

## 2. Human Computer Interaction (HCI)

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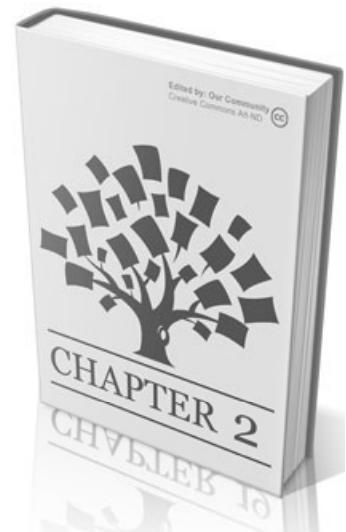
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Human-computer interaction (HCI) is an area of research and practice that emerged in the early 1980s, initially as a specialty area in computer science embracing cognitive science and human factors engineering. HCI has expanded rapidly and steadily for three decades, attracting professionals from many other disciplines and incorporating diverse concepts and approaches. To a considerable extent, HCI now aggregates a collection of semi-autonomous fields of research and practice in human-centered informatics. However, the continuing synthesis of disparate conceptions and approaches to science and practice in HCI has produced a dramatic example of how different epistemologies and paradigms can be reconciled and integrated in a vibrant and productive intellectual project.

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### About the author

## 2.1 Where HCI came from

Until the late 1970s, the only humans who interacted with computers were information technology professionals and dedicated hobbyists. This changed disruptively with the emergence of personal computing in the later 1970s. Personal computing, including both personal software (productivity applications, such as text editors and spreadsheets, and interactive computer games) and personal computer platforms (operating systems, programming languages, and hardware), made everyone in the world a potential computer user, and vividly highlighted the deficiencies of computers with respect to *usability* for those who wanted to use computers as tools.



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Figure 2.1 A-B: Personal computing rapidly pushed computer use into the general population, starting in the later 1970s. However, the non-professional computer user was often subjected to arcane commands and system dialogs.

The challenge of personal computing became manifest at an opportune time. The broad project of cognitive science, which incorporated cognitive psychology, artificial intelligence, linguistics, cognitive anthropology, and the philosophy of mind, had formed at the end of the 1970s. Part of the programme of cognitive science was to articulate systematic and scientifically informed applications to be known as "cognitive engineering". Thus, at just the point when personal computing presented the practical need for HCI, cognitive science presented people, concepts, skills, and a vision for addressing such needs through an ambitious synthesis of science and engineering. HCI was one of the first examples of cognitive engineering.

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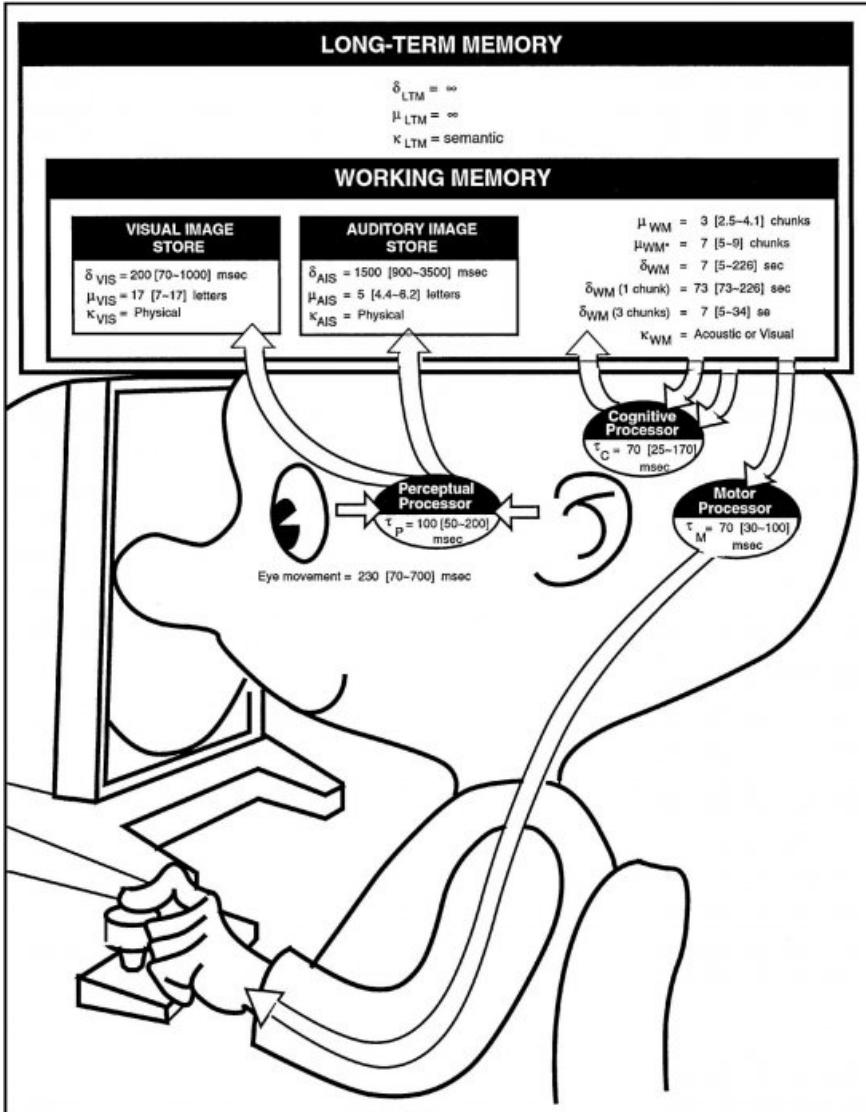
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Figure 2.2: The Model Human Processor was an early cognitive engineering model intended to help developers apply principles from cognitive psychology.



This was facilitated by analogous developments in engineering and design areas adjacent to HCI, and in fact often overlapping HCI, notably human factors engineering and documentation development. Human factors had developed empirical and task-analytic techniques for evaluating human-system interactions in domains such as aviation and manufacturing, and was moving to address interactive system contexts in which human operators regularly exerted greater problem-solving discretion. Documentation development was moving beyond its traditional role of producing systematic technical descriptions toward a cognitive approach incorporating theories of writing, reading, and media, with empirical user testing. Documents and other information needed to be usable also.

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### MOVING THE CURSOR

The four cursor-movement keys have arrows on them (they are located on the right of the keyboard).

PRESS THE ↓ CURSOR KEY SEVERAL TIMES AND WATCH THE CURSOR MOVE DOWN THE SCREEN.

The ↑, ←, and → cursor keys work analogously. Try them and see.

If you move the cursor all the way to the bottom of the screen, or all the way to the right, the display "shifts" so that you can see more of your document. By moving the cursor all the way up and to the left, you can bring the document back to where it started.

### DELETING TEXT

USE THE CURSOR KEYS TO MOVE THE CURSOR UNDER THE FIRST **r** IN THE WORD **regular**.

PRESS THE DEL KEY

The DEL key is located up and to the right of the keyboard keys. Is the Displaywriter prompting you?: **Delete what?**

- If you make a mistake at this point, use CODE + CANCL and start the deletion again.

USING THE → KEY, MOVE THE CURSOR THROUGH THE MATERIAL TO BE DELETED, THE WORD **regular**.

The word is highlighted: you can see exactly what is going to be deleted before it actually is deleted

- If the wrong characters are highlighted use CODE + CANCL and start the deletion again.

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Figure 2.3: Minimalist information emphasized supporting goal-directed activity in a domain. Instead of topic hierarchies and structured practice, it emphasized succinct support for self-directed action and for recognizing and recovering from error.



1 2 3 4 5 6

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Other historically fortuitous developments contributed to the establishment of HCI. Software engineering, mired in unmanageable software complexity in the 1970s (the “software crisis”), was starting to focus on nonfunctional requirements, including usability and maintainability, and on empirical software development processes that relied heavily on iterative prototyping and empirical testing. Computer graphics and information retrieval had emerged in the 1970s, and rapidly came to recognize that interactive systems were the key to progressing beyond early achievements. All these threads of development in computer science pointed to the same conclusion: The way forward for computing entailed understanding and better empowering users. These diverse forces of need and opportunity converged around 1980, focusing a huge burst of human energy, and creating a highly visible interdisciplinary project.

## 2.2 From cabal to community

The original and abiding technical focus of HCI was and is the concept of *usability*. This concept was originally articulated somewhat naively in the slogan “easy to learn, easy to use”. The blunt simplicity of this conceptualization gave HCI an edgy and prominent identity in computing. It served to hold the field together, and to help it influence computer science and technology development more broadly and effectively. However, inside HCI the concept of usability has been re-articulated and reconstructed almost continually, and has become increasingly rich and intriguingly problematic. Usability now often subsumes qualities like fun, well being, collective efficacy, aesthetic tension, enhanced creativity, flow, support for human



Steve Mann is the father of wearable computing and one of the founders of MIT's Wearable Computers group in the Media Lab. Currently, he is working on a “Silicon Brain”

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development, and others. A more dynamic view of usability is one of a programmatic objective that should and will continue to develop as our ability to reach further toward it improves.



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Figure 2.4: Usability is an emergent quality that reflects the grasp and the reach of HCI. Contemporary users want more from a system than merely “ease of use”.

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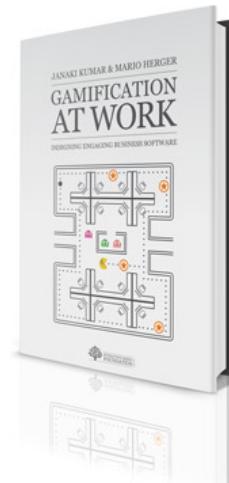
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Although the original academic home for HCI was computer science, and its original focus was on personal productivity applications, mainly text editing and spreadsheets, the field has constantly diversified and outgrown all boundaries. It quickly expanded to encompass visualization, information systems, collaborative systems, the system development process, and many areas of design. HCI is taught now in many departments/faculties that address information technology, including psychology, design, communication studies, cognitive science, information science, science and technology studies, geographical sciences, management information systems, and industrial, manufacturing, and systems engineering. HCI research and practice draws upon and integrates all of these perspectives.

A result of this growth is that HCI is now less singularly focused with respect to core concepts and methods, problem areas and assumptions about infrastructures, applications, and types of users. Indeed, it no longer makes sense to regard HCI as a specialty of computer science; HCI has grown to be broader, larger and much more diverse than computer science itself. HCI expanded from its initial focus on individual and generic user behavior to include social and organizational computing, accessibility for the elderly, the cognitively and physically impaired, and for all people, and for the widest possible spectrum of human experiences and activities. It expanded from desktop office applications to include games, learning and education, commerce, health and medical applications, emergency planning and response, and systems to support collaboration and community. It expanded from early graphical user interfaces to include myriad interaction techniques and devices, multi-modal interactions, tool support for model-based user interface specification, and a host of emerging ubiquitous, handheld and context-aware interactions.

There is no unified concept of an HCI professional. In the 1980s, the cognitive science side of HCI was sometimes contrasted with the software tools and user interface side of HCI. The landscape of core HCI concepts and skills is far more differentiated and complex now. HCI academic programs train many different types of professionals: user experience designers, interaction designers, user interface designers, application designers, usability engineers, user interface developers, application developers, technical communicators/online information designers, and more. And indeed, many of the sub-communities of HCI are themselves quite diverse. For example, ubiquitous computing (aka ubicomp) is subarea of HCI, but it is also a superordinate area integrating several distinguishable subareas, for example mobile computing, geo-spatial information systems, in-vehicle systems, community informatics, distributed systems, handhelds, wearable devices, ambient intelligence, sensor networks, and specialized views of usability evaluation, programming tools and techniques, and application infrastructures. The relationship between ubiquitous computing and HCI is paradigmatic: HCI is the name for a community of communities.



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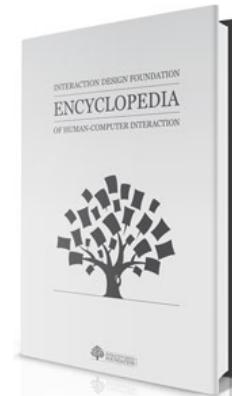


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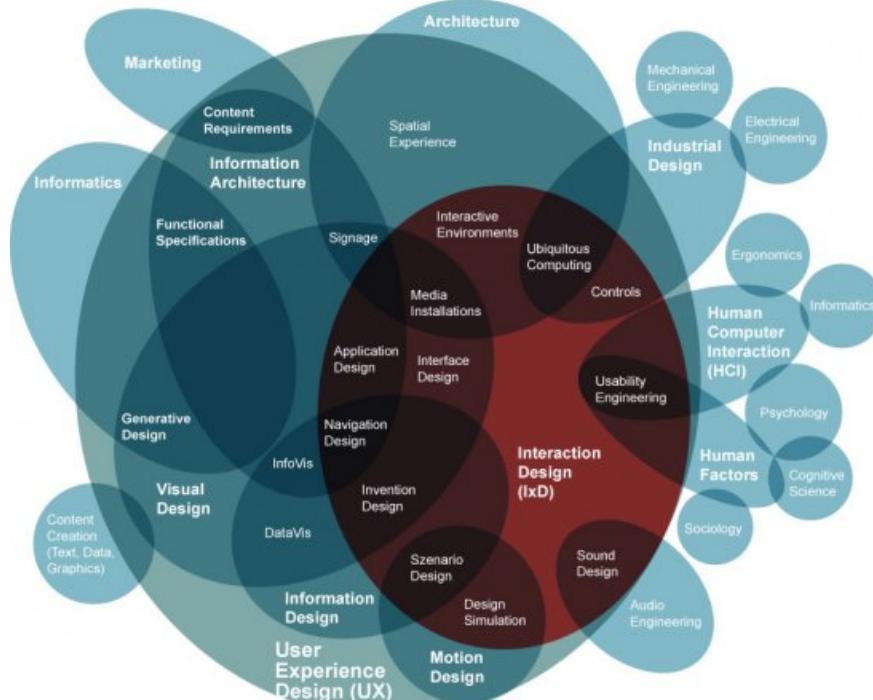




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Soegaard and Dam 2013: The Encyclopedia of Human-Computer Interaction, 2nd Ed.... by Mads Soegaard and Rikke Friis Dam



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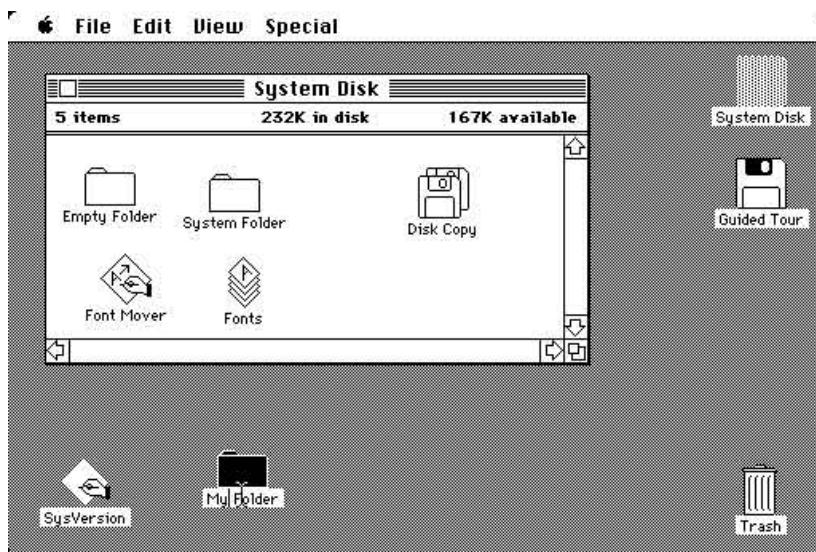


Figure 2.5 A-B: Two visualizations of the variety of disciplinary knowledge and skills involved in contemporary design of human-computer interactions

Indeed, the principle that HCI is a community of communities is now a point of definition codified, for example, in the organization of major HCI conferences and journals. The integrating element across HCI communities continues to be a close linkage of critical analysis of usability, broadly understood, with development of novel technology and applications. This is the defining identity commitment of the HCI community. It has allowed HCI to successfully cultivate respect for the diversity of skills and concepts that underlie innovative technology development, and to regularly transcend disciplinary obstacles. In the early 1980s, HCI was a small and focused specialty area. It was a cabal trying to establish what was then a heretical view of computing. Today, HCI is a vast and multifaceted community, bound by the evolving concept of usability, and the integrating commitment to value human activity and experience as the primary driver in technology.

## 2.3 Beyond the desktop

Given the contemporary shape of HCI, it is important to remember that its origins are personal productivity interactions bound to the desktop, such as word processing and spreadsheets. Indeed, one of biggest design ideas of the early 1980s was the so-called messy desk metaphor, popularized by the Apple Macintosh: Files and folders were displayed as icons that could be, and were scattered around the display surface. The messy desktop was a perfect incubator for the developing paradigm of graphical user interfaces. Perhaps it wasn't quite as easy to learn and easy to use as claimed, but people everywhere were soon double clicking, dragging windows and icons around their displays, and losing track of things on their desktop interfaces just as they did on their physical desktops. It was surely a stark contrast to the immediately prior teletype metaphor of Unix, in which all interactions were accomplished by typing commands.



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Figure 2.6: The early Macintosh desktop metaphor: Icons scattered on the desktop depict documents and functions, which can be selected and accessed (as System Disk in the example)

Even though it can definitely be argued that the desktop metaphor was superficial, or perhaps under-exploited as a design paradigm, it captured imaginations of designers and the public. These were new possibilities for many people in 1980, pundits speculated about how they might change office work. Indeed, the tsunami of desktop designs challenged, sometimes threatened the expertise and work practices of office workers. Today they are in the cultural background. Children learn these concepts and skills routinely.

As HCI developed, it moved beyond the desktop in three distinct senses. First, the desktop metaphor proved to be more limited than it first seemed. It's fine to directly represent a couple dozen digital objects as icons, but this approach quickly leads to clutter, and is not very useful for people with thousands of personal files and folders. Through the mid-1990s, HCI professionals and everyone else realized that search is a more fundamental paradigm than browsing for finding things in a user interface. Ironically though, when early World Wide Web pages emerged in the mid-1990s, they not only dropped the messy desktop metaphor, but for the most part dropped graphical interactions entirely. And still they were seen as a breakthrough in usability (of course, the direct contrast was to Unix-style tools like ftp and telnet). The design approach of displaying and directly interacting with data objects as icons has not disappeared, but it is no longer a hegemonic design concept.



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Figure 2.7: The early popularity of messy desktops for ↗ [Full quality](#)

The second sense in which HCI moved beyond the desktop was through the growing influence of the Internet on computing and on society. Starting in the mid-1980s, email emerged as one of the most important HCI applications, but ironically, email made computers and networks into communication channels; people were not interacting *with* computers, they were interacting with other people *through* computers. Tools and applications to support collaborative activity now include instant messaging, wikis, blogs, online forums, social networking, social bookmarking and tagging services, media spaces and other collaborative workspaces, recommender and collaborative filtering systems, and a wide variety of online groups and communities. New paradigms and mechanisms for collective activity have emerged including online auctions, reputation systems, soft sensors, and crowd sourcing. This area of HCI, now often called social computing, is one of the most rapidly developing.

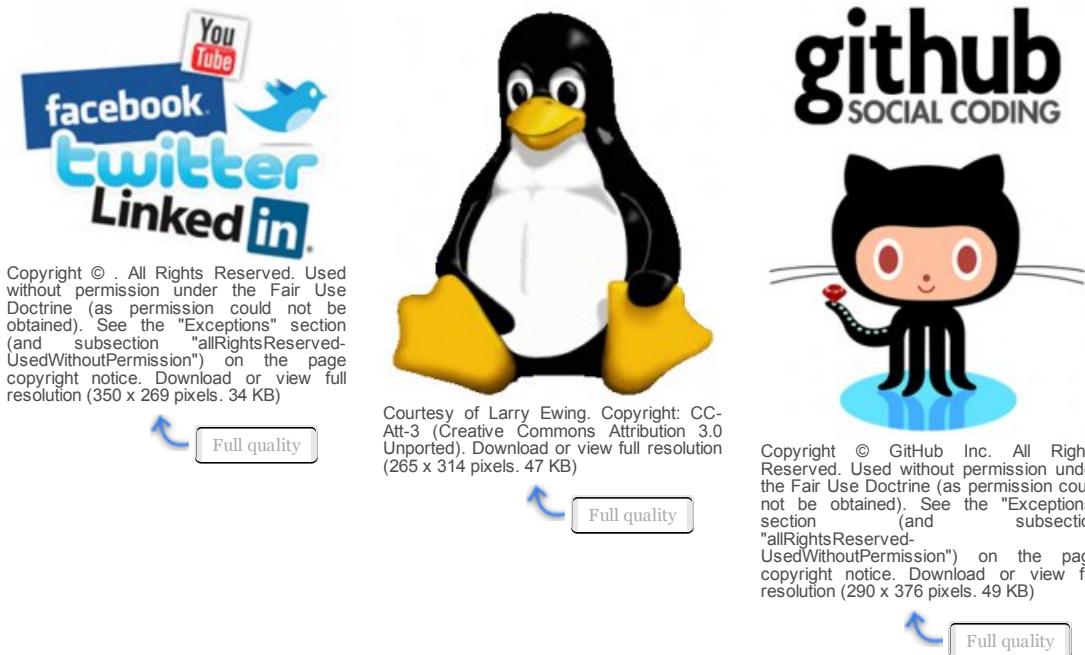


Figure 2.8 A-B-C: A huge and expanding variety of social network services are part of everyday computing experiences for many people. Online communities, such as Linux communities and GitHub, employ social computing to produce high-quality knowledge work.

The third way that HCI moved beyond the desktop was through the continual, and occasionally explosive diversification in the ecology of computing devices. Before desktop applications were consolidated, new kinds of device contexts emerged, notably laptops, which began to appear in the early 1980s, and handhelds, which began to appear in the mid-1980s. One frontier today is ubiquitous computing: The pervasive incorporation of computing into human habitats — cars, home appliances, furniture, clothing, and so forth. Desktop computing is still very important, though the desktop habitat has been transformed by the wide use of laptops. To a considerable extent, the desktop itself has moved off the desktop.



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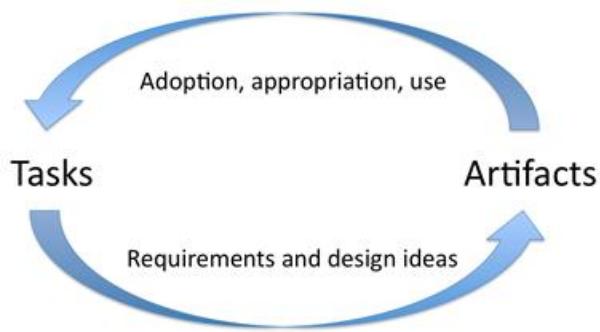
Figure 2.9 A-B-C: Computing moved off the desktop to be everywhere all the time. Computers are in phones, cars, meeting rooms, and coffee shops.

The focus of HCI has moved beyond the desktop, and its focus will continue to move. HCI is a technology area, and it is ineluctably driven to frontiers of technology and application possibility. The special value and contribution of HCI is that it will investigate, develop, and harness those new areas of possibility not merely as technologies or designs, but as means for enhancing human activity and experience.

## 2.4 The task-artifact cycle

The movement of HCI off the desktop is a large-scale example of a pattern of technology development that is replicated throughout HCI at many levels of analysis. HCI addresses the dynamic co-evolution of the activities people engage in and experience, and the artifacts — such as interactive tools and environments — that mediate those activities. HCI is about understanding and critically evaluating the interactive technologies people use and experience. But it is also about how those interactions evolve as people appropriate technologies, as their expectations, concepts and skills develop, and as they articulate new needs, new interests, and new visions and agendas for interactive technology.

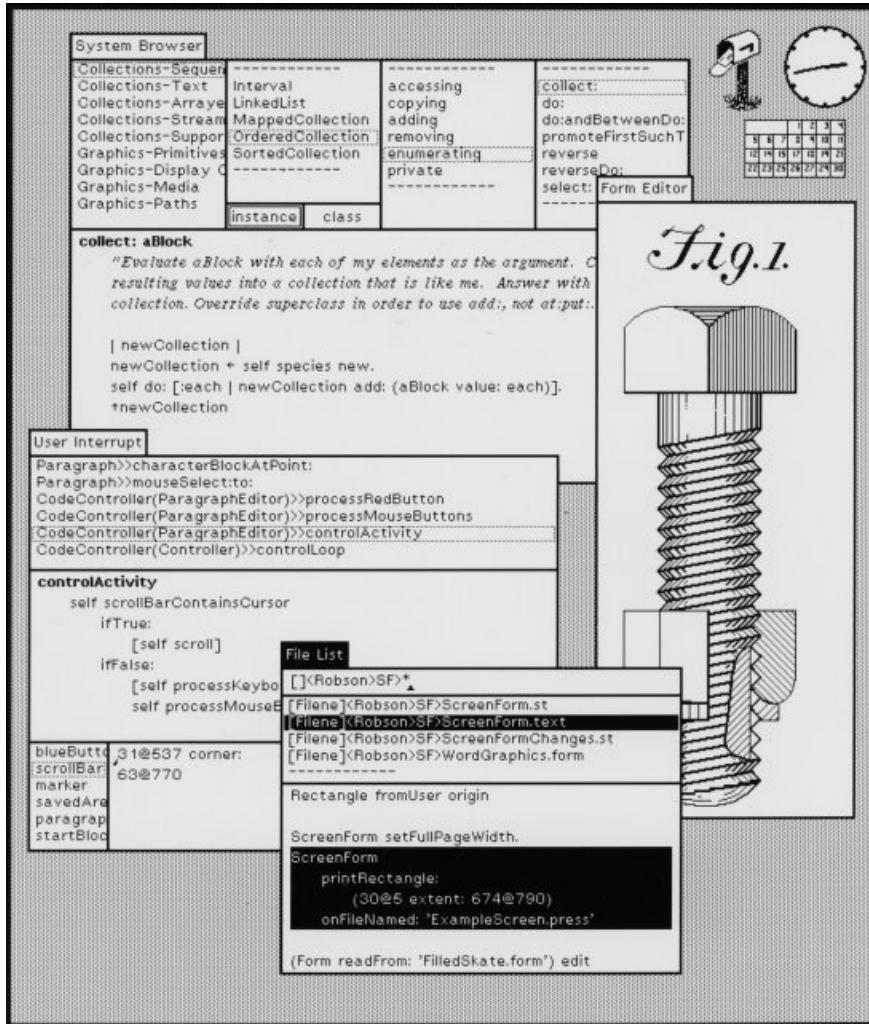
Reciprocally, HCI is about understanding contemporary human practices and aspirations, including how those activities are embodied, elaborated, but also perhaps limited by current infrastructures and tools. HCI is about understanding practices and activity specifically as requirements and design possibilities envisioning and bringing into being new technology, new tools and environments. It is about exploring design spaces, and realizing new systems and devices through the co-evolution of activity and artifacts, the task-artifact cycle.



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**Figure 2.10:** Human activities implicitly articulate needs, preferences and design visions. Artifacts are designed in response, but inevitably do more than merely respond. Through the course of their adoption and appropriation, new designs provide new possibilities for action and interaction. Ultimately, this activity articulates further human needs, preferences, and design visions.

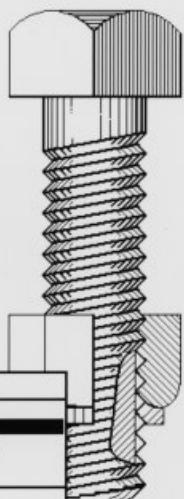
Understanding HCI as inscribed in a co-evolution of activity and technological artifacts is useful. Most simply, it reminds us what HCI is like, that all of the infrastructure of HCI, including its concepts, methods, focal problems, and stirring successes will always be in flux. Moreover, because the co-evolution of activity and artifacts is shaped by a cascade of contingent initiatives across a diverse collection of actors, there is no reason to expect HCI to be convergent, or predictable. This is not to say progress in HCI is random or arbitrary, just that it is more like world history than it is like physics. One could see this quite optimistically: Individual and collective initiative shapes what HCI is, but not the laws of physics.



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Figure 2.11: Smalltalk was a programming language and environment project in Xerox Palo Alto Research Center in the 1970s. The work of a handful of people, it became the direct antecedent for the modern graphical user interface.

*Fig.1*



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A second implication of the task-artifact cycle is that continual exploration of new applications and application domains, new designs and design paradigms, new experiences, and new activities should remain highly prized in HCI. We may have the sense that we know where we are going today, but given the apparent rate of co-evolution in activity and artifacts, our effective look-ahead is probably less than we think. Moreover, since we are in effect constructing a future trajectory, and not just finding it, the cost of missteps is high. The co-evolution of activity and artifacts evidences strong hysteresis, that is to say, effects of past co-evolutionary adjustments persist far into the future. For example, many people struggle every day with operating systems and core productivity applications whose designs were evolutionary reactions to misanalyses from two or more decades ago. Of course, it is impossible to always be right with respect to values and criteria that will emerge and coalesce in the future, but we should at least be mindful that very consequential missteps are possible.



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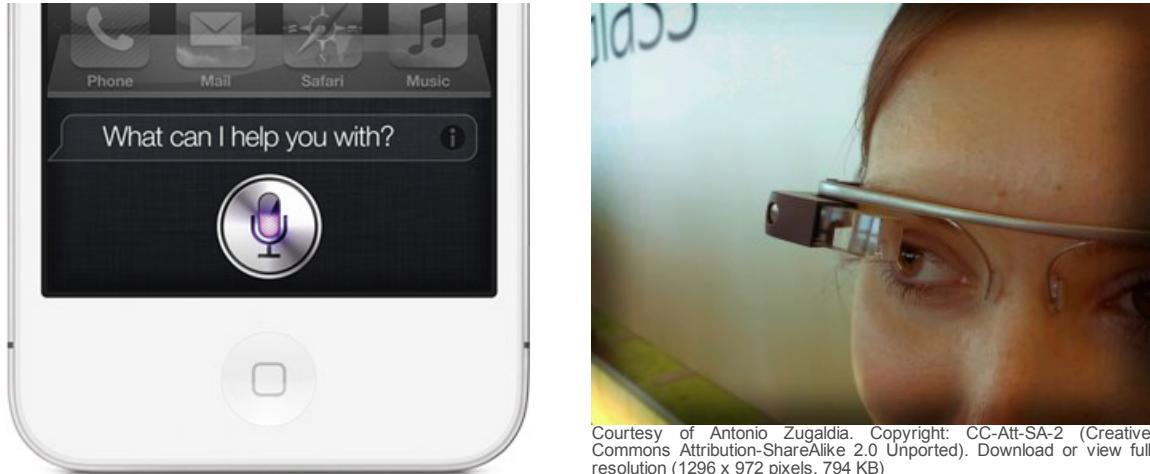


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Figure 2.12 A-B: The Drift Table is an interactive coffee table; aerial views of England and Wales are displayed the porthole on top; placing and moving objects on the table causes the aerial imagery to scroll. This design is intended to provoke reaction and challenge thinking about domestic technologies.

The remedy is to consider many alternatives at every point in the progression. It is vitally important to have lots of work exploring possible experiences and activities, for example, on design and experience probes and prototypes. If we focus too strongly on the affordances of currently embodied technology we are too easily and uncritically accepting constraints that will limit contemporary HCI as well as all future trajectories.



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Figure 2.13 A-B: Siri, the speech-based intelligent assistant for Apple's iPhone, and the augmented reality glasses of Google's Project Glass are recent examples of technology visions being turned into everyday HCI experiences.

HCI is not fundamentally about the laws of nature. Rather, it manages innovation to ensure that human values and human priorities are advanced, and not diminished through new technology. This is what created HCI; this is what led HCI off the desktop; it will continue to lead HCI to new regions of technology-mediated human possibility. This is why usability is an open-ended concept, and can never be reduced to a fixed checklist.

## Join our community and advance:



## 2.5 A caldron of theory

The contingent trajectory of HCI as a project in transforming human activity and experience through design has nonetheless remained closely integrated with the application and development of theory in the social and cognitive sciences. Even though, and to some extent because the technologies and human activities at issue in HCI are continually co-evolving, the domain has served as a laboratory and incubator for theory. The origin of HCI as an early case study in cognitive engineering had an imprinting effect on the character of the endeavor. From the very start, the models, theories and frameworks developed and used in HCI were pursued as contributions to science: HCI has enriched every theory it has appropriated. For example, the GOMS (Goals, Operations, Methods, Selection rules) model, the earliest native theory in HCI, was a more comprehensive cognitive model than had been attempted elsewhere in cognitive science and engineering; the model human processor included simple aspects of perception,

attention, short-term memory operations, planning, and motor behavior in a single model. But GOMS was also a practical tool, articulating the dual criteria of scientific contribution *plus* engineering and design efficacy that has become the culture of theory and application in HCI.



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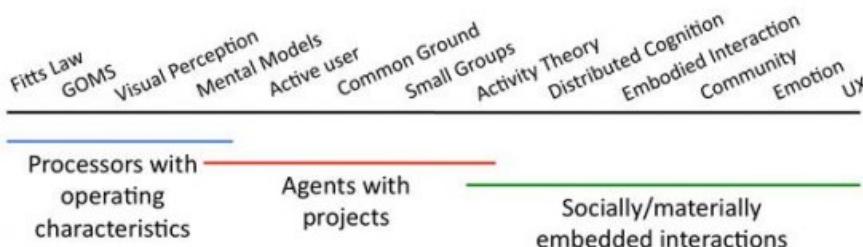
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Figure 2.14 A-B: CogTool analyzes demonstrations of user tasks to produce a model of the cognitive processes underlying task performance; from this model it predicts expert performance times for the tasks.

The focus of theory development and application has moved throughout the history of HCI, as the focus of the co-evolution of activities and artifacts has moved.<sup>28</sup> Thus, the early information processing-based psychological theories, like GOMS, were employed to model the cognition and behavior of individuals interacting with keyboards, simple displays, and pointing devices. This initial conception of HCI theory was broadened as interactions became more varied and applications became richer. For example, perceptual theories were marshaled to explain how objects are recognized in a graphical display, mental model theories were appropriated to explain the role of concepts — like the messy desktop metaphor — in shaping interactions, active user theories were developed to explain how and why users learn and making sense of interactions. In each case, however, these elaborations were both scientific advances and bases for better tools and design practices.

This dialectic of theory and application has continued in HCI. It is easy to identify a dozen or so major currents of theory, which themselves can be grouped (roughly) into three eras: theories that view human-computer interaction as information processing, theories that view interaction as the initiative of agents pursuing projects, and theories that view interaction as socially and materially embedded in rich contexts. To some extent, the sequence of theories can be understood as a convergence of scientific opportunity and application need: Codifying and using relatively austere models made it clear what richer views of people and interaction could be articulated and what they could contribute; at the same time, personal devices became portals for interaction in the social and physical world, requiring richer theoretical frameworks for analysis and design.



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Figure 2.15: Through the past three decades, a series of theoretical paradigms emerged to address the expanding ambitions of HCI research, design, and product development. Successive theories both challenged and enriched prior conception of people and interaction. All of these theories are still relevant and still in use today in HCI.

The sequence of theories and eras is of course somewhat idealized. People still work on GOMS models; indeed, all of the major models, theories and frameworks that ever were employed in HCI are still in current use. Indeed, they continue to develop as the context of the field develops. GOMS today is more a niche model than a paradigm for HCI, but has recently been applied in research on smart phone designs and human-robot interactions.

The challenge of integrating, or at least better coordinating descriptive and explanatory science goals with prescriptive and constructive design goals is abiding in HCI. There are at least three ongoing directions – traditional application of ever-broader and deeper basic theories, development of local, sometimes domain dependent proto-theories within particular design domains, and the use of design rationale as a mediating level of description between basic science and design practice.

## 2.6 Implications of HCI for science, practice, and epistemology

One of the most significant achievements of HCI is its evolving model of the integration of research and practice. Initially this model was articulated as a reciprocal relation between cognitive science and cognitive engineering. Later, it ambitiously incorporated a diverse science foundation, notably social and organizational psychology, Activity Theory, distributed cognition, and sociology, and a ethnographic approaches human activity, including the activities of design and technology development and appropriation. Currently, the model is incorporating design practices and research across a broad spectrum, for example, theorizing user experience and ecological sustainability. In these developments, HCI provides a blueprint for a mutual relation between science and practice that is unprecedented.

Although HCI was always talked about as a design science or as pursuing guidance for designers, this was construed at first as a boundary, with HCI research and design as separate contributing areas of professional expertise. Throughout the 1990s, however, HCI directly assimilated, and eventually itself spawned, a series of design communities. At first, this was a merely ecumenical acceptance of methods and techniques laying those of beyond those of science and engineering. But this outreach impulse coincided with substantial advances in user interface technologies that shifted much of the potential proprietary value of user interfaces into graphical design and much richer ontologies of user experience.

Somewhat ironically, designers were welcomed into the HCI community just in time to help remake it as a design discipline. A large part of this transformation was the creation of design disciplines and issues that did not exist before. For example, user experience design and interaction design were not imported into HCI, but rather were among the first exports from HCI to the design world. Similarly, analysis of the productive tensions between creativity and rationale in design required a design field like HCI in which it is essential that designs have an internal logic, and can be systematically evaluated and maintained, yet at the same time provoke new experiences and insights.<sup>28</sup> Design is currently the facet of HCI in most rapid flux. It seems likely that more new design proto-disciplines will emerge from HCI during the next decade.

No one can accuse HCI of resting on laurels. Conceptions of how underlying science informs and is informed by the worlds of practice and activity have evolved continually in HCI since its inception. Throughout the development of HCI, paradigm-changing scientific and epistemological revisions were deliberately embraced by a field that was, by any measure, succeeding intellectually and practically. The result has been an increasingly fragmented and complex field that has continued to succeed even more. This example contradicts the Kuhnian view of how intellectual projects develop through paradigms that are eventually overthrown. The continuing success of the HCI community in moving its meta-project forward thus has profound implications, not only for human-centered informatics, but for epistemology.

## 2.7 Pointers: How to learn more

In these “pointers” I have listed general background references to the discussion above, specific references to points made in the text, and reference to other chapters in the Encyclopedia of Human-Computer Interaction (Interaction-Design.org). I have organized the pointers by section, so the next six sections (below) echo the six major section headings in the paper itself (above).

### 2.7.1 Where HCI came from

There are many highly readable descriptions of the disciplinary landscape in which early HCI developed:

- » 1980 volume of the journal Cognitive Science provides a vivid picture of the foundations of cognitive science as they were being built (<http://cogsciarchive.rpi.edu/1980v04/index.html>);
- » F. Brooks' book *The Mythical Man-Month* (1975, Addison-Wesley) is an insightful analysis of software engineering, and the original source for the idea that iterative prototyping is inevitable in the design and development of complex software;