New Directions

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It has been estimated that science-based information industries account for more than half our nation's gross national product and half the jobs. The growth and exploitation of information rests, however, not only on the ability of science to produce knowledge, but also on society's capacity to absorb and to use it. Therefore, the real limits of scientific as well as economic growth may well be humankind's limited ability to absorb and to apply new information. In so far as the human-computer interface affects this ability, it serves as a gating function to the goals of the NII.

(Page Opposite) Visualization of the Topics of HCI (by W. Verplank and S. Card)

It is the belief of many within government that, if society is to continue to benefit from the production of new knowledge, and if business is to be more competitive, we must devise new and better ways to expand human capacity, multiply human reasoning, and compensate for human limitations. We must create new techniques and use powerful, new technologies to significantly augment the skills that are necessary to convert data into information and to transform information into knowledge. This knowledge and these skills must be translated into effective design, design not merely of graphical displays, but initial design that takes into account users and constraints in such a way that later changes are not necessary and users can immediately employ the products. We must spend as much effort on studying the inner frontiers of knowledge (human capacity) that affect the uptake of information as we do the outer frontiers of science, if we are to reap the benefits of the knowledge generated by science.

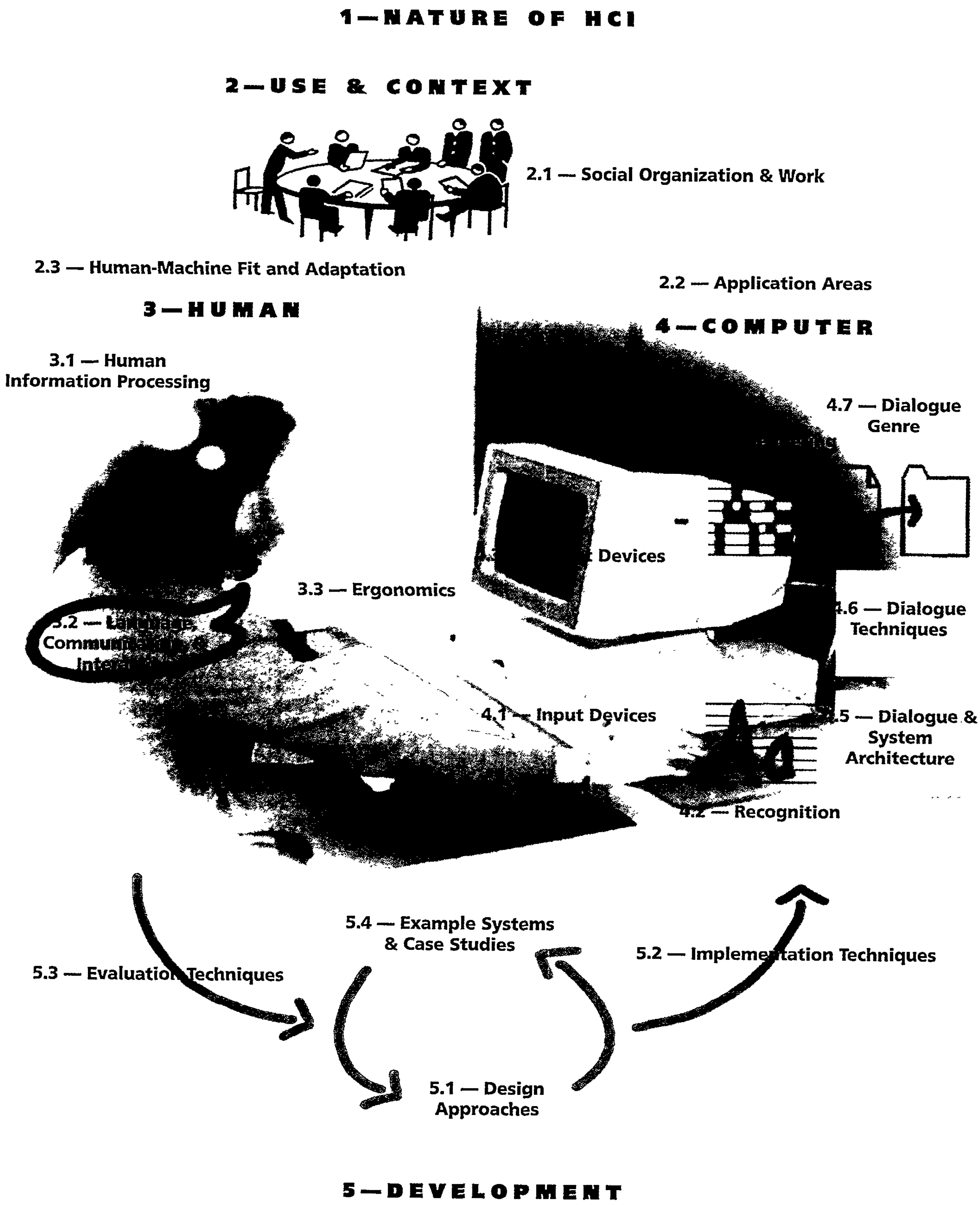
Since computers can contribute to the successful impact of information on society by making information accessible and usable, efforts must be focused on the design and development of user interfaces that promote these goals. Efforts to create such interfaces have already been made, and the effort has steadily increased. Recent reports estimate that over half the total cost of new computer systems can be attributed to the user interface [1, 20].

A recent report of a research group of 10 top industrial representatives concluded that "if the interface is ineffective, the system's functionality and usefulness are limited; users become confused, frustrated, and annoyed; developers lose credibility; and the organization is saddled with high support costs and low productivity." [22, pg. 19]. Another comprehensive summary of studies of information technology productivity presents the difficulties and outright failures of attempts to document productivity gains as a result of using information technology [3]. It may be that 'difficulty of use' should be added to that report's list of reasons why computers have not appeared to improve productivity [3, pg. 76].

Objectives

HCI is identified as the main gating function to the successful use of technology to increase the availability of information to the public and that, for this reason, computer science must establish HCI as a fundamental, core topic. It was therefore proposed that the infrastructure surrounding HCI be assessed and that suggestions be made on ways to improve it.

To gather opinion from a broad segment of experienced and recognized leaders in the field, a "Workshop on New Directions on Human-Computer Interaction Education and Research"


1—NATURE OF HCI
2—USE & CONTEXT
2.1 — Social Organization & Work
2.3 — Human-Machine Fit and Adaptation
2.2 — Application Areas
3—HUMAN
4—COMPUTER
3.1 — Human Information Processing
4.7 — Dialogue Genre
Devices
3.3 — Ergonomics
.6 — Dialogue Techniques
Commu
4.1 — Input Devices
.5 — Dialogue & System Architecture
— Recognition
5.4 — Example Systems & Case Studies
5.2 — Impleme tation Techniques
5.3 — Evaluatio Techniques
5.1 — Design Approaches
5—DEVELOPMENT

was conducted February 5-7, 1994, in Washington DC. The workshop participants met with two objectives:

1) To broaden the scope of previous curriculum recommendations (e.g. Hewett, T.T. et al (1992) *ACM SIGCHI Curricula for Human-Computer Interaction.* New York: The Association for Computing Machinery), through participation from a wide variety of disciplines including computer and software engineering, computer science, cognitive science and other communities of experienced practitioners in the field.
2) To indicate those research directions and needs in HCI that are considered strategic, most timely, and most needed given the present state-of-the-art.

Focus of this Report

The final report contains conclusions and recommendations regarding HCI education, research and practice. Other recent HCI-related reports [18, 2, 9, 6] have made recommendations that affect only portions of the field, such as one particular interface approach or only research issues. The scope of this report is more comprehensive than recent efforts in three ways: (i) it attempts to synthesize the entire HCI field and its impact; (ii) it focuses on education with no less priority than that of research; and (iii) it brings in the topic of practice as a critical link between academia and the effective application of HCI expertise.

Education

Education is essential for capitalizing on the enormous potential of the National Information Infrastructure (NII). Current computer scientists as well as the next generation of scientists and engineers must have the skills and must be motivated to tackle the new problems created by the information society. Additional developments must be addressed before our society can achieve the promised benefits of increased information access. One of the most important developments is the ability of the non-expert to use computers effectively and efficiently to accomplish their every-day goals. This requires dramatic changes in computer science education to address the problems of human-computer interaction and education of those who design interactive systems, i.e., HCI practitioners.

Readers are refered to the full report for the findings on education, which focus on the primary need to include a capstone design course in all undergraduate computer science programs.

Research

In order for our world-class national computer industry to respond to the challenges of the NII we must create user interfaces that will increase usability, heighten productivity, ensure health and safety, and improve security for all citizens. New quality assessment techniques and new multimodal interface paradigms must take into account these general needs of individuals as well as the capacity to adapt to more specific needs of each individual user. Interdisciplinary investigations are called for to span the range from relatively short-term efforts that move solutions quickly into practice, to longer-term efforts that result in more fundamental breakthroughs in how humans interact with computers and in how communities use systems in context. Such investigations and breakthroughs will improve software and user interface development tools and interactive system flexibility to minimize the need for training in system use and increase the adaptability of systems to users. Only in this way will the power of computation and the capabilities of the NII become available to the general public in a way that will allow this national initiative to meet its ultimate objective of creating a new information sector of the economy.

A substantial effort is called for to determine the basic theory of HCI. Although researchers will continue to seek new paradigms for interaction that are transparent to the user, as they have been doing since the field began, and efforts must also be spent on discovery of techniques for the design and development of interactive systems, the lack of a basic theory directing the field may be a significant handicap to its continued progress.

The aim of HCI research should be to understand the principles behind what is necessary for transparent interaction. What is it that allows users to conveniently and appropriately describe what they want to achieve with computer artifacts rather than having, or forcing, them to structure a solution within a given framework? HCI research should probably confront human-human communication as the first order approximation of information transfer, and study that. As development then works to make HCI more seamless with human-human interaction, success will be assured because interaction will then be transparent in the hands of the user, allowing the user to focus complete attention on the tasks at hand.

Even now, there is a tremendous diversity of problems that require HCI as an indispensable and generic component of their solutions. The time spent by US workers using computers is increasing rapidly and will certainly explode once the NII is implemented. Challenges that exist include finding an abstract, common user interface standard that provides reusable, generic interactivity and does so with little or no new learning across seamless and transparent interfaces.

Industrial Practice

Significant past achievements in the practice of applying computer-based technologies have led to the emergence of serious problems, unimagined even a decade ago, that occur when these complex technologies are applied to human needs and national goals. Now that widespread public access and use of computer technology are proposed, these problems must be faced squarely.

The major focus of this section is on HCI workers in applied settings. Within these areas, practitioners may specialize in analysis, design, evaluation, or combinations of these relatively formal activities. Practitioners may also be engaged in team participation or leadership, in business process re-engineering, or in advocacy. Their roles may change radically over time.

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Among the materials provided to the participants in the workshop leading to this report was a recent article by Dayton et al. [8]. This article described four different ways in which the work of a user-centered design (UCD) practitioner may be organizationally situated:

- one of many people on a team that has been deliberately composed to be interdisciplinary
- the (sole) UCD team member who leads the team of computer professionals (and perhaps ergonomists and technical writers)
- the (sole) UCD team member who does not lead the team of developers
- the outside consultant to a team of computer professionals

Each of these roles carries it own advantages and disadvantages. Different members of the HCI communities may find that certain roles are more likely—for example, faculty members are more likely to enter the commercial domain as external consultants.

It is also noted as well that many industry practitioners spend part of their time working as researchers, evaluating their own or others' practice. Many practitioners also spend part of their time as educators, teaching practitioner skills to others. It is also true that many university researchers spend part of their time as practitioners, consulting to industry. It was also implied above that such cross-fertilization between industry and academia should be greatly expanded to make education of the HCI professional more relevant.

HCI practice is quite diverse. Some of this diversity has been explicated by Dayton et al. [8], and earlier by Karat and Dayton [14]; see also Dayton [7] and Wroblewski [27]. In order to narrow the topic that they were addressing, Dayton et al. [8] went to some pains to differentiate the practice of user-centered design (UCD) from human factors, ergonomics, and HCI. For the present report, it is noted that many commercial HCI practitioners experience a blurring of professional boundaries—in themselves and in their colleagues—when they work in multidisciplinary teams, or even when they consult to software professionals with different skill sets. As a result, fine distinctions among related domains tend not to matter "in the trenches." Thus, many successful HCI practitioners have learned to work in part as dedicated specialists, and in part as opportunistic generalists.

Career Paths of HCI Practitioners

There are many career paths through which people become HCI practitioners in industry. Mantei and Hewett [17] provided a high-level analysis into the categories "researcher," "professionally oriented researcher," "research oriented professional," and "professional". Within their categories, several more detailed career paths are briefly sketched:

Researchers: Some industry HCI practitioners work in research organizations, where

"Activities or Tasks" Performed by Human Factors Practitioners

Prepare/conduct oral presentations
2 Prepare/contribute to written reports
Apply human factors criteria/principles
4 Analyze tasks
Prepare/contribute to project proposals
6 Evaluate reports of others
Specify user requirements
8 Interpret test and evaluation results
Design data collection procedures/questionnaires
10 Review/summarize prior literature
Interpret research results
12 Verify conformance to human factors specifications
Specify/perform data analyses
14 Collect field data
Plan/coordinate evaluations
16 Specify evaluation objectives
Design human-equipment interfaces
18 Develop criterion measures
Develop hypotheses/theories
20 Design workspace layouts
Design evaluations
22 Design software-user interface
Interpret engineering drawings
24 Assess mental workload
Prepare instructions/procedure documents
26 Develop/conduct computer simulations
Assess physical workload
28 Prepare software specifications
Prepare/review design drawings
30 Define instructional requirements
Specify training objectives
32 Assess training effectiveness
Collect laboratory data
34 Collect error/accident data
Prepare design mockups
36 Conduct training
Develop analytical models/methods
38 Design training aids
Develop training contents/methods
40 Write/debug computer programs
Perform safety analyses
42 Analyze effects of environmental stressors
Assess performance risks
44 Design simulation systems
Conduct network analyses
46 Perform human reliability analyses
Prepare engineering drawings
48 Conduct root cause analyses
Prepare product warnings
50 Perform failure-mode effect analyses
Develop/analyze fault trees
52 Support product liability litigation

they do work that is in some ways similar to the work of academic HCI professionals. Increasingly, their research agendas are dictated by corporate goals and needs, and their work is expected to demonstrate shorter-term impact. Nonetheless, they are the most obvious professional link between academia and industry. Some develop and/or analyze new methods for HCI work.

Research practitioners: Some HCI practitioners have received formal academic training through the MS or the Ph.D. in a relatively traditional, research-oriented graduate program, and become senior members of HCI or UCD organizations that are dedicated to practice, rather than research. Their career paths typically involve diverse practice settings and some in-house training of more junior practitioners. Some develop and/or analyze new methods for HCI work.

Systems or requirements analysts: Within computer engineering, there is a tradition of requirements being defined in advance of implementation. Analysts who produce requirements or specification documents are often trained in an engineering or systems discipline; some are trained within psychology or computer science programs. Often, requirements or specifications are expected to include at least high-level human interface descriptions. Part of the analyst's job may include work-flow or task analysis.

Ergonomists and human factors engineers: Human factors engineers receive training in applying well-defined methods to solve well-behaved problems. Practicing ergonomists receive similar training, with perhaps greater emphasis on finding, applying, and refining standards. Analyses, designs, and evaluations tend to emphasize productivity or other computing system characterizations. Career paths in these traditions tend to occur entirely within analysis or development organizations.

"Converts" from computer disciplines: Many companies continue to rely on software professionals to do HCI or UCD work as a component of their development jobs. In some cases, these practitioners are expected to pick up modest design skills without great effort. In other cases, development professionals have "conversion experiences" (often as a result of field visits to sites using their systems), and become committed to incorporating HCI concepts into their professional practices as developers. Some of them search out opportunities to broaden their practice in usability areas.

"Soft" profession transfers: Many companies practice HCI or UCD through people who are educated in allied "soft" disciplines, such as training or technical writing. Professionals in these traditions have membership in at least two fields—HCI and their parent discipline. Their career paths often reflect this ambiguity.

Graphical design professionals: Increasingly, high-technology companies are involving graphical designers who contribute to the aesthetics—as well as the usability—of the product. This career path is in some ways similar to earlier emphases on industrial design in development of the hardware aspects of computer systems. Similar trends are beginning to occur in the area of multimedia.

Knowledge and Skills Needed by HCI Practitioners

The diversity of the work context of HCI, of background of HCI practitioners, and of categorization of work [8] have, of course, led to great diversity of both techniques (or methods), and more global strategies and tactics of practice (or professionalism). A number of groups have attempted to develop profiles of practice required in several allied fields—e.g., UCD [8] and human factors [26]. There appears to be no similar treatment for HCI per se. The discussion here will briefly summarize related treatments, followed by an attempt to explain the challenges or crises that are perceived in HCI practice.

Van Cott and Huey [26] surveyed over 1000 practitioners in a field that they constructed as Human Factors (HF). Practice in this field is much broader than in HCI, as shown in Table 4.1; correspondingly, their treatment inevitably lacks some of the depth that would be desirable for an analysis of HCI practice.

The practitioner profile for User-Centered Design (UCD) practitioners is at a more preliminary stage. Dayton et al. [8] used the Van Cott and Huey [26] categories in their own ratings of UCD practitioners. However, they were not in a position to survey as broadly as the HF profilers. They therefore developed a set of ratings, through which they characterized the importance of each of the HF tasks for UCD work. Dayton et al. analyzed the "universal attributes" that they found to be "the characteristics essential to every UCD practitioner" (italics in original). These are presented in Table 4.2. Like the tasks in Table 4.1, not all of these are amenable to formal education.

As was noted above, HCI practice comprises great diversity in its tasks and activities. The tasks analyzed here show some of that diversity. They range from formal to informal, from planning to execution to assessment, from analysis to evaluation, and from relatively well-defined methodological exercises (e.g., "conduct simulations") to open-ended, creative undertakings (e.g., "prepare design mockups").

HCI and Work Practice

Many HCI practitioners experience identity conflicts within the first few years of entering an applied position. In general, they must reorient their views of how they work, what questions they ask, and what about their work is valued. Superb analyses and specifications may miss their objectives if they are not oriented toward the very pragmatic needs of specific developers using specific implementation tools. Optimized productivity may miss its objective if it is in support of the wrong goal, or if it is bought at an unacceptable cost in the quality of work life. Elegant algorithms and architectures may miss their objectives if they do not consider context of use, or—more frustratingly—if they are "packaged" within a human interface that makes them inaccessible. Quality of writing or curriculum is often considered secondary to the quality of code or user interface. Designs of any quality are frequently dismissed as being "mere" packaging, and the integrity of a design is often unwittingly undermined by implementation constraints.

At a minimum, relatively new practitioners struggle to determine what subset of their skills and knowledge is actually applicable in an applied setting. Many practitioners maintain a set of somewhat conflicting identities, valuing one set of attributes and achievements in the context of their loyalty to co-workers and organizations, and a rather different set of attributes and achievements in the context of their "home" discipline and their identities within that discipline. This is often experienced as a burden and as a continual challenge to the practitioner's self-esteem.

Some organizations have responded to the challenge of diversity in skill sets by establishing well-defined sequential models for analysis, design, implementation, delivery, and maintenance. Waterfall models provide a well-known class of examples. The contributions of distinct disciplines tend to occur within single steps of such a model. In practice, this separation of functions can fatally limit the bandwidth of communications between successive stages and different disciplines. There is a tendency to push problems off to later stages. One anonymous description of this tendency follows:

"Inadequacies in the analysis are left for implementation to resolve. Implementation creates a set of usability problems. Human factors workers do what they can with these after the design is relatively fixed. What they can't fix is given to technical writers to repair in documentation. Anything that the documentation doesn't fix is left to trainers. If the training curriculum can't fix a problem, then the hot-line takes it on. If we're very lucky, some record of these problems gets into the hands of the next iteration."

Other organizations approach this problem by convening *interdisciplinary* teams to work on applied projects. These teams provide opportunities for divergent perspectives to be brought together, both for problem resolution and for mutual education. Other intellectual disciplines have begun to explore the concept of "boundary workers" or "border intellectuals" (e.g., [15]). By virtue of placing themselves at the "frontier" between two different domains of work, knowledge, and practice, the boundary worker is considered to have a better opportunity to combine perspectives. The hope is that the resulting synthesis will have fewer mistakes than a view based on a single perspective. Interdisciplinary teams can make a similar contribution.

However, there remain the related problems of how to combine diverse perspectives, and how to select which perspectives should be brought into a team. These problems encourage HCI practitioners to, within themselves, develop a multidisciplinary approach—that is, to become the "boundary workers" who are celebrated in other disciplines. It is clear that certain domain areas—especially work of users—are likely to remain beyond the reach of most HCI multidisciplinary workers. Nonetheless, multidisciplinary individuals can help provide the bridges that are so clearly needed among the disparate components of HCI knowledge, theory, and practice.

Because of the diverse backgrounds of HCI workers, it is not surprising that there are many practices in HCI. These diverse practices emerge from different theoretical and practice traditions, that in turn have in some cases widely varying philosophical foundations. Engineering, art, business, science, craft, and political advocacy are among the parent disciplines of various HCI practice traditions. Each of these approaches contains one or more paradigms of practice (as well as research), although the disciplines vary in the extent to which they have articulated their paradigms.

Different institutional and work-process sites for HCI work add to the diversity of practices and paradigms for practices. Too much diversity has been fatal for some other fields (see, e.g., [16]). However, a premature selection of a paradigm for HCI is likely to deny membership to substantial portions of the current HCI community, and there are arguments that diversity of practices is and always will be the optimum approach [7].

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The field of HCI deals in part with the combination of stakeholder perspectives—that is to say, a system design (including the user interface) serves developers, users, marketers, analysts, technical writers, and so on [19]. Perhaps this model of the HCI external work domain can be applied as a model for HCI's internal conceptual domain as well. A system or product may be based on a set of divergent principles that are known to be in conflict with one another. Perhaps a discipline can be, as well. Several recent papers have attempted to articulate this on-going tension within HCI work (e.g., [4, 5, 10, 24]. Of particular importance is Floyd's [10] discussion of the reciprocal needs of "product-oriented" and "process-oriented" paradigms in software engineering.

As applied work, HCI practice fits within a context provided by itself and other workplace activities. One of the most important HCI contexts is the computer product development life cycle—usually denoted as the software development life cycle. HCI practice can help to inform and improve life cycle activities. Within such a life cycle, HCI emphasizes iteration and concrete communication. HCI research has demonstrated that straightforward activity categories—such as "analysis," "design," and "evaluation"—are not separable in practice (e.g., [11, 12, 23]). These tendencies, and their proven successes, are at variance with current wisdom in traditional management of large software projects, typically termed the waterfall model. HCI practitioners can help show the weaknesses of the waterfall model, but not without risk. The

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risk is that the somewhat marginalized field of HCI practice may lose some of its credibility and influence if it is perceived within organizations as opposing their received wisdom. There is a need to "scale up" the successes of HCI in analysis/design/assessment in the small, so that these achievements can be applied to computer product work in the large and in the very large.

Practice Conclusions

The following conclusions are drawn from interpretation of the studies reviewed here:

- Profiles of practice in HF and UCD are relatively similar, and therefore might be used as a placeholder for an as-yet-unavailable profile of HCI practice.
- Diversity and heterogeneity are the norm in HCI practice. The practice of HF, UCD, and HCI takes place in a variety of institutional settings; is conducted by people with a variety of backgrounds; is conducted to meet a variety of organizational and personal goals; and makes use of a great diversity of skills, abilities, and tasks. Multiple paradigms for HCI practice are the current reality, and are likely to remain so for a while. It is not clear whether a long-term heterogeneity (or multidisciplinarity) of paradigm is a danger, or is in fact exactly what the field ought to be fostering (for itself as well as its work domain).
- There is a need to develop a profile of HCI practice, to guide further development of support for HCI practice among industry and academe.
- Many aspects of HF and UCD (and HCI?) practice appear to be supportable by certain existing academic curricula. That is, Van Cott's and Huey's respondents reported some formal educational preparation for most of the 52 activities and tasks of practitioners. However, many practitioners are not exposed to this material in the formal education that they have received. It is recommended that both academic and trade educational institutions expand and enhance their curricula in these areas, in keeping with earlier sections of this report.
- Certain aspects of HF and UCD (and HCI?) practice may be more amenable to workplace training or on-the-job training, rather than traditional, formal education in a classroom setting. Previous sections of this report have presented means through which academic programs can provide internship, coop, or other practicum experiences for students while they are within the supporting environment of a degree program.
- However, it is also important for companies, unions, and other applied institutions to consider appropriate workshops, tutorials, apprenticeships, practica, and other on-the-job training experiences for those skills that are, for whatever reasons, not learned in academic programs.
- There is a need for a taskforce to produce a report on workplace-based training in HCI practice on a national level. This proposed work would complement the academically oriented nature of this report.
- As noted above, there is a need for a deeper understanding of HCI practice. It is proposed that NSF support a study of the content and organizational context of HCI practice to better understand the applied world problems that must guide the direction of future HCI research. This would involve the inverse composition to that of the present task force—namely, strong participation by HCI practitioners from diverse institutional settings, with a consulting panel of HCI educators from industry and academe.

Integration

It is very difficult, as a new field develops, to objectively identify specific new theory, or possibly even new science, that serves as its basis, especially concerning a field as seemingly interdisciplinary as HCI. On the other hand, after a period of development, if the domain is a true field with an independent basis, that basis eventually becomes self-evident. Furthermore, once stated, characterization of the basis even seems obvious, often to the dismay of the more dramatic practitioner. Sometimes a new field, that initially appear to be highly interdisciplinary, eventually finds its true home in an established discipline. It is likely that the true home discipline of HCI is computer science and, perhaps, even within software engineering in particular. This is not to say that ancillary disciplines, such as information systems, psychology, or general design, won't or shouldn't teach HCI topics. For example, applied programming and psychology of programming courses exist for good reasons. On the other hand, the design and development bases to what was presented in this report are most likely a part of the established field of software engineering within computer science.

Computer graphics, and more recently multimedia, have expanded the horizon of the computer interface to other communication modalities than that of textual communication, upon which traditional programming languages are based. Formal languages, compilers, and computational linguistics are well-developed sub-disciplines of computer science, and they are largely based on text and corresponding textual or verbal interaction with a computer. Since computer interface technology has, for some time, escaped textual "flatland", new theory must be developed for the analysis and application of video and audio to the control of computers. This way of looking at HCI may call for the development of formal graphic and sound stream "languages" with their own lexicons, syntaxes, and semantics, video and audio compilers, and computational perception. Clearly, computer science is already deeply involved in pursuing these topics with current efforts on robotics, speech understanding and synthesis, and computer vision. Part of the problem, however, is that the formal structures of communication modalities other than that of the textual and verbal are not well-understood, and the sentence or dialog equivalents in visual scenes or in audio streams have not been clearly established. A major result of design efforts in HCI must be toward revealing these kinds of structures in vision and sound.

A complicating factor in trying to create a simple analogy between HCI and programming languages is that understanding of human use of technology has advanced significantly since the development of early, prototypical programming languages (see, for example, [21]). Study of the relation between humans and tools in the context of tasks has revealed structures that can be exploited in the design of new computer-based tools, whether they be multimedia or merely verbal. Most of the time, when humans use computers, and often when they communicate with each other, they are seeking to accomplish something. While the ways in which people accomplish task goals are widely varied, their methods tend to have a strategy and a structure. Identification of the structure of tasks and its exploitation in HCI design has the potential to significantly augment human task performance as shown in success stories (e.g., [13]). Clearly, one of the most important points is that any HCI design should be based on a model of the tasks to be performed, but should not force users into using overly-constraining interface frameworks that may be hard to learn and that may stifle creativity or serendipity. The vision of the next generation of interfaces as augmenters of human performance is the primary motivation behind this report's elevation of practice to a level equivalent to that of education and research.The principal target of this report, however, remains academia and its infrastructure. Although prior reports, such as the ACM/IEEE-CS Joint Curriculum Task Force [25], have recommended the inclusion of HCI as a common requirement in computer science programs, their effect on the presence of HCI in all computer science departments has been less than spectacular. All computer science departments are encouraged to reconsider the primacy of HCI to their field and to seek to develop courses and faculty to teach and research the topics outlined in this report. Not only does the continued vitality of computer science depend on a reconsideration of the place of HCI within computer science infrastructure, the success of the critical, national mission of building an information infrastructure for its citizens depends on it.

Conclusion

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This report is the product of many people besides the sponsors and the organizing committee. Many of the workshop participants put in time beyond the workshop itself to contribute in one way or another. There were also a large number of reviewers who contributed greatly to the final draft, and who must be thanked for catching the obvious or for helping us to avoid the ridiculous. Different drafts received comments from open public forums, such as the CHI'94 Conference in Boston and the Snowbird'94 Conference in Utah. Although each of the many contributors cannot be listed one-by-one, thanks is due to them all. We are especially grateful to John Thomas Dayton, Jr. for his timely and voluminous editorial assistance on the final draft. Even so, errors may still be present in this report, and they remain the sole fault of the principal investigator.

challenge presented by new national initiatives, primarily that of the National Information Infrastructure. In order to make the proposed information infrastructure available to all citizens of the United States, communication barriers between technology and the citizenry must be broken. This means that new educational objectives for technologists must be established, that new approaches to HCI design and development must be sought, and that effective interface engineering must be practiced.

This report contains many suggestions regarding education, research, and practice in HCI. Not all of them will be seen as equally relevant to all readers. On the other hand, there is no more important task for members of the field than to express their interest and intent in addressing at least some of these suggestions. This report is not a final story. It is a beginning to a new story that will be written as our nation embraces the information age through the NII. The sponsors of this workshop will be doing their part to fund and administer support in this effort, but what is more important is that educators, researchers, and practitioners act on these recommendations in their daily work. If they can see ways to go beyond these recommendations and to improve them, then they must do so.

There are few occasions when large social and political forces join in a common vision with members of an academic field. This is one of those few times in history. Furthermore, success in bringing the vision into fruition is not at all assured. It is only with the greatest of effort and drawing together of forces within the field that success will be even possible. It is the hope of the writers of this report that the excitement and promise that motivates us will, at least in some small way, infect each and every reader of this report.

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