive interfaces and ubiquitous computing, are presented. These interfaces involve different levels of user activity: physical, cognitive, and affection.

3 The Next Interaction Style

Beyond this general framework, and beyond improvements in particular device technologies, a trend toward a new class of input/output device and human-computerinteraction style is emerging. Its effect on the field of input devices specifically is tomove from providing objects for the user to actuate through specific commands to simply sensing the user's body. Nielsen describes this next generation interaction style as non-command-based:

"The fifth generation user interface paradigm seems to be centered aroundnon-command-based dialogues. This term is a somewhat negative way ofcharacterizing a new form of interaction but so far, the unifying concept does seem to be exactly the abandonment of the principle underlying all

earlier paradigms: That a dialogue has to be controlled by specific and precise commands issued by the user and processed and replied to by the computer. The new interfaces are often not even dialogues in the traditional meaning of the word, even though they obviously can be analyzed as having some dialogue content at some level since they do involve the exchange of information between a user and a computer. The principles shown at CHI'90 which I am summarizing as being non-command-based interaction are eye tracking interfaces, artificial realities, play-along music accompaniment, and agents." (Nielsen, 1990)

This new style of input will require new devices, new types of interaction techniques, and new software approaches to deal with them. Unlike traditional inputs, such as keyboards and mice, the new inputs represent less intentional actuation of a device or issuance of a command, but are more like passive monitoring of the user. For that reason the inputs tend to occur concurrently with one another, as different aspects of the user are monitored. From the point of view of research in input devices, this style requires a change from conventional devices to passive equipment that senses the user. Examples of such devices are unobtrusive three-dimensional trackers, hand-measuring devices, remote cameras (plus appropriate pattern recognition), range cameras, eye movement monitors, and even physiological monitors. The "natural" qualities of these input devices are well matched to new output technologies such as stereoscopic displays, head-coupled displays, and directional, non-speech audio.

3.1 Research in Interaction Style

The general framework in which to view research into styles of human-computer interaction is a search for both higher bandwidth communication between human and computer and better "fit" between human and computer (that is, reductions in cognitive load on the user, training required, and effort devoted to non-task concerns). While natural speech already provides appropriate bandwidth for verbal communication, there is no such counterpart for symbolic, non-verbal styles of interaction, and that is where the search for increased bandwidth is of greatest interest, as are abstractions and encodings that increase effective bandwidth.

The principal interaction styles currently in use and emerging are command languages, menus, natural language, direct manipulation, and virtual reality. Command languages are concise and unambiguous but typically difficult to learn and use. Their continuing advantage in the face of newer interaction styles is that they are most amenable to abstraction, or writing programs or scripts of user input commands. Menus require the user to recognize the desired entry rather than recall it, reducing the load on long-term memory. Menus can exist in many forms. although their traditional implementation has the user click with a mouse over the item to be selected, the user could just as well respond via voice command, just as real menus are used in restaurants. Natural language is still a misnomer, since, given the state of the art, working natural language interfaces must still be restricted to a subset of natural language, and the subset must be chosen carefully––in vocabulary, range of syntactic constructs, and domain. Although future research in natural language offers the hope of humancomputer communication that is so natural it is "just like talking to a person," such conversation may not always be the most effective way of commanding a machine (Small, 1983). Direct manipulation interfaces present a set of objects on a screen and provide the user a repertoire of manipulations that can be performed on any of them (Shneiderman, 1983). The result is a computer interface consisting of a set of objects and operations that closely resemble their counterparts in the physical world. Finally, research in virtual reality carries the user's illusion of manipulating real objects still further, allowing interaction with computer-generated images as if they were real objects located in space surrounding the user. Some aspects of virtual reality can be approached as "three-dimensional direct manipulation plus voice input/output," but not all virtual reality interactions can be characterized that simply (Fisher, 1986, Fisher, 1988, Foley, 1987).

4 Our Changing World

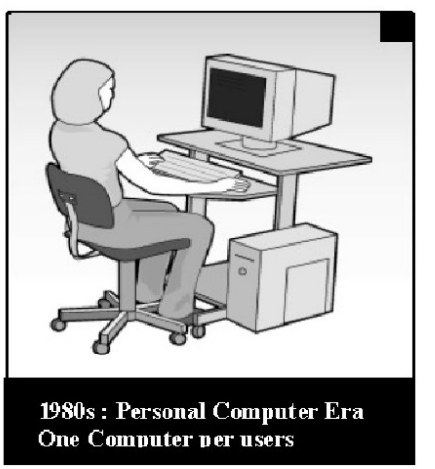
Major changes have occurred within the computer revolution; changes which encompass all aspects of its role. These are not just quantitative in nature, such as exponential increases in processing power and storage capacity, but are more

fundamental, pointing not only to the function of computer technology, but its emerging diversity both in terms of its form and place in the world. Computers are now embedded within a huge range of materials and artefacts, and take on roles in almost all aspects of life. People and lifestyles are altering. These changes are sometimes spurred on by technology, but other times work in parallel or provoke technological innovation. There is a global scale of change which is taking place hand in hand with new technologies. This gives rise to tensions between individuals and governments, and between globalisation and cultural diversity. In this Part, we comment on change at all levels, and provide pointers to where we are going in future.

3.1 Changing Computer

There have been various computer-driven revolutions in the past: the widespread introduction of the personal computer (PC) was one, the invention of the graphical browser was another, and the Internet yet another. There have also been computer eras where one type of computer has dominated, having straightforward implications for whether the computers were shared or personal, and for whether they were specialized commodities or not (see diagram below). But the ways computers have altered our lives, all aspects of our lives, is more comprehensive than, at first blush, recollections of these technological revolutions or eras might suggest.

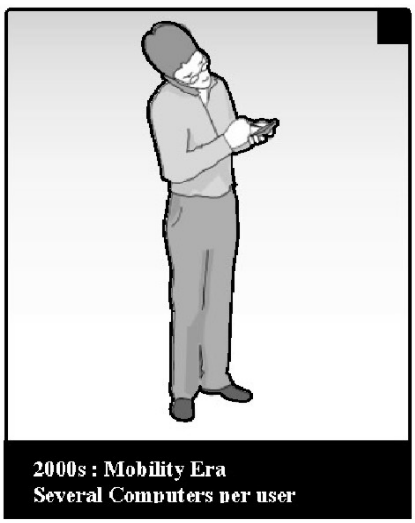
Computers affect how we undertake the most prosaic of activities – from buying food to paying our bills – and they do so in ways we might not have imagined when the first personal computers arrived on our desks. They have also created wholly new experiences, for example, allowing us to inhabit virtual worlds with people from many different parts of the globe. In between these extremes, from the prosaic to the wholly new, computers have taken over from older technologies in ways that looked merely like substitution at first but which have ended up creating radical change.



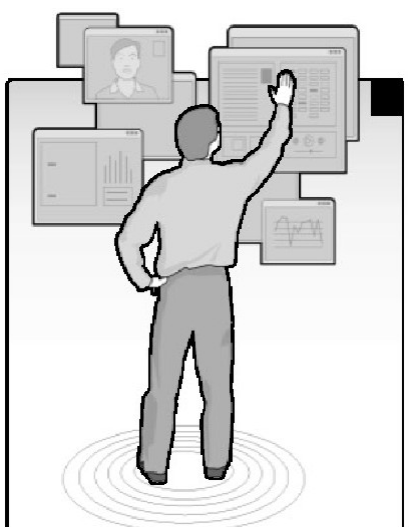
However, what one can do with images when they are digital is quite different. Whereas, before, we may have only printed one or two rolls of film, displaying the photos on the mantelpiece or in an album, digital images are now reproduced many times over, and are often broadcast around the world on websites.

The activities we undertake and the goals we have in mind when we take photos and share them, then, are not at all the same now as they were even five

years ago. It is not just in terms of user experiences, such as shopping, games, and picture-taking that the world has changed. Computers have altered our sense of the world at large, letting us see images of far-away places, instantaneously and ubiquitously. The world, now, seems so much smaller than it was even a decade ago. In this section we begin to look at many different aspects of how computing technologies have changed and their impact on our lives.



2000s : Mobility Era
Several Computers per user



2020 and beyond : Ubiquity Era
Thousands of computers per user

4 RESEARCH OVERVIEW

A Framework for Research in Input/Output Devices and Interaction Styles

Research in the field of input/output for human-computer interaction centers around the two ends of the communication channel:

- the devices and techniques computers can use for communicating with people, and
- the perceptual abilities, processes, and organs people can use for communicating with computers.

Attempts are then made to find the common ground through which the two can be related. The basic approach is to study new modes of communication that could be used for human-computer communication and simultaneously to develop devices and techniques to use such modes. The research paradigm is to invent new interaction techniques, implement them in hardware and software, and then study them experimentally to see their effect. In an ideal world, the development of new input/output devices would be motivated or guided by the studies of human perceptual facilities and effectors as well as the needs uncovered in studies of existing interfaces. More often, though, the hardware developments come first, people simply attempt to build "whatever can be built," and then HCI researchers try to find uses for the resulting artifacts.

5 CONCLUSION

Human-Computer Interaction is an important part of systems design. Quality of system depends on how it is represented and used by users. Therefore, enormous amount of attention has been paid to better designs of HCI. The new direction of research is to replace common regular methods of interaction with intelligent, adaptive, multimodal, natural methods. Ambient intelligence or ubiquitous computing which is called the Third Wave is trying to embed the technology into the environment so to make it more natural and invisible at the same time. Virtual reality is also an advancing field of HCI which can be the common interface of the future. This paper attempted to give an overview on these issues and provide a survey of existing research through a comprehensive reference list. The second is in application of these

results: it can lead to faster and more natural communication with interactive systems, enable better quality and efficiency in the operation of such systems, and improve the working conditions of their users by providing them with richer and more natural means of communication.

The study of mental models that allow humans to use these interfaces provides a secondary, higher level approach to understanding Human Computer Interaction. Though mental models are far from concrete objects, we do understand to a how they are used to allow people to interact with the world. By studying them both in the domain of the real world, as well as the domain of the virtual world on a computer screen, we can gain insight into how these models are formed, and how they can be moved from domain to domain.

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