User-System Interaction (USI)

Overview and Introduction

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1 User-System Interaction (USI)

[this part is copied from URL http://www.acm.org/sigchi/cdg/cdg2.html with some modifications: e.g., "human-computer interaction (HCI)" is replaced by "user-system interaction (USI)"]

1.1 Definition of USI

We offer a working definition that at least permits us to get down to the practical work of deciding what is to be taught:

User-system interaction is 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.

From a computer science perspective, the focus is on interaction and specifically on interaction between one or more humans and one or more computational machines. The classical situation that comes to mind is a person using an interactive graphics program on a workstation. But it is clear that varying what is meant by interaction, human, and machine leads to a rich space of possible topics, some of which, while we might not wish to exclude them as part of user-system interaction, we would, nevertheless, wish to identify as peripheral to its focus. Other topics we would wish to identify as more central.

Take the notion of machine. Instead of workstations, computers may be in the form of embedded computational machines, such as parts of spacecraft cockpits or microwave ovens. Because the techniques for designing these interfaces bear so much relationship to the techniques for designing workstations interfaces, they can be profitably treated together. But if we weaken the computational and interaction aspects more and treat the design of machines that are mechanical and passive, such as the design of a hammer, we are clearly on the margins, and generally the relationships between humans and hammers would not considered part of user-system interaction. Such relationships clearly would be part of general human factors, which studies the human aspects of all designed devices, but not the mechanisms of these devices. User-system interaction, by contrast, studies both the mechanism side and the human side, but of a narrower class of devices.

Or consider what is meant by the notion human. If we allow the human to be a group of humans or an organization, we may consider interfaces for distributed systems, computer-aided communications between humans, or the nature of the work being cooperatively performed by means of the system. These are all generally regarded as important topics central within the sphere of user-system interaction studies. If we go further down this path to consider job design from the point of view of the nature of the work and the nature of human satisfaction, then computers will only occasionally occur (when they are useful for these ends or when they interfere with these ends) and user-system interaction is only one supporting area among others.

There are other disciplinary points of view that would place the focus of USI differently than does computer science, just as the focus for a definition of the databases area would be different from a computer science vs. a business perspective. USI in the large is an interdisciplinary area. It is emerging as a specialty concern within several disciplines, each with different emphases: computer science (application design and engineering of human interfaces), psychology (the application of theories of cognitive processes and the empirical analysis of user behavior),

sociology and anthropology (interactions between technology, work, and organization), and industrial design (interactive products). In this report, we have adopted, as an ACM committee, an appropriate computer science point of view, although we have tried at the same time to consider user-system interaction broadly enough that other disciplines could use our analysis and shift the focus appropriately. From a computer science perspective, other disciplines serve as supporting disciplines, much as physics serves as a supporting discipline for civil engineering, or as mechanical engineering serves as a supporting discipline for robotics. A lesson learned repeatedly by engineering disciplines is that design problems have a context, and that the overly narrow optimization of one part of a design can be rendered invalid by the broader context of the problem. Even from a direct computer science perspective, therefore, it is advantageous to frame the problem of user-system interaction broadly enough so as to help students (and practitioners) avoid the classic pitfall of design divorced from the context of the problem.

To give a further rough characterization of user-system interaction as a field, we list some of its special concerns: User-system interaction is concerned with the joint performance of tasks by humans and machines; the structure of communication between human and machine; human capabilities to use machines (including the learnability of interfaces); algorithms and programming of the interface itself; engineering concerns that arise in designing and building interfaces; the process of specification, design, and implementation of interfaces; and design trade-offs. User-system interaction thus has science, engineering, and design aspects.

Regardless of the definition chosen, USI is clearly to be included as a part of computer science and is as much a part of computer science as it is a part of any other discipline. If, for example, one adopts Newell, Perlis, and Simon's (1967) classic definition of computer science as "the study of computers and the major phenomena that surround them," then the interaction of people and computers and the uses of computers are certainly parts of those phenomena. If, on the other hand, we take the recent ACM (Denning, et al., 1988) report's definition as "the systematic study of algorithmic processes that describe and transform information: their theory, analysis, design, efficiency, implementation, and application," then those algorithmic processes clearly include interaction with users just as they include interaction with other computers over networks. The algorithms of computer graphics, for example, are just those algorithms that give certain experiences to the perceptual apparatus of the human. The design of many modern computer applications inescapably requires the design of some component of the system that interacts with a user. Moreover, this component typically represents more than half a system's lines of code. It is intrinsically necessary to understand how to decide on the functionality a system will have, how to bring this out to the user, how to build the system, how to test the design.

Because user-system interaction studies a human and a machine in communication, it draws from supporting knowledge on both the machine and the human side. On the machine side, techniques in computer graphics, operating systems, programming languages, and development environments are relevant. On the human side, communication theory, graphic and industrial design disciplines, linguistics, social sciences, cognitive psychology, and human performance are relevant. And, of course, engineering and design methods are relevant.

1.2 Field of USI

The goal of this section is to provide background for this report in terms of some of the major themes and influences that have shaped the field of USI. In addition, an attempt is made to project some current trends into the near future as a basis for anticipating some of the conditions with which students will be faced upon, or even before, graduation. This section is not intended to provide either an exhaustive history of the past or a full scale "futures projection." It is, rather, to provide a context for the recommendations which follow.

1.2.1 Historical Roots

User-system interaction arose as a field from intertwined roots in computer graphics, operating systems, human factors, ergonomics, industrial engineering, cognitive psychology, and the systems part of computer science. Computer graphics was born from the use of CRT and pen devices very early in the history of computers. This led to the development of several user-system interaction techniques. Many techniques date from Sutherland's Sketchpad Ph.D. thesis (1963) that essentially marked the beginning of computer graphics as a discipline. Work in computer graphics has continued to develop algorithms and hardware that allow the display and manipulation of ever more realistic-looking objects (e.g., CAD/CAM machine parts or medical images of body parts). Computer graphics has a natural interest in USI as "interactive graphics" (e.g., how to manipulate solid models in a CAD/CAM system).
A related set of developments were attempts to pursue "man-machine symbiosis" (Licklider, 1960), the "augmentation of human intellect" (Engelbart, 1963), and the "Dynabook" (Kay and Goldberg, 1977). Out of this line of development came a number of important building blocks for user-system interaction. Some of these building blocks include the mouse, bitmapped displays, personal computers, windows, the desktop metaphor, and point-and-click editors (see Baecker & Buxton, 1987, Chapter 1).
Work on operating systems, meanwhile, developed techniques for interfacing input/output devices, for tuning system response time to human interaction times, for multiprocessing, and for supporting windowing environments and animation. This strand of development has currently given rise to "user interface management systems" and "user interface toolkits".
Human factors, as a discipline, derives from the problems of designing equipment operable by humans during World War II (Sanders & McCormick, 1987). Many problems faced by those working on human factors had strong sensory-motor features (e.g., the design of flight displays and controls). The problem of the human operation of computers was a natural extension of classical human factors concerns, except that the new problems had substantial cognitive, communication, and interaction aspects not previously developed in human factors, forcing a growth of human factors in these directions. Ergonomics is similar to human factors, but it arose from studies of work. As with human factors, the concerns of ergonomics tended to be at the sensory-motor level, but with an additional physiological flavor and an emphasis on stress. Human interaction with computers was also a natural topic for ergonomics, but again, a cognitive extension to the field was necessary resulting in the current "cognitive ergonomics" and "cognitive engineering." Because of their roots, ergonomic studies of computers emphasize the relationship to the work setting and the effects of stress

factors, such as the routinization of work, sitting posture, or the vision design of CRT displays.

Industrial engineering arose out of attempts to raise industrial productivity starting in the early years of this century. The early emphasis in industrial engineering was in the design of efficient manual methods for work (e.g., a two-handed method for the laying of bricks), the design of specialized tools to increase productivity and reduce fatigue (e.g., brick pallets at waist height so bricklayers didn't have to bend over), and, to a lesser extent, the design of the social environment (e.g., the invention of the suggestion box). Interaction with computers is a natural topic for the scope of industrial engineering in the context of how the use of computers fit into the larger design of work methods.

Cognitive psychology derives from attempts to study sensation experimentally at the end of the 19th century. In the 1950's, an infusion of ideas from communications engineering, linguistics, and computer engineering led to an experimentally-oriented discipline concerned with human information processing and performance. Cognitive psychologists have concentrated on the learning of systems, the transfer of that learning, the mental representation of systems by humans, and human performance on such systems.

Finally, the growth of discretionary computing and the mass personal computer and workstation computer markets have meant that sales of computers are more directly tied to the quality of their interfaces than in the past. The result has been the gradual evolution of a standardized interface architecture from hardware support of mice to shared window systems to "application management layers." Along with these changes, researchers and designers have begun to develop specification techniques for user interfaces and testing techniques for the practical production of interfaces.

1.2.2 Likely Future Developments

The means by which humans interact with computers continues to evolve rapidly. A curriculum in a changing area must be put together with some understanding of the forces shaping the future so that its concepts are not quickly out of date. Although the curriculum can always be revised in the light of greater understanding in the future, students cannot generally be recalled for retraining. They must build their own future understanding upon the foundations provided by the courses taken at the time they were students.

User-system interaction is, in the first instance, affected by the forces shaping the nature of future computing. These forces include:

- Decreasing hardware costs leading to larger memories and faster systems.
- Miniaturization of hardware leading to portability.
- Reduction in power requirements leading to portability.
- New display technologies leading to the packaging of computational devices in new forms.
- Assimilation of computation into the environment (e.g., VCRs, microwave ovens, televisions).
- Specialized hardware leading to new functions (e.g., rapid text search).
- Increased development of network communication and distributed computing.
- Increasingly widespread use of computers, especially by people who are outside of the computing profession.

- Increasing innovation in input techniques (e.g., voice, gesture, pen), combined with lowering cost, leading to rapid computerization by people previously left out of the "computer revolution."
- Wider social concerns leading to improved access to computers by currently disadvantaged groups (e.g., young children, the physically/visually disabled, etc.).

Because user-system interaction involves transducers between humans and machines and because humans are sensitive to response times, viable human interfaces are more technology-sensitive than many parts of computer science. For instance, the development of the mouse gave rise to the point-and-click style of editor interface and the mouse-based graphics program. Partially based on the above trends, we expect a future for USI with some of the following characteristics:

1.2.2.1.1 Ubiquitous communication.

Computers will communicate through high speed local networks, nationally over wide-area networks, and portably via infrared, ultrasonic, cellular, and other technologies. Data and computational services will be portably accessible from many if not most locations to which a user travels.

1.2.2.1.2 Embedded computation.

Computation will pass beyond desktop computers into every object for which uses can be found. The environment will be alive with little computations from computerized cooking appliances to lighting and plumbing fixtures to window blinds to automobile braking systems to greeting cards. To some extent, this development is already taking place. The difference in the future is the addition of networked communications that will allow many of these embedded computations to coordinate with each other and with the user. Human interfaces to these embedded devices will in many cases be very different from those appropriate to workstations.

1.2.2.1.3 High functionality systems.

Systems will have large numbers of functions associated with them. There will be so many systems that most users, technical or non-technical, will not have time to learn them in the traditional way (e.g., through thick manuals).

1.2.2.1.4 Mass availability of computer graphics.

Computer graphics capabilities such as image processing, graphics transformations, rendering, and interactive animation will become widespread as inexpensive chips become available for inclusion in general workstations.

1.2.2.1.5 Mixed media.

Systems will handle images, voice, sounds, video, text, formatted data. These will be exchangeable over communication links among users. The separate worlds of consumer electronics (e.g., stereo sets, VCRs, televisions) and computers will partially merge. Computer and print worlds will continue to cross assimilate each other.

1.2.2.1.6 High-bandwidth interaction.

The rate at which humans and machines interact will increase substantially due to the changes in speed, computer graphics, new media, and new input/output devices. This

will lead to some qualitatively different interfaces, such as virtual reality or computational video.

1.2.2.1.7 Large and thin displays.

New display technologies will finally mature enabling very large displays and also displays that are thin, light weight, and have low power consumption. This will have large effects on portability and will enable the development of paper-like, pen-based computer interaction systems very different in feel from desktop workstations of the present.

1.2.2.1.8 Group interfaces.

Interfaces to allow groups of people to coordinate will be common (e.g., for meetings, for engineering projects, for authoring joint documents). These will have major impacts on the nature of organizations and on the division of labor. Models of the group design process will be embedded in systems and will cause increased rationalization of design.

1.2.2.1.9 User Tailorability.

Ordinary users will routinely tailor applications to their own use and will use this power to invent new applications based on their understanding of their own domains. Users, with their deeper knowledge of their own knowledge domains, will increasingly be important sources of new applications at the expense of generic systems programmers (with systems expertise but low domain expertise).

1.2.2.1.10 Information Utilities.

Public information utilities (such as Compuserve, Prodigy, home banking and shopping, etc.) and specialized industry services (e.g., weather for pilots) will continue to proliferate. The rate of proliferation will accelerate with the introduction of high-bandwidth interaction and the improvement in quality of interfaces.
One consequence of the above developments is that computing systems will appear partially to dissolve into the environment and become much more intimately associated with their users' activities. One can make an analogy to the development of motion power. Once, strikingly visible, large, centralized water wheels were used to drive applications via belt drives; now electric motors are invisibly integrated into applications from VCRs to refrigerators.
Of course, personal computers in some form will continue to exist (although many might take the form of electronic notebooks) and there will still be the problem of designing interfaces so that users can operate them. But the rapid pace of development means that the preparation of students must address not only the present state of technology, but also provide the foundations for future possibilities.

1.3 The Content of User-System Interaction

The aim in this section is to inventory the current state of results in the field of user-system interaction. Our object is to delimit the scope of our concerns and to specify the connections with other fields. The discussion is not constrained by the need to distribute this content into courses or to tailor a curriculum for various sorts of students. The objective is, rather, to survey what is known that is worth teaching.

Different courses might be carved out of parts of this inventory, and the program at a particular school or in any given instructional environment might wish to utilize only part of this material, together with other topics in a reorganized point of view (e.g., for a course in a design department or for a short, in-house training course for members of product development teams). For convenience, we have loosely arranged the topics in the field into 16 groups.

The topics in this table derive from a consideration of five interrelated aspects of user-system interaction: (N) the nature of user-system interaction, (C) the use and context of computers, (U) human characteristics, (S) interactive system and interface architecture, and (D) the development process.

Interactive systems exist within a larger social, organizational and work milieu (C1). Within this context there are applications for which we wish to employ computer systems (C2). But the process of putting computers to work means that the human, technical, and work aspects of the application situation must be brought into fit with each other through human learning, system tailorability, or other strategies (C3).

In addition to the use and social context of computers, on the human side we must also take into account the human information processing (U1), communication (U2), and physical (U3) characteristics of users.

On the computer side, a variety of technologies have been developed for supporting interaction with humans: Input and output devices connect the human and the machine (S1). These are used in a number of techniques for organizing a dialogue (S2). These techniques are used in turn to implement larger design elements, such as the metaphor of the interface (S3). Getting deeper into the machine substrata supporting the dialogue, the dialogue may make extensive use of computer graphics techniques (S4). Complex dialogues lead into considerations of the systems architecture necessary to support such features as interconnectable application programs, windowing, real-time response, network communications, multi-user and cooperative interfaces, and multi-tasking of dialogue objects (S5).

Finally, there is the process of development which incorporates design (D1) for user-system dialogues, techniques and tools (D2) for implementing them (D2), techniques for evaluating (D3) them, and a number of classic designs for study (D4). Each of these components of the development process is bound up with the others in a relationship of mutual, reciprocal influence whereby choices made in one area impact upon the choices and the options available in the others.

The following inventory of topics contains representative entries relating to all of these aspects of the design and analysis of user-system interaction systems. This inventory is a current snapshot of topics on which there are results that could be taught. In addition to direct USI topics, we have included in this inventory results from other disciplines central enough to be taught within courses in USI. Such a list cannot hope to be complete or even non-controversial, but it should be heuristically useful in the practical business of preparing courses.

FIGURE 1. User-System Interaction
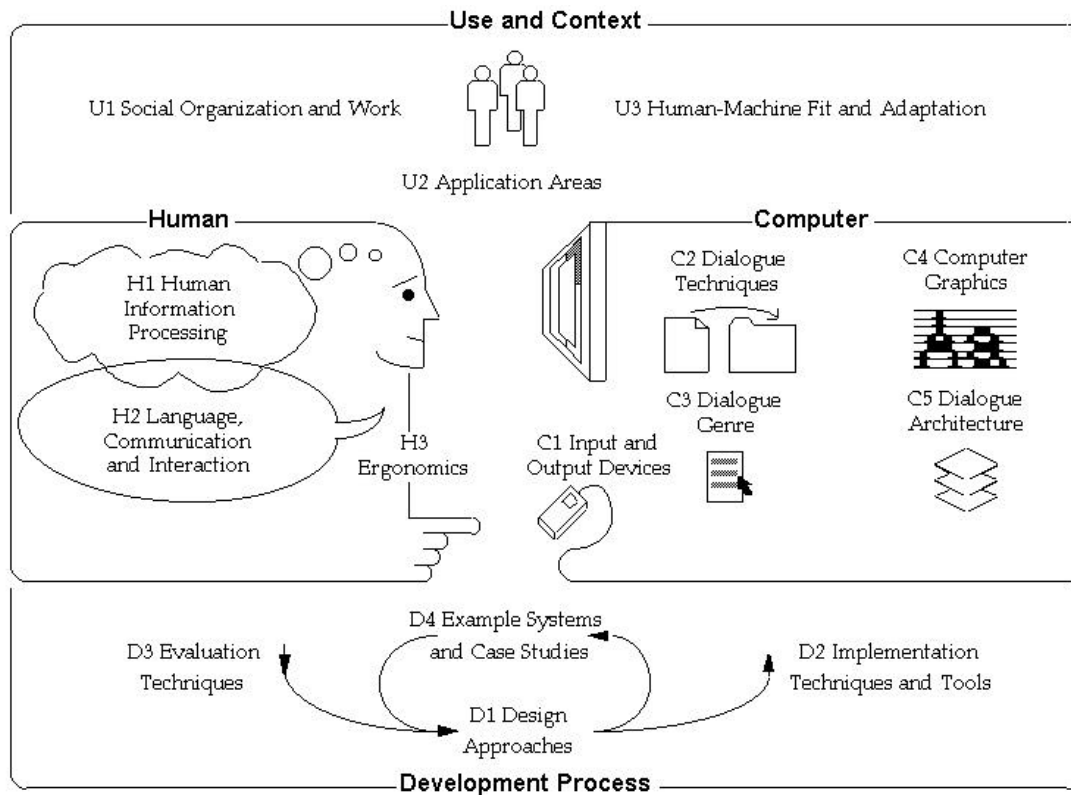
1.3.1 Nature of User-System Interaction (N)

Under this heading are overviews of, and theoretical frameworks for, topics in user-system communication.

1.3.1.1 The Nature of User-System Interaction (N1)

- Points of view: USI as communication, agent paradigm, tool paradigm, the work-centered point of view, human/system/tasks division, supervisory control
- Objectives (e.g. productivity, user empowerment)
- History and intellectual roots
- USI as an academic topic: journals, literature, relation to other fields, science vs. engineering vs. design aspects

1.3.2 Use and Context of Systems (C)

The uses to which computers are put are spoken of as 'applications' or interactive products. These uses and the extent to which the interface (and the application logic in the rest of the system) fits them can have a profound impact on every part of the interface and its success. Moreover, the general social, work, and business context may be important. In addition to technical requirements, an interface may have to satisfy quality-of-work-life goals of a labor union or meet legal constraints on "look and feel" or position the image of a company in a certain market. The following topics are concerned with general problems of fitting computers, uses, and context of use together.

1.3.2.1 Social Organization and Work (C1)

This heading relates to the human as an interacting social being. It includes a concern with the nature of work, and with the notion that human systems and technical systems mutually adapt to each other and must be considered as a whole.
Points of view (e.g., industrial engineering, operations research, Rasmussen's cognitive engineering, the Aarhus participatory design approach, Hewitt's open systems)

- Models of human activity (e.g., opportunistic planning, open procedures)
- Models of small-groups, organizations
- Models of work, workflow, cooperative activity, office work
- Socio-technical systems, human organizations as adaptive open systems, mutual impact of computer systems on work and vice versa, computer systems for group tasks, case studies
- Quality of work life and job satisfaction

1.3.2.2 Application Areas (C2)

The focus of this section is on classes of application domains and particular application areas where characteristic interfaces have developed.
Characterization of application areas (e.g., individual vs. group, paced vs. unpaced)

- Embedded systems: Copier controls, elevator controls, consumer electronics and home appliance controllers (e.g., TVs, VCRs, microwave ovens, etc.)
- Communications-oriented interfaces: Electronic mail, computer conferencing, telephone and voice messaging systems
- Multimedia information kiosks
- Continuous control systems: process control systems, virtual reality systems, simulators, cockpits, video games
- Document-oriented interfaces: Text-editing, document formatting, illustrators, spreadsheets, hypertext
- Design environments: programming environments, CAD/CAM
- On-line tutorial systems and help systems

1.3.2.3 Human-Machine Fit (C3)

Part of the purpose of design is to arrange a fit between the designed object and its use. There are several dimensions to this fit and it is possible to place the burden of adjustment in different places: Adjustments can be made (1) either at design time or at time of use (2) by either changing the system or the user and (3) the changes can be made by either the users themselves or, sometimes, by the system. Topics under this heading all relate to changing some component of a socio-technical system so as to improve its fit.

- User selection: compatibilities of user and system characteristics
- User adaptation: ease of learning, training methods (e.g., on-line tutorials), relation to system design
- User guidance: help techniques, documentation, error-handling techniques

1.3.2.4 Adaptation (C4)

Advanced technology for interactive systems will be based on adaptive system behaviour, partly controlled by input from intelligent sensor systems.

Nature of adaptive systems, adaptations of human systems that cancel reliability improvements, the nature of error in adaptive redundant systems, empirical findings on user improvisation with routine systems, determinants of successful systems introduction.

- System selection: theories of system adoption
- System adaptation: customization and tailorability techniques

1.3.3 User Characteristics (U)

It is important to understand something about human information-processing characteristics, how human action is structured, the nature of human communication, and human physical and physiological requirements.

1.3.3.1 Human Information Processing (U1)

Characteristics of the human as a processor of information.
Models of cognitive architecture: symbol-system models, connectionist models, engineering models

- Phenomena and theories of memory
- Phenomena and theories of perception
- Phenomena and theories of motor skills
- Phenomena and theories of attention and vigilance
- Phenomena and theories of problem solving
- Phenomena and theories of learning and skill acquisition
- Phenomena and theories of motivation
- Users' conceptual models
- Models of human action
- Human diversity, including disabled populations

1.3.3.2 Language, Communication and Interaction (U2)

- Language as a communication and interface medium. Communication phenomena.
- Aspects of language: syntax, semantics, pragmatics
- Formal models of language
- Pragmatic phenomena of conversational interaction (e.g., turn-taking, repair)
- Language phenomena
- Specialized languages (e.g., graphical interaction, query, command, production systems, editors)
- Interaction reuse (e.g., history lists)

1.3.3.3 Ergonomics (U3)

- Anthropometric and physiological characteristics of people and their relationship to workspace and environmental parameters.
- Human anthropometry in relation to workspace design
- Arrangement of displays and controls, link analysis
- Human cognitive and sensory limits
- Sensory and perceptual effects of CRT and other display technologies, legibility, display design

- Control design
- Fatigue and health issues
- Furniture and lighting design
- Temperature and environmental noise issues
- Design for stressful or hazardous environments
- Design for the disabled

1.3.4 System and Interface Architecture (S)

Machines have specialized components for interacting with humans. Some of these components are basically transducers for moving information physically between human and machine. Other components have to do with the control structure and representation of aspects of the interaction. These specialized components are covered in the following topics.

1.3.4.1 Input and Output Devices (S1)

The technical construction of devices for mediating between humans and machines.
- Input devices:
  Survey, mechanics of particular devices, performance characteristics (human and system), devices for the disabled, handwriting and gestures, speech input, eye tracking, exotic devices (e.g., EEG and other biological signals)
- Output devices:
  Survey, mechanics of particular devices, vector devices, raster devices, frame buffers and image stores, canvases, event handling, performance characteristics, devices for the disabled, sound and speech output, 3D displays, motion (e.g., flight simulators), tactile feedback, exotic devices
- Characteristics of input/output devices
  e.g., weight, portability, bandwidth, sensory modality; Virtual devices

1.3.4.2 Dialogue Techniques (S2)

The basic software architecture and techniques for interacting with humans.

1.3.4.2.1 Dialogue Inputs:

Types of input purposes (e.g., selection, discrete parameter specification, continuous control)
Input techniques: keyboard techniques (e.g, commands, menus), mouse-based techniques (e.g., picking, rubber-band lines), pen-based techniques (e.g., character recognition, gesture), voice-based techniques

1.3.4.2.2 Dialogue Outputs:

Types of output purposes (e.g., convey precise information, summary information, illustrate processes, create visualizations of information)
Output techniques (e.g., scrolling display, windows, animation, sprites, fish-eye displays)
Screen layout issues (e.g., focus, clutter, visual logic)

1.3.4.2.3 Dialogue Interaction Techniques:

- Dialogue type and techniques (e.g., alphanumeric techniques, form filling, menu selection, icons and direct manipulation, generic functions, natural language)
- Navigation and orientation in dialogues, error management
- Multimedia and non-graphical dialogues: speech input, speech output, voice mail, video mail, active documents, videodisc, CD-ROM
- Agents and AI techniques
- Multi-person dialogues
- Dialogue Issues:
- Real-time response issues
- Manual control theory
- Supervisory control, automatic systems
- embedded systems

1.3.4.2.4 Standards:

- Industry standards, e.g. "Look and feel"
- ISO standards
- guidelines
- intellectual property protection

1.3.4.3 Dialogue Genre (S3)

The conceptual uses to which the technical means are put. Such concepts arise in any media discipline (e.g., film, graphic design, etc.).
- Interaction metaphors (e.g., tool metaphor, agent metaphor)
- Content metaphors (e.g., desktop metaphor, paper document metaphor)
- Persona, personality, point of view
- Workspace models
- Transition management (e.g., fades, pans)
- Relevant techniques from other media (e.g., film, theater, graphic design)
- Style and aesthetics

1.3.4.4 Computer Graphics (S4)

Basic concepts from computer graphics that are especially useful to know for USI.
- Geometry in 2- and 3- space, linear transformations
- Graphics primitives and attributes: bitmap and voxel representations, raster-op, 2-D primitives, text primitives, polygon representation, 3-D primitives, quadtrees and octtrees, device independent images, page definition languages
- Solid modeling, splines, surface modeling, hidden surface removal, animation, rendering algorithms, lighting models
- Color representation, color maps, color ranges of devices

1.3.4.5 Dialogue Architecture (S5)

Software architectures and standards for user interfaces.
- Layers model of the architecture of dialogues and windowing systems, dialogue system reference models
- Screen imaging models (e.g., RasterOp, Postscript, Quickdraw)

- Window manager models (e.g., Shared address-space, client-server), analysis of major window systems (e.g., X, New Wave, Windows, Open Look, Presentation Manager, Macintosh)
- Models of application-to-dialogue manager connection
- Models for specifying dialogues
- Multi-user interface architectures "Look and feel"
- Standardization and interoperability

1.3.5 Development Process (D)

The construction of human interfaces is both a matter of design and engineering. These topics are concerned with the methodology and practice of interface design. Other aspects of the development process include the relationship of interface development to the engineering (both software and hardware) of the rest of the system.

1.3.5.1 Design Approaches (D1)

The process of design. Relevant topics from other design disciplines.
- Graphic design basics (e.g., design languages, typography, use of color, 2D & 3D spatial organization, temporal sequencing, etc.)
- Alternative system development processes (e.g., waterfall model, participatory design), lifecycle model, iterative design, choice of method under time/resource constraint
- Task analysis techniques (e.g., field studies, analytical methods), task allocation, market analysis
- Design specification techniques
- Design analysis techniques (e.g., objects and actions)
- Industrial design basics
- Design case studies and empirical analyses of design

1.3.5.2 Implementation Techniques and Tools (D2)

Tactics and tools for implementation.
- Relationships among design, evaluation, and implementation
- Independence and reusability, application independence, device independence
- Prototyping techniques (e.g., storyboarding, video, "Wizard of Oz", HyperCard, rapid prototype implementations)
- Dialogue toolkits (e.g., MacApp, NextStep, UIMS's, HyperCard)
- Object-oriented methods
- Data representation and algorithms

1.3.5.3 Evaluation Techniques (D3)

Specific methods for evaluations.
- Productivity
- Figures of merit (e.g., time, errors, learnability, design for guessing, preference, etc.)
- Usability testing techniques, linking testing to specifications

- Formative and summative evaluation techniques for empirical evaluation, including, field observation methods, participant observation, interviewing techniques, questionnaire design, psychometric methods, video protocols, system logging, experiment design (e.g, concern with sample bias, etc.), methods from psychological and sociological evaluation fields, ethics of working with participants

1.3.5.4 Example Systems and Case Studies (D4)

Classic designs to serve as extended examples of human interface design.

1.3.5.4.1 Command-oriented:

- OS/360 JCL (batch-oriented command style, baseline for seeing later improvements)
- PC DOS (command style interface learned by millions)
- Airline check-in system (time pressure, ambiguous input, distributed system)

1.3.5.4.2 Graphics-oriented:

- Xerox Star (icon-window interface, generic commands)
- Apple Macintosh (similar interface over many applications)
- MacPaint (widely known and available graphics program)

1.3.5.4.3 Frame-based:

- Promis (Rapid response to large set of frames, touch-panel oriented)
- Zog (User-tailorable, rapid-response system, large number of frames, first commercial frame-based system)
- HyperCard (Graphically-oriented frame-based system with user programming language, first mass market frame-oriented system).

1.3.5.4.4 User-defined combinatorics:

- Unix operating system (strong combinatoric architecture paired with weak human factors)
- Emacs (language-oriented, large combinatoric command set)
- Visicalc (a "home-run" application with strong conceptual model that succeeded despite weak human factors)
- DBaseIII (simple, but successful, user applications generator)

1.3.5.4.5 Interfaces for untrained, walk-up users:

- Olympic Message System (practical use of user testing under time pressure)
- Nintendo Super Mario Brothers (learnable without a manual by grade school children)

1.4 Concluding Remarks

The topics listed in this chapter constitute an attempt to inventory the results of USI and its supporting fields that are available for teaching. The topics are not arranged

according to how they would appear in courses. Rather, they are the raw material out of which courses and curricula might be fashioned.

However, USI as a field is continuing to develop rapidly. It is expected, therefore, that the above topics will undergo change as new results occur and as our understanding of the area deepens. New paradigms will emerge as our fundamental concepts evolve, become more clearly articulated, and spin off entirely new subtopics. These changes will necessitate continual revision of courses and curricula as new topics and results emerge.

2 Vision for future USI research

2.1.1 Introduction

Our vision is based on actual trends in the field of user-system interaction. We will focus on new, challenging research topics which will lead to design knowledge of advanced interactive technology.

2.1.2 Actual trends in user-system interaction

2.1.2.1 Ubiquitous Computing

[this part is copied from Rauterberg [1]]

By definition, the goal of ubiquitous computing is to make computational devices ubiquitous in the everyday world. Although oft described as making these devices "invisible," most efforts have focused on replication and dissemination. The vision is something like "Computing devices will be everywhere. They will be smaller so that we can carry them around with us and they will be able to communicate back and forth with each other." [2] The end result is that although computational devices are more likely to be seen as ubiquitous, they are far from invisible. Our world is now cluttered with various computational things that vie for our attention.
Ubiquitous computing is an inevitably evolving topic in computing. Many devices, which are already equipped with computers, can be found in our homes or offices. Nevertheless people still use their washing machines and telephones not considering them as a computers. Additionally, growing communication possibilities and the advent of small computers like Personal-Digital-Assistance (PDA) let Mark Weiser's vision come true [2]. In the ubiquitous computing research we consider technology and applications, using PDAs, other mobile devices and extented "dump" machines (like TV) to set up prototypes for the demonstration of ubiquitous computing scenarios.
A common focus shared by researchers in mobile, ubiquitous and wearable computing is the attempt to break away from the traditional desktop computing paradigm. Computational services need to become as mobile as their users. Whether that service mobility is achieved by equipping the user with computational power or by instrumenting the environment, all services need to be extended to take advantage of the constantly changing context in which they are accessed.
Attaining the goals of ubiquitous computing will require a highly sophisticated infrastructure. In the ideal system, a real-time tracking mechanism will derive the locations and operational status of many system components and will use that context to deliver messages more intelligently. Users will be able to choose from among a variety of devices to gain mobile, high-bandwidth access to data and computational resources anywhere on the network. These devices will be intuitive, attractive and responsive. They will automatically adapt their behavior to suit the current user and context.

2.1.2.2 Ambient intelligence

[this part is copied from URL http://www.research.philips.com/generalinfo/special/ambintel/]

During the past decade, computer scientists have developed the notion of ubiquitous computing to situate a world in which it would be possible to have access to any source of information at any place at any point in time by any person. Such a world can be conceived by a huge distributed network consisting of thousands of interconnected embedded systems that surround the user and satisfy his needs for information, communication, navigation, and entertainment. This concept can be viewed as a first approach to the development of third generation computing systems, where the first and second generations are given by the main frame and the personal computer, respectively.

The ongoing distribution of storage and processing may move the computer as a standalone system into the background, yet maintaining its functionality as a computing device. This development provides the consumer electronics industry with a challenging opportunity by replacing the disappearing computer with a new user experience through the addition of ambience intelligence.

Ambient intelligence refers to the presence of a digital environment that is sensitive, adaptive, and responsive to the presence of people. Within a home environment, ambient intelligence will improve the quality of life of people by creating the desired atmosphere and functionality via intelligent, personalized inter-connected systems and services.

Ambient intelligence can be characterized by the following basic elements:

ubiquity, transparency, and intelligence.

Ubiquity refers to a situation in which we are surrounded by a multitude of interconnected embedded systems. Transparency indicates that the surrounding systems are invisible and moved into the background of our surroundings. Intelligence refers to the fact that the digital surroundings exhibit specific forms of intelligence, i.e., it should be able to recognize the people that live in it, adapt themselves to them, learn from their behavior, and possibly show emotion.
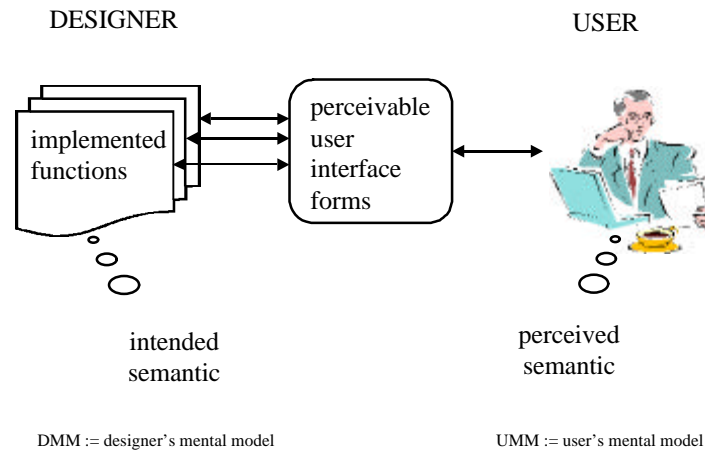
The developments in computer technology follow the laws issued by Moore, who states that the integration density of systems on silicon doubles every eighteen months. This law seems to hold a self-fulfilling prophecy because the computer industry follows this trend for already two decades. Moreover, other characteristic quantities of information processing systems, such as communication bandwidth, and storage capacity seem to follow similar rules.

The Internet can be viewed as one of the first truly worldwide ubiquitous information systems realized by mankind. By now, 2.5% of the world population is online, and in western countries the subscription rate is close to 10%. Furthermore, the network quickly develops and the variety of online services is fascinating. Furthermore, there is a strong economical driver given by the total yearly turnover in the market of electronic systems. In 1999 this figure exceeds 3000 billion US dollars, with a yearly expected growth of more than 10% for the forthcoming decade. This implies an enormous market volume for new electronics products of which ambient intelligent systems may take a substantial share. Finally, and most importantly, there is a social driver given by the need of human beings to feel more comfortable and at ease in the quickly developing technocratic world than they use to feel. Ambient intelligence can increase the quality time for people through novel services, and entertainment providing an enhanced user experience.

One may distinguish between four different scenarios to describe the development of the market of information processing systems. the current situation is fragmented with features, which refers to a world in which the home and the office is scattered by electronic devices that are only loosely connected and exhibit no interoperability. The ultimate future is a world of ambient intelligence that is realized with virtual devices. There are two intermediate scenarios; one in which the transfer is achieved through the integration of the required ubiquitous computing functions into a closed system provided and serviced by a few dominant industries. In this so-called powerful clients scenario only a few major players will survive, who provide the world with all the needed services and information. The alternative transient scenario is called centers of excellence, and refers to a world in which the buildup of ubiquity proceeds via the development of networked centers that exhibit ubiquity at a confined and localized level. In the course of the development the centers get connected to ultimately reach global ubiquity. This scenario offers many more options and freedom for different players to participate and contribute in an open market that does not only follow the rules set by a few dominant players. We consider the latter scenario as the more probable one since it complies more with modern business developments.

Given the technology described, we are faced with the challenge to develop and implement applications that provide the ubiquitous home system with functions that enable easy, intelligent, and meaningful interaction with the system. This requires the design and implementation of application scenarios that bring ambient intelligence to life. The believability of ambient intelligent home systems is determined by two major aspects: the social nature of the user interface that is used, and the extent to which the system can adapt itself to the user and its environment. The social character of the user interface will be determined by the extent to which the system complies with the intuition and habits of its users. The self adaptability is determined by the capability of the system to learn through interaction with the user. The combination of human specific communication modalities such as speech, handwriting, and gesture, as well as the possibility to personalize to consumer needs play a major role in the design of novel applications and services. Finally, ambient intelligent devices need to express some form of emotion to make them truly intelligent. So, these devices must be able to detect user moods and they must react accordingly.

2.1.2.3 Active Forms

One of the most challenging USI research problem is the proper mapping of a given functionality to a perceivable and appropriate form in a given context of use.

DESIGNER

USER

perceivable
user
interface
forms

implemented
functions

intended
semantic

perceived
semantic

DMM := designer's mental model

UMM := user's mental model

How to relate function and form, so that DMM == UMM ?

Figure 1: The function-form mapping problem in design

Taking a look to the history of USI, three different approaches for relating functionality to a proper form can be distinguished: (1) mechanical style, (2) electronic style, and (3) mechatronic style. We will shortly discuss each style separately.

mechatronic style

electronic style
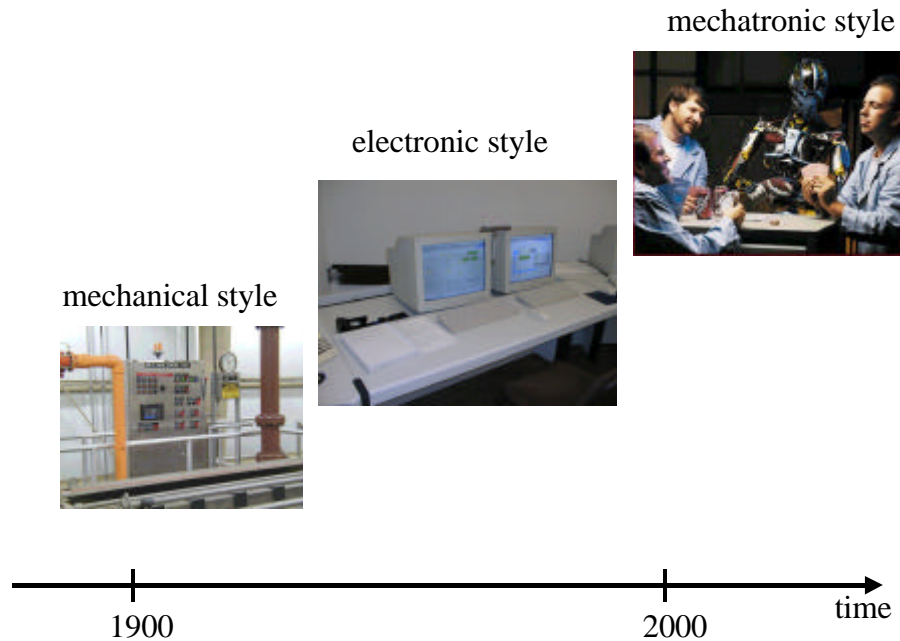
mechanical style

1900

2000

time

Figure 2: The history and future trend of function-form mapping approaches

Mechanical style:
In the mechanical phase the mapping of a function to a proper form is mostly one-to-one. For each given function a particular interface object (e.g., button, switch, etc.) is provided. This relationship is fixed, and therefor a huge interface space is needed for a

complex system with a lot of functions. With increasing complexity of the function space, new interface styles were introduced.

Electronic style:

Interactive devices of the electronic style are characterized by a fundamental separation between form (given as hardware) and the functionality (given as software). Most of all modern devices (e.g., PC, TV, etc.) follow this design of separating the hardware layout and the provided functionality. The hardware of all this devices has a 'channel function' through which the user can get access to the needed functionality in form of mode sensitive appearance of the 'channel content'. One of the major bottleneck of this approach is the limitation of the design space for the function-form mapping to visual and/or auditory perception only. Trying to include tactile perception as well, will lead to new technological challenges.

Mechatronic style:

We call this new trend 'mechatronic style', because in the near future the design space for the function-form mapping will be opened towards 'active elements'. Active elements as a new approach for design user-system interaction will enable the designer to combine the advantages of the old mechanical style with the powerful new expression space of active elements. Active interaction elements will change their whole appearance (hardware and software) according to the actual context of use and their internal state. The most elaborated versions of this approach are developed and investigated in robotics; but this new style is powerful enough to go significantly beyound human like robot design.

2.1.3 References

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