SECTION IV

Technology Trends

CHAPTER 8

Human–Computer Interaction

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Preamble: History in a Time of Rapid Change

Efforts to define information science are hardy perennials. As the debate continues, hundreds of papers on the history of the field have appeared (see Burke's [2007] meta review). We are not sure what information science is, but we are getting a grip on its history.

There is greater consensus on the early history, from the antecedents of library and information science through the so-called "golden years" of the 1950s to the 1970s. Burke writes, "Hardly any publications have explored … the science of information or the information business after the mid-1970s" (p. 19). In the late 1970s computer use began to dominate how many people create, manage, and use information, adding theoretical and organizational complexity.

As more information is represented digitally, human–computer interaction (HCI), broadly defined, becomes more central to information science. Reflecting this convergence, information schools have hired leading human–computer interaction researchers and initiated HCI programs and degree concentrations. Several such schools adopted simple names—school of information, faculty of information, information school—thereby sidestepping definitional disputes and shedding associations with library and information science. (Dropping "science" did not signal a renewed outreach to the humanities.)

Prior to this convergence, information science (or information) and its antecedents evolved apart from human–computer interaction and its antecedents. HCI developed as sub-disciplines in three fields: human factors, management information systems, and computer science. The three threads of HCI research mingled less than one might have expected. This survey covers the evolution of these four fields of research, with a view to understanding better the forces underlying the trajectories they have followed, forces that are still in play and thus will influence our future.

My focus is on the computer era. Other recent *ARIST* chapters that have dealt with aspects of human–computer interaction include Rogers's (2004) survey of HCI theory, Callahan's (2005) discussion of interface design and culture, and Ruthven's (2008) analysis of interactive information retrieval.

However, Burke (1994), Michael Buckland (1998), W. Boyd Rayward (1998), and others have shown that prior to the digital era, researchers, technology developers, and dreamers anticipated issues that are prominent today. My favorite illustration is H. G. Wells's 1905 proposal for a system built on index cards:

> These index cards might conceivably be transparent and so contrived as to give a photographic copy promptly whenever it was needed, and they could have an attachment into which would slip a ticket bearing the name of the locality in which the individual was last reported. A little army of attendants would be at work on this index day and night. … An incessant stream of information would come, of births, of deaths, of arrivals at inns, of applications to post offices for letters, of tickets taken for long journeys, of criminal convictions, marriages, applications for public doles and the like. A filter of offices would sort the stream, and all day and all night for ever a swarm of clerks would go to and fro correcting this central register, and photographing copies of its entries for transmission to the subordinate local stations, in response to their inquiries. (Wells, 1905, online)

Would this human-powered Web 2.0 be a tool for social control or public information access? The image evokes the potential and the challenges of the coming information era.

Why Study the History of Human–Computer Interaction?

Information may have persistent qualities, but technologies fade away. For most of the computing era, interaction involved 80-column punch cards, paper tape, line editors, 1920-character displays, 1-megabyte diskettes, and other extinct species. Are the interaction issues of those times relevant today? No.

On the other hand, aspects of the psychology of human–computer interaction change more slowly, or not at all. Much of what was learned about perceptual, cognitive, social, and emotional processes in interacting with older technologies applies to emerging technologies. But there, history is of less interest than *what* was learned.

Nevertheless, the rapid pace of change strengthens some reasons for understanding aspects of the field's history:

1. Although several disciplines are engaged in human–computer interaction research and application, few people are exposed to more than one. By seeing how the others evolved, we can identify benefits in expanding our focus, as well as obstacles to doing so.

2. The recognition of past visionaries and innovators is part of building a community and inspiring future contributors, even when specific past achievements are difficult to appreciate today.

3. Some visions and prototypes were quickly converted to widespread application, others took decades, and some remain unrealized. By understanding the reasons for different outcomes, we might assess today's visions more realistically.

4. Crystal balls are notoriously unreliable, but anyone planning or managing a career in a rapidly changing field must consider the future. One thing is certain: It will not resemble the present. Our best chance to anticipate change is to find trajectories that extend from the past through the present.

This account is not an engineering history that emphasizes "firsts." It focuses on when technologies and practices became widely used, as reflected in the spread of systems and applications. This is often accompanied by disciplinary development, formalized in the growth of associations and research fields. More social history than conceptual history, this survey points to trends and trajectories that you might download into your crystal ball.

A central theme is the impact of successive waves of hardware innovation, "Moore's Law" broadly construed. This familiar phenomenon, unexamined in previous HCI histories, is essential to discussing disciplines and associations, which often sprang up around a new technology and withered or died when it was replaced. In addition, hardware costs had to drop for some applications to become practical. Conceptual histories pass over these factors. For example, graphical user interface concepts were invented early in the era of transistor-based computers. Conceptual development progressed slowly over the next half century. Only in the mid-1980s were widely available computers powerful enough to devote that much memory and processing to supporting interaction.

In terms of broad movements, the HCI threads within human factors, information systems, and computer science quickly expanded from narrow user bases to embrace broad constituencies. This is less true of technology use in information science and its predecessors. Until more recently the latter remained focused on narrower target audiences—librarians, document managers in business and government agencies, scientists and engineers, and other specialists. Nevertheless, the early history enables us to understand the developments in recent decades, when broad HCI concerns became significant in information studies.

An historical account is a perspective. It emphasizes some things while deemphasizing or omitting others. A history can be wrong in details but is never right in any final sense. Your questions and interests determine whether a perspective is useful to you.

Ron Baecker established a blueprint for intellectual histories of HCI in the opening chapters of the 1987 and 1995 editions of *Readings in Human–Computer Interaction* (Baecker & Buxton, 1987; Baecker, Grudin, Buxton, & Greenberg, 1995). Brian Shackel's (1997) account of European contributions and specialized essays by Brad Myers (1998) on HCI engineering history and Alan Blackwell (2006) on the history of metaphor in design added insights and references. Perlman, Green, and Wogalter (1995) provide a compendium of HCI papers that appeared in the human factors literature through 1994. Banker and Kaufmann (2004) cover HCI research within management information systems. Burke's (1998) chapter represents an example of a focused study of a digital effort within information science.

A wave of popular and scholarly books has addressed the history of personal computing, which is part of this account (e.g., Bardini, 2000; Hertzfeld, 2005; Hiltzik, 1999; Markoff, 2005). This chapter expands on Grudin's (2005, 2006, 2008) work. Historical topics are also present in the "Timelines" column of *ACM Interactions* from March 2006 through the present, including several of direct relevance to information science.

Few of the writers and editors listed here are trained historians. Many of us lived through much of the computing era as participants and witnesses, leaving us with rich insights and questionable objectivity. This account draws on extensive literature and hundreds of formal interviews and discussions, but we all have biases.

Acronyms: HCI, CHI, HF&E, IT, IS, LIS

Exploration of human–computer interaction literature is complicated by differences in how many simple terms are used. This is covered later in the chapter. Here I explain how several key disciplinary labels will be used. Unlike many authors, I use *human–computer interaction* broadly to cover work in several disciplines. *Computer–human interaction* (CHI) refers to one narrower focus, associated mainly with computer science, the Association for Computing Machinery Special Interest Group (ACM SIGCHI), and the latter's annual CHI conference. I use *human factors* (HF), *ergonomics*, and HF&E interchangeably—some writers define ergonomics a little more narrowly. The Human Factors Society (HFS) became the Human Factors and Ergonomics Society (HFES) in 1992. I use *information systems* (IS) to refer to the management discipline that has also been labeled data processing (DP) and management information systems (MIS). I follow common parlance in referring to organizational information systems specialists as "IT professionals (IT pros)." With IS taken, I do not abbreviate information studies or information science, but use LIS for *library and information science*.

Human–Tool Interaction and Information Processing at the Dawn of Computing

In the century prior to the first computers, advances in tool use and information processing technology initiated two fields of research that eventually contributed to human–computer interaction. One focused on making the human use of tools more efficient, the other on ways to represent and distribute information more effectively.

Origins of Human Factors

Frederick Taylor (1911) employed technologies and methods developed in the late 19th century—photography, moving pictures, and statistical analysis—to improve work practices. Time-and-motion studies were successful with assembly-line manufacturing and other manual tasks. In spite of the uneasiness with "Taylorism" reflected in Charlie Chaplin's popular satire *Modern Times*, science and engineering continued to pursue gains in efficiency.

The World Wars accelerated these efforts, matching people to jobs, training them, and then designing equipment and jobs to be more easily mastered. Engineering psychology was born during World War II after investigators found that simple flaws in the design of aircraft controls (Roscoe, 1997) and escape hatches (Dyson, 1979) led to aircraft losses and thousands of casualties. After the war, American aviation psychologists created the Human Factors Society. Two legacies of the conflict were respect for the potential of computing, based on its use in code-breaking, and enduring interest in behavioral requirements for design. For more on this period, see the books by Roscoe (1997) and Meister (1999, 2005).

Early tool use, whether by assembly-line workers or pilots, was not discretionary. If training was necessary, people were trained. One research goal was to reduce training time, but more important was to increase the speed and reliability of skilled performance.

Origins of the Focus on Information

As the cost of paper, printing, and transportation dropped in the late 19th and early 20th centuries, information dissemination and librarianship as a profession grew. Library associations formed in the U.S. and Great Britain in the 1870s. The Dewey Decimal System was developed the same decade. In the U.S., thousands of public libraries sprang up to serve local demand. They were poorly funded. In Europe, government-funded libraries appeared, often serving scientists and other specialized elites. This distinction had consequences that persisted through World War II, to the dawn of the computing era.

Librarianship

In the U.S., a pragmatic focus on library management and the training of thousands of librarians took precedence. There was no central funding for technology development, or for the needs of specialists in medicine, science, and the humanities. Public libraries were happy with the simple if inflexible Dewey Decimal system. Europe manifested more interest in technology and sophisticated information management, as reflected in the H. G. Wells quotation. Early in the 20th century, Belgian Paul Otlet obtained Melvil Dewey's permission to extend his classification system to enable the aggregation and linking of concepts in ways that foreshadowed tagging and hyperlinks—only after agreeing not to use it in English, an early example of legal constraint of technology use. Otlet's Universal Decimal Classification (UDC) is still used.

In the late 19th century, technologies and practices for compressing, distributing, and organizing information bloomed. In addition to the index card—a simple yet influential innovation—were Hollerith cards and electromechanical tabulation, celebrated steps toward computing that were heavily used to process information in industry. Typewriters and carbon paper facilitated information dissemination, as did the mimeograph machine, patented by Thomas Edison. Filing cabinets and folders—models for icons on computer displays much later—were important inventions that contributed to information management. Yates (1989) describes their impact on the management of organizations through the 1920s. Photography-based microform or microfilm, first developed in the 19th century, was the most efficient way to store information for a century.

Bibliography, Documentation, Documentalism

The American Library Association's (ALA) pragmatic focus meant that American research into technologies to advance indexing, cataloging, and retrieving information within or across libraries (called bibliography, documentation, or documentalism) formed a distinct thread outside the ALA. In Europe, research did not splinter: With a greater focus on scientific and specialized publishing in general, special libraries faced more sophisticated reader demands and a greater need to share resources; the creation in the U.K. of the Association for Special Libraries and Information Bureaux (Aslib) is a case in point. Different views of this history are forcefully presented in a discussion led by W. Boyd Rayward (1983) in Section 5 of Machlup and Mansfield's (1983) book; Burke (1994) presents a unified account.

Library Science

Over time, some American libraries engaged in limited scholarly work. The focus varied from technology innovation intended to support specialists in science and engineering to social science topics such as the history of publishing and typography. Then, in 1926, in a fateful move, the Carnegie Foundation endowed the Graduate Library School (GLS) at the University of Chicago to focus solely on research. For two decades Chicago was the only university granting the Ph.D. in library studies. The GLS included a laboratory for research on microphotography and social scientists who applied sophisticated statistical research methods (W. B. Rayward, personal communication, April 8, 2010), but its influential publications positioned library studies squarely in the humanities (Buckland, 1998). Professor Pierce Butler, whose interests included historical writing and typography, published *An Introduction to Library Science* (Butler, 1933). It became the major library research text for the next forty years. It did not mention information technologies in an era when Europeans and American documentalists were actively developing and exploring them. Studies of human-tool interaction were not part of the GLS program as conveyed by this book, and its prestige shaped the field until well into the computer era.

Specialist Use of Technology

Burke (2007, p. 15) summarized the early history, with its emphasis on training librarians and other specialists:

> Most information professionals … were focusing on providing information to specialists as quickly as possible. The terms used by contemporary specialists appeared to be satisfactory for many indexing tasks and there seemed no need for systems based on comprehensive and intellectually pleasing classification schemes. The goal of creating tools useful to non-specialists was, at best, of secondary importance.

As noted earlier, this chapter focuses on when computer technologies came into non-specialist use. Only recently, with the web and declining digital storage costs, came the realization that each of us will soon be our own information manager, just as we are all now telephone operators. But we get ahead of our story. This section concludes with accounts of two individuals who, in different ways, shaped the history of information research.

Paul Otlet and the Mundaneum

Otlet envisioned a vast network of information organized on index cards and microfilm. Unlike his contemporary Wells, Otlet and his collaborators built it. Otlet had begun cataloging bibliographic references on index cards in the late 19th century and established a commercial research service around them. In 1919 the Belgian government provided additional financing and supported establishing a center, called the Mundaneum, in Brussels. By 1934, 15 million index cards and millions of images were collected and organized via Otlet's Universal Decimal Classification, which included a numerical formula that enabled items to be linked to others. Government funding was eventually cut off and the collection was damaged during World War II. Although the work was largely forgotten for half a century (for example, it was not cited in the 1980s by the developers of the metaphorically identical Xerox Notecards, an influential hypertext system), Rayward (1990) has shown that Otlet and collaborators such as the microphotography pioneer Robert Goldschmidt represented a significant thread of European research that was much less prominent in North America.

Technological innovation continued in Europe with the development of mechanical systems of remarkable ingenuity (Buckland, 2009). These included the use of photoreceptors to detect light passing through holes in index cards positioned to represent different terms, which enabled very rapid retrieval of items on specific topics. These innovations inspired little-known efforts by a well known American scientist and research manager, discussed next.

Vannevar Bush and Microfilm Machines

Massachusetts Institute of Technology (MIT) professor Vannevar Bush was one of the most influential American scientists. He advised Presidents Franklin Roosevelt and Harry Truman, served as Director of the Office of Scientific Research and Development, and was President of the Carnegie Institute. Bush is best known for a 1945 *Atlantic Monthly* essay titled "As We May Think." It described a hypothetical microfilm-based electromechanical information processing machine called the Memex. The Memex was to be a workstation that enabled professionals to index and retrieve documents or pictures quickly and to create hypertext-like associations among them. This essay inspired computer engineers and computer scientists who contributed to computer graphics and human–computer interaction in the 1960s and 1970s.

The core of Bush's essay was written in the early 1930s. For over two decades, shrouded in secrecy, he devoted unprecedented resources to the design and construction of numerous machines comprising a subset of the Memex features. None was successful.

Microfilm—photographic miniaturization—had qualities that attracted Bush, as they had Otlet. Microfilm was light, easily transported, and easily copied (which paper documents were not: Xerox photocopiers did not appear until 1959). Microfilm was also the most efficient storage medium then available. Index codes placed on microfilm could be read by passing the film between light beams and photoreceptors. The moving picture industry had created tools for handling film and lowered the cost. Memory based on vacuum tubes would never be competitive. Magnetic memory, when it eventually arrived, was less versatile and far more expensive. It is easy to overlook the compelling case that existed for basing information systems on microfilm.

As recounted in Colin Burke's (1994) comprehensive book *Information and Secrecy: Vannevar Bush, Ultra, and the Other Memex,* Bush's machines failed because of overly ambitious compression and speed goals, patent ownership issues, and because Bush ignored librarians, documentalists, and decades of work on classification systems. American documentalists were active, albeit underfunded, prior to World War II. In 1937, the American Documentation Institute (ADI) formed, forerunner to today's American Society for Information Science and Technology (ASIST). Bush, an electrical engineer by training, did not work with them. He assumed that users could easily avoid problems arising from conflicting uses of terms, which was known to be false then and remains a key research challenge.

At times Bush considered libraries and the public as potential users, but his projects began with the Federal Bureau of Investigation (FBI) in mind, settled heavily on military uses for cryptography and information retrieval, and included a major Central Intelligence Agency (CIA) project. His machines cost far too much for librarians or library users to be plausible customers. These efforts might not belong in an account of broad technology deployments, were it not for Bush's influence. Through his academic and government positions, his writings, the vast resources he commandeered, and the scores of brilliant engineers diverted to his projects, Bush promoted his projects and exerted influence for two decades, well into the computer era that followed World War II.

Bush's (1945, online) vision emphasized the linking of information and discretionary use:

> associative indexing, the basic idea of which is a provision whereby any item may be caused at will to select immediately and automatically another. This is the essential feature of the Memex. … Any item can be joined into numerous trails. … New forms of encyclopedias will appear, ready made with a mesh of associative trails [which a user could extend].
>
> The lawyer has at his touch the associated opinions and decisions of his whole experience and of the experience of friends and authorities. The patent attorney has on call the millions of issued patents, with familiar trails to every point of his client's interest. The physician, puzzled by a patient's reactions, strikes the trail established in studying an earlier similar case and runs rapidly through analogous case histories, with side references to the classics for the pertinent anatomy and histology. The chemist, struggling with the synthesis of an organic compound, has all the chemical literature before him in his laboratory, with trails following the analogies of compounds and side trails to their physical and chemical behavior.
>
> The historian, with a vast chronological account of a people, parallels it with a skip trail which stops only on the salient items, and can follow at any time contemporary trails which lead him all over civilization at a particular epoch. There is a new profession of trail blazers, those who find

> delight in the task of establishing useful trails through the enormous mass of the common record.

Bush knew that the Memex was not realistic. None of his many projects included designs for the "essential" associative linking. His inspirational account describes today's hands-on discretionary use of computers by professionals. But that was 50 years in the future and required technologies then undreamt of. Bush did not support the early use of computers, which were slow, bulky, and expensive, lacking the many qualities of microfilm.

1945–1955: Managing Vacuum Tubes

World War II changed everything. The unprecedented investment in science and technology during the war years revealed that huge sums could be directed to academic and industrial research that addressed national goals. Research expectations and strategies would never be the same. Sophisticated electronic computation machines built before and during World War II were designed for specific purposes, such as solving equations or breaking codes. Their limitations made clear the desirability of general-purpose computational devices. Extremely expensive cryptographic machines played a major part in winning the war, but each was designed to attack a specific encryption device; a new one was needed when the enemy changed machines. General purpose computers, more feasible as a consequence of war-time improvements in technologies such as vacuum tubes, eventually brought human–computer interaction into the foreground.

When engineers and mathematicians emerged from the military and government (and secret project rooms on university campuses), secrecy eroded. The Electronic Numeric Integrator and Calculator (ENIAC), arguably the first general-purpose computer, was begun in secret during the war but announced publicly as a "giant brain" when finished in 1946 (Berkeley, 1949). Its initial use, for calculations supporting hydrogen bomb development, was not publicized. Accounts of ENIAC dimensions vary, but it stood eight to ten feet high, occupied as many as 1,800 square feet, and consumed as much energy as a small town. It provided far less computation and memory than can be acquired for a few dollars, slipped into a pocket, and run on a small battery today.

Reducing operator burden was a key focus. Two major accomplishments were the reduction in the time to replace or reset vacuum tubes and the invention of stored-program computers that could be loaded from tape rather than by manually attaching cables and setting switches. These early human–computer interaction endeavors were straight post-war "knobs and dials" human factor/ergonomics efforts. Before long, one computer operator could do work that previously required a team.

Memory was inordinately expensive. The largest computers of the time had little of it. These computers were used for computation, not symbolic representation or information processing. Library schools continued to focus on librarianship, alongside some social science and historical research. Simple microfilm readers were used to assist in storing information as publication of scholarly and popular material soared.

Foundations for the emergence of information science were set. The war forged alliances among documentalists, electrical engineers, and mathematicians interested in communication and information management. Vannevar Bush's collaborators who were active after the war included Claude Shannon and Warren Weaver, co-authors in 1949 of the seminal work on information theory (then called communication theory) (Shannon & Weaver, 1949). Prominent American documentalist Ralph Shaw joined Bush's efforts. But libraries and librarians, where the GLS humanities orientation still dominated, were not involved. The divide was, if anything, greater: In the 1930s, the American Documentation Institute included librarians and support for systems spanning the humanities and science, but during and after the war its concerns became those of government and "Big Science" (Price, 1963).

Three Roles in Early Computing

Early computer projects employed people as managers, programmers, and operators. Managers oversaw design, development, and operation, specifying the programs to be written and distributing the output. Mathematicians, scientists, and engineers wrote the programs in concert with people skilled in mathematics who decomposed tasks into components the computer could manage (for ENIAC, a team of six women). A small army of operators was needed. Once a program was written, it might take days for people to load it by setting switches, dials, and cable connections. In spite of design innovations that boosted vacuum tube reliability, including operating them at lower than normal power and building in visible indicators of tube failure, ENIAC was down much of the time as people looked for and replaced tubes. Shopping carts full of vacuum tubes were reportedly wheeled around.

Eventually, each of these occupations—computer operation, management, and programming—became a major focus of HCI research, centered respectively in human factors, information systems, and computer science. Computers and our interaction with them evolved, but the research spectrum today reflects aspects of this early division of labor.

Grace Hopper, Liberating Computer Users

As computers became more reliable and capable, programming emerged as a central activity. The development of computer languages, compilers, and constructs such as subroutines can be seen as facilitating programmers' interfaces to computers. Grace Hopper, a pioneer in these areas, was unusually explicit about this, describing her goal as freeing mathematicians to do mathematics (mathematicians were the computer users of the 1940s and 1950s) (Hopper, 1952; see also Sammet, 1992). These words are echoed in today's usability goal of freeing users to do their work. Just as HCI professionals often complain of being marginalized by software developers, one could argue that Hopper's accomplishments are undervalued by computer scientists who focus on algorithms and operating systems.

1955–1965: Transistors, New Vistas

Early forecasts that the world would need few computers reflected the limitations of vacuum tubes. Solid-state computers, first available commercially in 1958, changed everything. Still used primarily for scientific and engineering tasks, they were reliable enough not to require a staff of computer engineers. The less computer-savvy operators overseeing them needed better interfaces. Although computers were too expensive and limited for wide use, researchers envisioned future possibilities that were previously unimaginable.

Supporting Operators: The First Systematic HCI Research

> In the beginning, the computer was so costly that it had to be kept gainfully occupied for every second; people were almost slaves to feed it. —Brian Shackel (1997, p. 977)

Almost all computer use of this period involved programs and data that were read in from cards or tape. Programs then ran without interruption until they terminated, along the way producing printed, punched, or tape output. This batch processing restricted human–computer interaction to basic operation, programming, and use of the output, of which only operation involved hands-on computer use.

Low-paid computer operators set switches; pushed buttons; read lights; loaded and burst printer paper; loaded and unloaded cards, magnetic tapes, and paper tapes; and so on. Teletypes supported direct interaction: commands typed by the operator interleaved with computer responses and status messages. Eventually, the paper that scrolled up one line at a time yielded to glass teletypes (tty's), also called visual display units (VDUs), terminals (VDTs), or cathode ray tubes (CRTs). They, too, scrolled operator commands and computer-generated messages, one line at a time. A monochrome terminal restricted to displaying alphanumeric characters cost $50,000 in today's dollars—expensive, but a small fraction of the cost of a computer. A large computer might have one such console, used only by the operator.

Improving the design of buttons, switches, and displays was a natural extension of human factors/ergonomics. Experts in this field authored the HCI papers. In 1959, British researcher Brian Shackel published the article, "Ergonomics for a Computer" (Shackel, 1959) followed in 1962 by "Ergonomics in the Design of a Large Digital Computer Console" (Shackel, 1962). These described the redesign of the consoles for the EMIac and EMIdec 2400 analog and digital computers. The latter was the largest computer at the time (Shackel, 1997).

In the U.S., the Human Factors Society formed in 1957 and focused on improving the efficiency of skilled performance, reducing errors in skilled performance, and training people to achieve skilled performance. Sid Smith's (1963) chapter "Man–Computer Information Transfer" marked the start of his career in the human factors of computing.

Visions and Demonstrations

As transistors replaced vacuum tubes, a wave of imaginative writing, conceptual innovation, and prototype building swept through the research community. Although some of the language now seems dated, notably the use of male generics, many of their key concepts resonate today.

J. C. R. Licklider at BBN and ARPA

Between 1960 and 1965, ideas and systems tied to the newly realized potential of computers poured out. Licklider, a psychologist, played a dual role. He wrote influential essays and backed highly influential research projects as a manager at Bolt Beranek and Newman (BBN) from 1957–1962 and as Director of the Information Processing Techniques Office (IPTO) of the Department of Defense Advanced Research Projects Agency (called ARPA and DARPA at different times) from 1962–1964.

BBN conducted extensive computer-related work funded by the government and employed dozens of influential researchers, including John Seely Brown, Richard Pew, and many who also worked at MIT (e.g., John McCarthy, Marvin Minsky, and Licklider himself). IPTO funding was crucial in launching computer science departments and establishing artificial intelligence as a field in the 1960s, in addition to its best-known accomplishment, giving birth to the internet.

In 1960, Licklider described *man-machine symbiosis*: "There are many man-machine systems. At present, however, there are no man-computer symbioses—answers are needed." The computer was "a fast information-retrieval and data-processing machine" destined to play a larger role: "One of the main aims of man-computer symbiosis is to bring the computing machine effectively into the formulative parts of technical problems" (Licklider, 1960, pp. 4–5).

This would require more rapid real-time interaction than batch systems supported. Licklider and Wes Clark (1962, p. 113) outlined the requirements of a system for "on-line man-computer communication." They identified capabilities that were ripe for development: time-sharing of a computer among many users; electronic input-output surfaces for the display and communication of symbolic and pictorial information; interactive, real-time support for programming and information processing; large-scale information storage and retrieval systems; and facilitation of human cooperation. They foresaw that other desirable technologies, such as speech recognition and natural language understanding, would be very difficult to achieve.

In a 1963 memorandum, Licklider addressed his ARPA colleagues as "the members and affiliates of the Intergalactic Computer Network," anticipating the internet that ARPA would be instrumental in developing (a copy of the memorandum is available at www.chick.net/wizards/memo.html) (Pew, 2003). His book *Libraries of the Future* summarized and expanded this vision (Licklider, 1965). Waldrop (2001) details Licklider's role in advancing computer science and HCI.

John McCarthy, Christopher Strachey, Wesley Clark

McCarthy and Strachey worked out details of time sharing, a crucial step in enabling interactive computing (Fano & Corbato, 1966). Apart from a small number of researchers using computers that were built with spare-no-expenses military funding, no one could use a computer interactively if exclusive access was required. Time sharing allowed several (and later dozens) of simultaneous users at terminals. Languages were developed to facilitate on-line control and programming of time-sharing systems (e.g., JOHNNIAC Open Shop System [JOSS] in 1964).

Clark was instrumental in building the TX-0 and TX-2 at MIT's Lincoln Labs to demonstrate time sharing and other innovative concepts. These machines, which cost on the order of $10 million, helped establish the Boston area as a center for computer research (all prices are in 2007 U.S. dollars). A CHI '05 panel focusing on this period, with Clark and Ivan Sutherland participating, can be viewed online (ePresence, 2006). The TX-2 was the most powerful and capable in the world at the time. It was less powerful than a smartphone is today.

Ivan Sutherland and Computer Graphics

Sutherland's (1963, online) doctoral dissertation, describing the Sketchpad system built on the TX-2 to make computers "more approachable," is arguably the most impressive and influential document in the history of HCI. (Alan Blackwell and Kerry Rodden have provided an edited version, available at www.cl.cam.ac.uk/TechReports/UCAM-CL-TR-574.pdf.) Sketchpad launched computer graphics, a field of research that would have a decisive impact on HCI twenty years later.

Sutherland demonstrated the iconic representations of constraints, the copying, moving, and deleting of hierarchically organized objects, and object-oriented programming concepts. He explored novel interaction techniques, such as picture construction using a light pen. He facilitated visualization by separating the coordinate system used to define a picture from the one used to display it, and demonstrated animated graphics, noting the potential for digitally rendered cartoons 20 years before *Toy Story*. His frank description of what did not work—when engineers found Sketchpad too limited for computer-assisted design (CAD) he called it a "big flop" —enabled others to make rapid progress (p. 97).

In 1964, his Ph.D. behind him, Sutherland succeeded Licklider as the director of IPTO. Among those whose work he then funded was Douglas Engelbart at the Stanford Research Institute.

Douglas Engelbart, Augmenting Human Intellect

In 1962, Engelbart published *A Conceptual Framework for the Augmentation of Man's Intellect*; over the next several years he built systems that made great strides toward realizing this vision (Engelbart, 1962). He also supported and inspired engineers and programmers who subsequently made major independent contributions.

Echoing Bush and Licklider, Engelbart saw the potential for computers to become congenial tools that people would choose to use interactively:

> By "augmenting human intellect" we mean increasing the capability of a man to approach a complex problem situation, to gain comprehension to suit his particular needs, and to derive solutions to the problems. … By "complex situations" we include the professional problems of diplomats, executives, social scientists, life scientists, physical scientists, attorneys, designers … We refer to a way of life in an integrated domain where hunches, cut-and-try, intangibles, and the human "feel for a situation" usefully co-exist with powerful concepts, streamlined terminology and notation, sophisticated methods, and highly-powered electronic aids. (Engelbart, 1962, online)

Engelbart used his ARPA funding to develop and integrate rapidly an extraordinary set of prototype applications into his NLS system. In doing so, he conceptualized and implemented the foundations of word processing, invented or refined input devices including the mouse and multikey control box, and made use of multi-display environments that integrated text, graphics, and video in windows. In 1968 these were demonstrated in a sensational 90-minute event at the Fall Joint Computer Conference in San Francisco (sloan.stanford.edu/MouseSite/1968Demo.html). The focal point for interactive systems research in the U.S. appeared to have moved from the East Coast to the West Coast.

Engelbart, an engineer, believed in careful human factors testing of systems to improve efficiency and reduce errors in skilled use, with concern for effects of fatigue and stress. He also emphasized training, feeling that people should be willing to tackle a difficult interface that delivered greater power once mastered. The relative importance of optimizing for skilled vs. initial use later became a source of contention and still surfaces in HCI discussions.

Ted Nelson's Vision of Interconnectedness

In 1960, while a graduate student in sociology, the inventor of the term *hypertext* founded Project Xanadu to create an easily used computer network. In 1965, he published a paper titled "A file structure for the complex, the changing and the indeterminate" (Nelson, 1965). Nelson continued to produce works (often self-published) with stirring calls for systems to democratize computing through a highly interconnected, extensible network of digital objects (e.g., Nelson, 1973). Xanadu was never fully realized. Nelson did not consider the early World Wide Web to be an adequate realization of his vision, but features of lightweight technologies such as weblogs, wikis, collaborative tagging, and search are enabling many of the activities he envisioned.

Nelson also foresaw the significance of intellectual property issues that would arise in digital domains. Although his solutions were again not fully implemented, they drew attention to the issues.

From Documentation to Information Science

This period saw the last major investments in microfilm and other predigital systems. The most ambitious were military and intelligence systems, including Vannevar Bush's final efforts (Burke, 1994). However, many documentalists recognized that declining memory costs would enable computation engines to become information processing machines. Conceptually, the evolution was relatively continuous, but at the institutional level changes were radical. New professions—mathematicians and engineers—were involved. New initiatives were launched, bearing few ties to contemporary librarianship or the humanities orientation of library schools. A new banner was needed.

Merriam Webster dates "information science" to 1960. Conferences at Georgia Institute of Technology in 1961 are credited with shifting the focus from information as a technology to that of an incipient science. In 1963, chemist-turned-documentalist Jason Farradane taught the first information science courses at City University, London. Chemistry as a profession had invested in organizing its literature systematically; another chemist-turned-documentalist, Allen Kent, was at the center of a major information science initiative at the University of Pittsburgh (Aspray, 1999). Preceding him at Pittsburgh, Anthony Debons, a psychologist and friend of J. C. R. Licklider, organized a series of North Altantic Treaty Organization (NATO)-sponsored congresses in the early 1960s. Guided by Douglas Engelbart, these meetings centered on people, whose activities technology was to augment. In 1964 the Graduate Library School at the University of Pittsburgh became the Graduate School of Library and Information Sciences and Georgia Tech formed a School of Information Science, initially with one full-time faculty member.

Conclusion: Visions, Demos, and Widespread Use

Progress in HCI can be understood in terms of inspiring visions, conceptual advances that enabled aspects of the visions to be demonstrated in working prototypes, and the evolution of design and application. The engine, enabling visions to be realized and soon thereafter to be widely deployed, was the relentless hardware advances that produced devices millions of times more powerful than the far more expensive systems designed and used by the pioneers.

At the conceptual level, much of the basic foundation for today's graphical user interfaces was in place by 1965. However, it required individual use of a $10 million custom-built machine. Pew (2003, p. 3) describes the breakthrough 1960 Digital Equipment Corporation (DEC) PDP-1 as "truly a computer with which an individual could interact." The PDP-1 came with CRT display, keyboard, light pen, and paper tape reader. It cost about $1 million and had the capacity of a Radio Shack TRS 80 twenty years later. It required considerable technical and programming support. The PDP-1 was used by a few fortunate computer-savvy researchers.

Licklider's "man-computer symbiosis," Engelbart's "augmenting human intellect," and Nelson's (1973) "conceptual framework for man-machine everything" described a world that did not exist. It was a world in which attorneys, doctors, chemists, and designers chose to become hands-on users of computers. The reality, for some time to come, was that most hands-on use was routine, nondiscretionary operation. As for the visions, 40 years later some of the capabilities are taken for granted, some are just being realized, and others remain elusive.

1965–1980: HCI Before Personal Computing

Control Data Corporation launched the transistor-based 6000 series computers in 1964. In 1965, commercial computers based on integrated circuits arrived with the IBM System/360. These powerful systems, later called mainframes to distinguish them from minicomputers, brought computing into the business realm. Each of the three roles in computing—operation, management, programming—became a significant profession.

Operators interacted directly with computers to perform routine maintenance, load and run programs, handle printouts, and so on. As time-sharing spread, this hands-on category expanded to include data entry and other repetitive tasks.

Managers oversaw hardware acquisition, software development, operation, and routing and the use of output. They were usually not hands-on users, but people who relied on printed output and reports; they considered themselves computer users.

Apart from those working in research settings, programmers were rarely direct users until late in this period. Many flowcharted and wrote programs on paper forms. Keypunch operators then punched the program instructions onto cards. These were sent to computer centers for computer operators to run. Printouts and other output were picked up later. Many programmers would use computers directly when they could, but the cost of computer use generally dictated this efficient division of labor.

Human Factors and Ergonomics Embrace Computer Systems

In 1970, Brian Shackel founded the Human Sciences and Advanced Technology (HUSAT) Research Institute at Loughborough University in the U.K., devoted to ergonomics research emphasizing HCI. Sid Smith and other human factors engineers examined a range of input and output issues, notably the representation of information on displays (e.g., Smith, Farquhar, & Thomas, 1965); another early focus was computer-generated speech (Smith & Goodwin, 1970). In 1972, the Computer Systems Technical Group (CSTG) of the Human Factors Society formed; soon it was the largest technical group in the society.

Leading publications were the general journal *Human Factors* and, starting in 1969, the computer-focused *International Journal of Man-Machine Studies (IJMMS*).

The first widely read HCI book was James Martin's 1973 *Design of Man-Computer Dialogues*. A comprehensive survey of interfaces for operation and data entry, it began with an arresting opening chapter that described a world in transition. Extrapolating from declining hardware prices, Martin (1973, pp. 3–4) wrote:

> The terminal or console operator, instead of being a peripheral consideration, will become the tail that wags the whole dog. … The computer industry will be forced to become increasingly concerned with the usage of people, rather than with the computer's intestines.

In the mid-1970s, U.S. government agencies responsible for agriculture and social security initiated large-scale data processing system development efforts, described by Pew (2003). Although not successful, these efforts led to methodological innovation in the use of style guides, usability labs, prototyping, and task analysis.

In 1980, three significant HF&E books were published: two on VDT design (Cakir, Hart, & Stewart, 1980; Grandjean & Vigliani, 1980) and one general guideline (Damodaran, Simpson, & Wilson, 1980). German work on VDT standards, first released in 1981, provided an economic incentive to design for human capabilities by threatening to ban noncompliant products. Later that year a corresponding American National Standards Institute (ANSI) standards group formed for office and text systems.

Information Systems Addresses the Management of Computing

Beginning in 1967, the journal *Management Science* published a column titled "Information Systems in Management Science." Early definitions of IS included "an integrated man/machine system for providing information to support the operation, management, and decision-making functions in an organization" and "the effective design, delivery and use of information systems in organizations" (Davis, 1974; Keen, 1980; quoted by Zhang, Nah & Preece, 2004, p. 147). A historical survey of IS research (Banker & Kaufmann, 2004) identifies HCI as one of five major research streams and places its origin in Ackoff's (1967) paper describing challenges in handling computer-generated information.

Companies acquired expensive business computers to address major organizational concerns. At times the principal concern was to appear modern (Greenbaum, 1979), but when computers were used, managers could be chained to them almost as tightly as operator and data entry "slaves." That said, operator or end-user resistance to using a system was a major management concern. The sociotechnical approach to system design was one response; it educated representative workers in technology possibilities and involved them in design, in part to increase acceptance of the resulting system (Mumford, 1971).

Cognitive style, a major topic of early IS research, focused on difficulties that managers had communicating with computer-savvy employees. IS researchers published HCI articles in management journals and in the human factors-oriented *IJMMS*. The latter was rated the twenty-third most influential IS journal by Mylonopoulos and Theoharakis (2001, as amended in Grudin, 2005, p. 60 note 17).

Programming: Subject of Study, Source of Change

In the 1960s and 1970s, more than 1,000 research papers on variables affecting programming performance were published (Baecker & Buxton, 1987). Most viewed programming in isolation, independent of organizational context. Gerald Weinberg's landmark *The Psychology of Computer Programming* appeared in 1971 (Weinberg, 1971). Nine years later Ben Shneiderman (1980) published *Software Psychology* and the next year (1981) Beau Sheil reviewed studies of programming notation (conditionals, control flow, data types), practices (flowcharting, indenting, variable naming, commenting), and tasks (learning, coding, debugging).

Programmers changed their fields through invention. In 1970, Xerox Palo Alto Research Center (PARC) was founded to advance computer technology by developing new hardware, programming languages, and programming environments. It drew researchers and system builders from the labs of Engelbart and Sutherland. In 1971, Allen Newell of Carnegie Mellon University proposed a project to PARC, launched three years later: "Central to the activities of computing—programming, debugging, etc.—are tasks that appear to be within the scope of this emerging theory (a psychology of cognitive behavior)" (quoted by Card & Moran, 1986, p. 183).

Like HUSAT, also launched in 1970, PARC had a broad research charter. HUSAT focused on ergonomics, anchored in the tradition of nondiscretionary use, one component of which was the human factors of computing. PARC focused on computing, anchored in visions of discretionary use, one component of which was also the human factors of computing. Researchers at PARC and a few other places extended the primarily perceptual-motor focus of human factors to higher-level cognition. HUSAT, influenced by sociotechnical design, extended human factors by considering organizational factors.

Computer Science: A New Discipline

Computer science departments emerged in the mid-1960s. Some arose out of engineering. Computer graphics was a specialization of particular relevance to HCI; software engineering came later. Other computer science departments originated as applied mathematics, a background shared by many early artificial intelligence researchers.

Early machines capable of interesting work were very expensive. They were funded without regard to cost by branches of the military, for which technical success was the sole criterion (Norberg & O'Neill, 1996). ARPA under the direction of Licklider, Sutherland, and their successors played a major role. Reliance on massive funding meant that researchers were concentrated at a few centers, which bore little resemblance to the batch and time-shared environments of business computing. User needs also differed: The technically savvy hands-on users in research settings had less need for low-level interface enhancements.

The computer graphics and AI perspectives that developed in these centers differed from those of HCI researchers, who focused on less expensive systems that could be studied in many more settings. To these HCI researchers, hardware advances led to greater computing capability at a relatively fixed low price. Computer graphics and AI required processing power—hardware advances meant declining cost for a relatively fixed high level of computation. Only later could widely available machines support graphical interfaces and AI programming. Nevertheless, between 1965 and 1980 some computer science researchers focused on interaction, which was part of Ivan Sutherland's initial vision.

Computer Graphics: Realism and Interaction

In 1968 Sutherland joined David Evans to establish a hugely influential computer graphics lab at the University of Utah. The Utah computer science department was founded in 1965, in the first wave that emerged from mathematics and electrical engineering. The western migration continued as students from the lab, including Alan Kay and William Newman (and later Jim Blinn and Jim Clark), went to California. Most graphics systems were built on the DEC PDP-1 and PDP-7. These expensive machines—the list price of a high-resolution display alone was over $100,000 in today's dollars—were capable of multitasking, but a graphics program generally monopolized the processor.

In 1973, the Xerox Alto arrived, a powerful step toward realizing Alan Kay's vision of computation as a medium for personal computing (Kay & Goldberg, 1977). Too expensive to be widely used—the Alto never became a commercial product—and not powerful enough to support high-end graphics research, the Alto was produced in volume and supported graphical interfaces of the kind Engelbart had prototyped.

William Newman expressed the result this way: "Everything changed—the computer graphics community got interested in realism, I remained interested in interaction, and I eventually found myself doing HCI" (personal communication). Ron Baecker and Jim Foley were other graphics researchers whose focus shifted to broader interaction issues. Foley and Wallace (1974, p. 462) identified requirements for designing "interactive graphics systems whose aim is good symbiosis between man and machine"; 18 papers in the first SIGGRAPH conference that year had "interactive" or "interaction" in their titles.

At Xerox, Larry Tesler and Tim Mott recognized that the Alto could support a graphical interface accessible to untrained people, a significant step. By early 1974 they had developed the GYPSY text editor. GYPSY and Xerox's Bravo editor developed by Charles Simonyi preceded and influenced Microsoft Word (Hiltzik, 1999).

A distinct focus on interaction was highlighted in 1976, when SIGGRAPH sponsored a two-day workshop in Pittsburgh titled "User Oriented Design of Interactive Graphics Systems." Participants who were later active in CHI included Jim Foley, William Newman, Ron Baecker, John Bennett, Phyllis Reisner, and Tom Moran. J. C. R. Licklider and Nicholas Negroponte presented vision papers. The conference was managed by the chair of Pittsburgh's Computer Science Department and one participant was Anthony Debons, a key figure in building Pittsburgh's world-renowned information science program.

Perhaps UODIGS'76 marked the end of a visionary period, embodying an idea whose time had not quite yet come. Licklider (1976, p. 89) saw it clearly:

> Interactive computer graphics appears likely to be one of the main forces that will bring computers directly into the lives of very large numbers of people during the next two or three decades. Truly user-oriented graphics of sufficient power to be useful to large numbers of people has not been widely affordable, but it will soon become so, and, when it does, the appropriateness and quality of the products offered will to a large extent determine the future of computers as intellectual aids and partners of people.

UODIGS was not repeated. The 150-page proceedings was not cited. Not until 1981 was another user-oriented design conference held (*Proceedings of the Joint Conference on Easier and More Productive Use of Computer Systems*, 1981), after which they were held every year. Application was not quite at hand; most HCI research remained focused on interaction driven by commands, forms, and full-page menus.

Artificial Intelligence: Winter Follows Summer

In the late 1960s and early 1970s, AI burst onto the scene, promising to transform HCI. It did not go as expected. Logically, AI and HCI are closely related. What are intelligent machines for if not to interact with people? AI research has influenced HCI: speech recognition and natural language are perennial HCI topics; expert, knowledge-based, adaptive, and mixed-initiative systems have been tried, as have applications of production systems, neural nets, and fuzzy logic. Recently, human-robot interaction and machine learning have been attracting attention.

Although some AI features make their way into systems and applications, frequent predictions that more powerful machines would soon bring major AI technologies into widespread use were not borne out. Thus, AI did not come into focus in HCI, and AI researchers have shown limited interest in HCI.

To piece this together requires a brief review of the early history. The term *artificial intelligence* first appeared in a 1955 call by John McCarthy for a meeting on machine intelligence that was held in Dartmouth the next year. Also in 1956, Alan Turing's prescient essay, "Computing Machinery and Intelligence" attracted attention when reprinted in *The World of Mathematics*. (It was first published in 1950 [Turing, 1950], as were Claude Shannon's [1950] "Programming a Computer for Playing Chess" and Isaac Asimov's [1950] *I, Robot,* exploring his three laws of robotics.) Newell and Simon's (1956) logic theory machine appeared in 1956, after which they focused on developing a general problem solver. McCarthy invented the LISP programming language in 1958 (McCarthy, 1960).

Many AI pioneers were trained in mathematics and logic, where much is built from a few axioms and a small set of rules. Mathematics is considered a high form of intelligence, even by non-mathematicians. AI researchers anticipated that machines that operate logically and tirelessly would make great strides. The mathematicians overlooked the complexity and inconsistency that mark human beings and our social constructs. Early work on AI focused heavily on theorem-proving and on games and problems with a strong logical focus, such as Chess and Go. In 1988 McCarthy, who espoused predicate calculus as a foundation for AI, summed it up as follows:

> As suggested by the term "artificial intelligence" we weren't considering human behavior except as a clue to possible effective

> ways of doing tasks. The only participants who studied human behavior were Newell and Simon. (The goal) was to get away from studying human behavior and consider the computer as a tool for solving certain classes of problems. Thus AI was created as a branch of computer science and not as a branch of psychology. (McCarthy, 1988, online)

Strong expectations for AI date back to its pre-dawn, when in the summer of 1949 Alan Turing was quoted in the *London Times*:

> I do not see why [the computer] should not enter any one of the fields normally covered by the human intellect, and eventually compete on equal terms. I do not think you can even draw the line about sonnets, though the comparison is perhaps a little bit unfair because a sonnet written by a machine will be better appreciated by another machine. (Turing, 1949, online)

Licklider, a psychologist, saw that speech understanding was important to AI and difficult; he predicted that intelligent machines would appear in 15 to 500 years (Pew, 2003). As director of ARPA's Information Processing Techniques Office from 1962–1964, he initiated extensive support for computer science in general and AI in particular. MIT's Project Mac, founded in 1963 by Marvin Minsky and others, initially received $13M per year, rising to $24M in 1969. ARPA also sponsored the Artificial Intelligence Laboratory at Stanford Research Institute (SRI), AI research at SRI and Carnegie Mellon University (CMU), and Nicholas Negroponte's Machine Architecture Group at MIT. A dramatic early achievement, SRI's Shakey the Robot, was featured in 1970 articles in *Life* (Darrach, 1970) and *National Geographic* (White, 1970). Given a simple but non-trivial task, Shakey could apparently go to the desired location, scan and reason about the surroundings, and move objects as needed to accomplish the goal (for Shakey at work, see www.ai.sri.com/shakey).

In 1970, Negroponte outlined the case for machine intelligence:

> People generally distrust the concept of machines that approach (and thus why not pass?) our own human intelligence. … Why ask a machine to learn, to understand, to associate courses with goals, to be self-improving, to be ethical—in short, to be intelligent? (Negroponte, 1970, quoted by Baecker & Buxton, 1987, p. 50)

His answer to his own question was, "Because any design procedure, set of rules, or truism is tenuous, if not subversive, when used out of context or regardless of context" (p. 50). This insightful analysis, that it is risky to apply algorithms without understanding the situation at hand, led to a false inference: "It follows that a mechanism must recognize and understand the context before carrying out an operation" (p. 50).

A more tractable alternative is for the mechanism to be guided by humans who are cognizant of the context: Licklider's human-machine symbiosis. Ignoring this, Negroponte built a case for an ambitious research program:

> Therefore, a machine must be able to discern changes in meaning brought about by changes in context, hence, be intelligent. And to do this, it must have a sophisticated set of sensors, effectors, and processors to view the real world directly and indirectly. … A paradigm for fruitful conversations must be machines that can speak and respond to a natural language. … But, the tete-à-tete [sic] must be even more direct and fluid; it is gestures, smiles, and frowns that turn a conversation into a dialogue. … Hand waving often carries as much meaning as text. Manner carries cultural information: the Arabs use their noses, the Japanese nod their heads. …
>
> Imagine a machine that can follow your design methodology and at the same time discern and assimilate your conversational idiosyncrasies. This same machine, after observing your behavior, could build a predictive model of your conversational performance. Such a machine could then reinforce the dialogue by using the predictive model to respond to you in a manner that is in rhythm with your personal behavior and conversational idiosyncrasies. … The dialogue would be so intimate—even exclusive—that only mutual persuasion and compromise would bring about ideas, ideas unrealizable by either conversant alone. No doubt, in such a symbiosis it would not be solely the human designer who would decide when the machine is relevant. (Negroponte, 1970, quoted by Baecker & Buxton, 1987, p. 50)

The same year, Negroponte's MIT colleague Minsky went further, as reported in *Life*:

> In from three to eight years we will have a machine with the general intelligence of an average human being. I mean a machine that will be able to read Shakespeare, grease a car, play office politics, tell a joke, have a fight. At that point the machine will begin to educate itself with fantastic speed. In a few months it will be at genius level and a few months after that its powers will be incalculable. (Darrach, 1970, p. 59)

Other AI researchers told Darrach (p. 59) that Minsky's timetable was ambitious: "'Give us 15 years' was a common remark—but all agreed that there would be such a machine and that it would precipitate the third Industrial Revolution, wipe out war and poverty and roll up centuries of growth in science, education and the arts."

Such predictions were common. In 1960, Nobel laureate and AI pioneer Herb Simon wrote, "Machines will be capable, within twenty years, of doing any work that a man can do" (Simon, 1960, p. 96). Five years later, I. J. Good (1965, p. 31), an Oxford mathematician, wrote, "the survival of man depends on the early construction of an ultra-intelligent machine" that "could design even better machines; there would then unquestionably be an 'intelligence explosion,' and the intelligence of man would be left far behind" (p. 33).

Responding to such calls, ARPA initiated major funding of speech recognition and natural language understanding in 1971. Five years later, disappointed with the progress, ARPA discontinued support for speech and language—for a while.

In Europe, a similar story unfolded. Through the 1960s, AI research expanded in Great Britain. A principal proponent was Turing's former colleague Donald Michie. Then in 1973, the Lighthill Report (Lighthill, 1973), which had been commissioned by the Science and Engineering Research Council, reached generally negative conclusions about the prospects for AI systems to scale up to address real-world problems. Almost all government funding was cut off.

The next decade is considered an AI winter, a recurrent season in which research funding is redirected away from AI due to disillusionment over unfulfilled promises.

Library Schools Embrace Information Science

The emphasis on technology in response to Sputnik had shown that the World War II "Big Science" research was not an anomaly. Aligning research and national priorities became a priority. Early information science, as well as studies of "human information behavior" initiated in the 1960s and 1970s, focused on support for scholarship and applications in science and engineering (Fidel, 2010).

Terminal-based computing costs declined. Concern about "information explosions" increased. With information science and technology unquestionably part of the future, the terms swept into use. The Pittsburgh and Georgia Institute of Technology programs flourished. Pittsburgh created the first information science Ph.D. program in the U.S. in 1970, focused on training information science scholars, and identifying humans "as the central factor in the development of an understanding of information phenomena" (Aspray, 1999, p. 12). The program balanced behavioral sciences (psychology, linguistics, communications) and technical grounding (automata theory, computer science). The emphasis shifted from behavior to technology over time. In 1973, Pittsburgh established the first information science department, and its program developed an extremely strong international reputation. Upon being awarded a major National Science Foundation (NSF) center grant in 1966, the Georgia Tech school expanded, and in 1970 became a Ph.D.-granting school rechristened Information and Computer Science.

In 1968, the American Documentation Institute became the American Society for Information Science; two years later the journal *American Documentation* became the *Journal of the American Society for Information Science*. In 1978 the ACM Special Interest Group on Information Retrieval (SIGIR) formed and launched an annual conference (titled "Information Storage and Retrieval" in this period), modeled on a 1971 conference. In 1984, the Association of American Library Schools somewhat belatedly embraced the i-word by renaming itself the Association for Library and Information Science Education (ALISE).

By 1980, schools at over a dozen universities had added *information* to their titles, many of them library school transitions. Delivery on the promise lagged, however. For example, from 1965 to 1972 the Ford and Carnegie Foundations, NSF, DARPA, and the American Newspaper Publishers Association invested over $30 million of today's dollars in MIT's Project Intrex (Burke, 1998). The largest non-military information research project of its time, Intrex was to be the library of the future. Online catalogs were to include up to 50 index fields per item, accessible on CRT displays, with full text of books and articles converted to microfilm and read via television displays. None of this proved feasible.

The ARPANET debuted in 1969, supporting email in 1971 and file-sharing in 1973. This spurred visions of a network society of the future (Hiltz & Turoff, 1978). As an aside, the technological optimism of AI and networking researchers of this era seems less insightful and nuanced than the view of E. M. Forster (1909), who in 1909 anticipated both developments in his story "The Machine Stops."

1980–1985: Discretionary Use Comes Into Focus

In 1980, most people in HF&E and IS were focused on the down-to-earth business of making efficient use of expensive mainframes. Almost unnoticed was the start of a major shift. Less expensive but highly capable minicomputers based on LSI technology enabled Digital Equipment Corporation, Wang Laboratories, and Data General to make inroads into the mainframe market. At the low end, home computers gained capability. Students and hobbyist programmers were drawn to these minis and micros, creating a population of hands-on discretionary users. There were limited trials of online library catalogs and electronic journal production.

Then, between 1981 and 1984, a flood of innovative and powerful computers was released: Xerox Star, IBM PC, Apple Lisa, Lisp machines from Symbolics and LMI (Lisp Machines, Inc.), workstations from Sun Microsystems and Silicon Graphics, and the Apple Macintosh. On January 1, 1984, AT&T's breakup into competing companies took effect. AT&T had the most employees and the most customers of any U.S. company. Neither its customers nor its employees had had much discretion in technology use, so AT&T and its Bell Laboratories division had focused on improving training and efficiency through human factors. Suddenly freed from a ban on entering the computer business while it had a monopoly on telephony, AT&T launched the ill-fated Unix PC in 1985. AT&T and the regional telephone operating companies now faced customers who had choices, and their HCI focus broadened accordingly (see Israelski & Lund, 2003).

In general, lower-priced computers created markets for shrinkwrap software; and for the first time, computer and software companies targeted significant numbers of non-technical hands-on users who received little or no formal training.

After twenty years, early visions were being realized. Non-programmers were choosing to use computers to do their work. The psychology of discretionary users was of particular interest to two groups: psychologists who liked to use computers and technology companies planning to sell to discretionary users. Result: Computer and telecommunication companies hired many experimental psychologists. Before describing this, I elaborate on the shift from non-discretionary operation to discretionary use of computers.

Discretion in Computer Use

Our lives are distributed along a continuum between the assembly line nightmare of *Modern Times* and utopian visions of completely empowered individuals. To use a technology or not to use it: Sometimes we have a choice, other times we do not. On the telephone, we may have to wrestle with speech recognition and routing systems. In contrast, home computer use may be largely discretionary. The workplace often lies in between: Technologies are recommended or prescribed, but we can ignore some injunctions, obtain exceptions, use some features but not others, and join with colleagues to press for changes in policy or availability.

For early computer builders, work was more a calling than a job, but operation required a staff to carry out essential if less interesting tasks. For the first half of the computing era, most hands-on use was by people given a mandate. Hardware innovation, more versatile software, and steady progress in understanding the psychology of users and tasks—and transferring that understanding to software developers—led to hands-on users with more choice in what they did and how they did it. Rising expectations played a role—people learned that software is flexible and expected it to be more congenial. Competition among vendors produced alternatives. Today there is more emphasis on marketing to consumers, more stress on user-friendliness.

Discretion is not all-or-none. No one must use a computer, but many jobs and pastimes require it. True, people can resist, sabotage, or quit the job. However, a clerk or systems administrator is in a different situation from someone using technology for leisure activity. For an airline reservation operator, computer use is mandatory. For a traveler booking a flight, computer use is discretionary. I explore effects of these differences.

The shift toward greater discretion was gradual. A quarter of a century ago, John Bennett (1979) predicted that discretionary use would lead to more emphasis on usability. The book *Human Interaction With Computers,* edited by Harold Smith and Thomas Green (1980) and published the following year, perched on a cusp. Jens Rasmussen's (1980) chapter, "The Human as a Systems Component," covered the nondiscretionary perspective. One-third of the book covered research on programming. The remainder addressed "non-specialist people," discretionary users who are not computer-savvy (Smith & Green, 1980, p. viii). The editors continued, "It's not enough just to establish what computer systems can and cannot do; we need to spend just as much effort establishing what people can *and want to do*" (emphasis in the original).

A decade later, Liam Bannon (1991, p. 25) noted broader implications of a shift "from human factors to human actors." The trajectory is not always toward choice. Discretion can be curtailed—for example, word processor use is now often a job requirement, not simply an alternative to using a typewriter. Even in an era of specialization, customization, and competition, the exercise of choice varies over time and across contexts.

Discretion is one factor of many, but an analysis of its role casts light on how HCI efforts differ and why they have remained distinct (Figure 8.1).

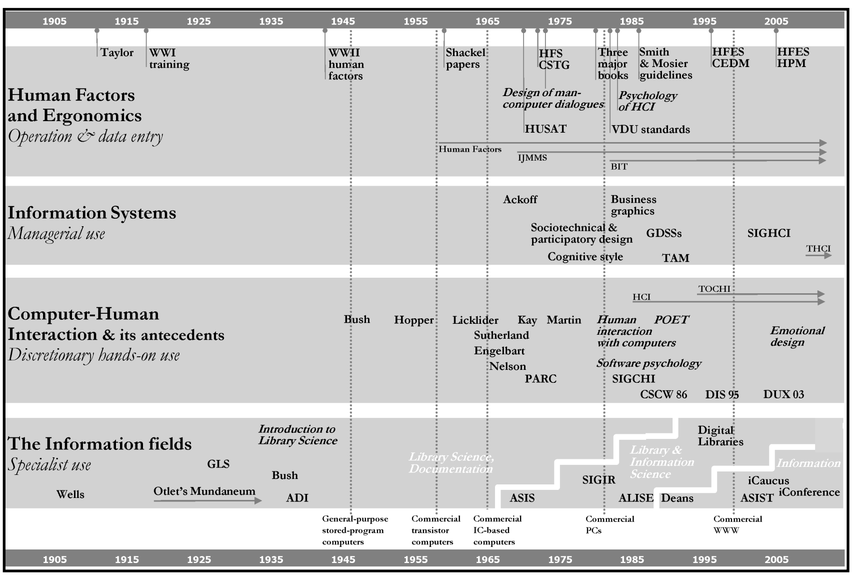

Figure 8.1 Some of the HCI events and topics discussed. Acronym expansions are in the text.

Minicomputers and Office Automation

Cabinet-sized computers that could support several people were available from the mid-1960s. Starting with the VAX 11/780, super-minis by the late 1970s supported integrated suites of productivity tools. In 1980, Digital Equipment Corporation, Data General, and Wang Laboratories were growth companies near Boston. Digital became the second largest computer company in the world.

A minicomputer could handle a database of moderate size or personal productivity tools used from terminals. For "dumb terminals," the central processor handled each keystroke; other minicomputer terminals had a processor that supported entering a screenful of data that was then sent as a batch to the central processor. These minis could provide a small group (or office) with file sharing, word processing, spreadsheets, email, and output devices. They were marketed as "office systems," "office automation systems," or "office information systems."

In 1980, the Stanford International Symposium on Office Automation launched a research field that was influential for a decade. Douglas Engelbart contributed two papers to the proceedings (Landau, Bair, & Siegman, 1982). The same year, the American Federation of Information Processing Societies (AFIPS, which was underwriting ACM and IEEE at the time) held the first of seven annual office automation conferences and product exhibitions. Also in 1980, ACM formed a Special Interest Group on Office Automation (SIGOA), which two years later launched the biennial Conference on Office Information System (COIS). In 1983 *ACM Transactions on Office Information Systems* (*TOIS*) emerged, one year after the independent journal *Office: Technology and People*.

Office information systems, which focused on the use of minicomputers, was positioned alongside management information systems, which focused on mainframes. Its scope was reflected in the charter of *TOIS:* database theory, artificial intelligence, behavioral studies, organizational theory, and communications. Minis were accessible database research tools; Digital's PDP series was a favorite of AI researchers; minis were familiar to behavioral researchers who used them to run and analyze experiments; and they became interactive computers of choice for many organizations. Computer-mediated communication was an intriguing new capability. Networking was still rare, but users at different terminals of a minicomputer could exchange email or chat in real time.

Researchers were discretionary computer users, but most office workers did not choose their tools. The term automation, challenging and exciting to the researchers, conjured up different images for office workers; some researchers preferred Engelbart's focus on augmentation rather than automation.

Papers in the SIGOA newsletter, COIS, and *TOIS* included technical work on database theory, a modest number of AI papers (the AI winter had not yet ended), decision support and computer-mediated communication papers from the IS community, and behavioral studies by researchers who later became active in CHI. IS papers were prevalent in the newsletter and technical papers in the journal. The journal was also a major outlet for behavioral studies before *HCI* started in 1985.

Although OA/OIS research was eventually absorbed by other fields, it led the way in identifying a range of important emerging issues, including hypertext, computer-mediated communication, and collaboration support more generally. Some OIS work was conceptually linked to the technical side of information science, notably in information retrieval and language processing.

The Formation of ACM SIGCHI

Major threads of HCI research are illustrated in Figure 8.1: Human factors, information systems, and the research focused on discretionary hands-on use that became a significant force with the spread of microcomputers. In 1980, as IBM prepared to launch the PC, a groundswell of attention to computer user behavior was building. IBM had recently added software to hardware as a product focus. Several cognitive psychologists joined an IBM research group that included John Gould, who had engaged in human factors research since the late 1960s. They initiated empirical studies of programming and software design and use. Other psychologists leading recently formed HCI groups included Phil Barnard at the Medical Research Council Applied Psychology Unit in Cambridge, England; Tom Landauer at Bell Labs; Donald Norman at the University of California, San Diego; and John Whiteside at Digital Equipment Corp.

Xerox PARC and its CMU collaborators were particularly active, continuing work in several areas that proved to have singular influence. The 1981 Star, with its carefully designed graphical user interface, was not a commercial success (nor was a flurry of GUIs that followed, including the Apple Lisa), but it influenced researchers and developers—and of course the Macintosh.

Communications of the ACM created a "Human Aspects of Computing" department in 1980. The next year, Tom Moran edited a special issue of *Computing Surveys* on "The Psychology of the Computer User." Also in 1981, the ACM Special Interest Group on Social and Behavioral Science Computing (SIGSOC) extended its workshop to cover interactive software design and use. In 1982 a conference in Gaithersburg, Maryland on "Human Factors in Computing Systems" was unexpectedly well attended. Shortly afterward, SIGSOC shifted its focus to computer-human interaction and its name to SIGCHI (Borman, 1996).

In 1983, the first CHI conference drew more than 1,000 people. Half of the 58 papers were from the seven research labs just mentioned. Cognitive psychologists in industry dominated the program, although the Human Factors Society co-sponsored the conference and contributed the program chair Richard Pew, committee members Sid Smith, H. Rudy

Ramsay, and Paul Green, and several presenters. Brian Shackel and HFS president Robert Williges gave tutorials the first day.

The first profession to become discretionary hands-on users was computer programming, as paper coding sheets were discarded in favor of text editing at interactive terminals, PCs, and small minicomputers. Therefore, many early CHI papers, by Ruven Brooks, Bill Curtis, Thomas Green, Ben Shneiderman, and others, continued the psychology-of-programming research thread. IBM Watson researchers also contributed, as noted by John Thomas (personal communication, October 2003):

> One of the main themes of the early work was basically that we in IBM were afraid that the market for computing would be limited by the number of people who could program complex systems so we wanted to find ways for "non-programmers" to be able, essentially, to program.

Psychologists and studies of editing were so prevalent that Thomas Green remarked at the 1984 INTERACT Conference that "text editors are the white rats of HCI." As personal computing spread and the same methods were applied to studying other discretionary use, studies of programming gradually disappeared from HCI conferences.

CHI focused on novice use. Initial experience is particularly important to discretionary users and to the vendors developing software for them. Novice users are also a natural focus when studying new technologies and a critical focus when more people take up computing each year than did the year before.

Routinized heavy use was still widespread. Databases were used by airlines, banks, government agencies, and other organizations. This hands-on activity was rarely discretionary. Managers oversaw development and analyzed data, leaving data entry and information retrieval to people hired for those jobs. Improving skilled data handling was a human factors undertaking. CHI studies of database use were few—I count three over a decade, all focused on novice or casual use.

Fewer European companies produced mass-market software. European research favored in-house development and use. In his perceptive essay, Bannon (1991) urged that more attention be paid to discretionary use, yet criticized CHI's heavy emphasis on initial experiences, perhaps reflecting the European perspective. At Loughborough University, HUSAT focused on job design (the division of labor between people and systems) and collaborated with the Institute for Consumer Ergonomics, particularly on product safety. In 1984, Loughborough initiated an HCI graduate program drawing on human factors, industrial engineering, and computer science. The International Conference on Human–Computer Interaction (INTERACT), first held in London in 1984 and chaired by Shackel, drew HF&E and CHI researchers.

The early visionaries were not familiar to many of the CHI researchers who turned some of the visions into reality. The 633 references in the 58 papers presented at CHI '83 included many authored by cognitive scientists, but Bush, Sutherland, and Engelbart were not cited at all. Many computer scientists familiar with the early work entered CHI a few years later and the CHI psychologists eventually discovered and identified with these pioneers. Both groups were concerned with discretionary use. This conceptual continuity bestowed legitimacy on a young enterprise seeking to establish itself academically and professionally.

CHI and Human Factors Diverge

> Hard science, in the form of engineering, drives out soft science, in the form of human factors. —Newell and Card (1985, p. 212)

Between 1980 and 1985, researchers at Xerox PARC and CMU launched another influential research program. Card, Moran, and Newell (1980a, 1980b) introduced a "keystroke-level model for user performance time with interactive systems" (Card, Moran, & Newell, 1980b, p. 396), followed by the cognitive model GOMS—goals operators, methods, and selection rules—in their landmark book, *The Psychology of Human–Computer Interaction* (Card, Moran, & Newell, 1983).

This work was highly respected by the cognitive psychologists who made up much of CHI at the time. However, these models did not address discretionary, novice use. They focused on the repetitive expert use studied in human factors. In fact, GOMS was explicitly positioned in opposition to the stimulus-response bias of human factors research:

> Human factors specialists, ergonomists, and human engineers will find that we have synthesized ideas from modern cognitive psychology and artificial intelligence with the old methods of task analysis. … The user is not an operator. He does not operate the computer, he communicates with it. (Card, Moran, & Newell, 1983, p. viii)

Newell and Card (1985, p. 221) noted that human factors had a role in design, but continued: "Classical human factors … has all the earmarks of second-class status. (Our approach) avoids continuation of the classical human-factors role (by transforming) the psychology of the interface into a hard science."

In an email message sent in June 2004, Card wrote: "Human factors was the discipline we were trying to improve. … I personally changed the (CHI conference) call in 1986 so as to emphasize computer science and reduce the emphasis on cognitive science, because I was afraid that it would just become human factors again."

Ultimately, human performance modeling drew a modest but fervent CHI following. Key goals of the modelers differed from those of practitioners and other researchers. "The central idea behind the model is that the time for an expert to do a task on an interactive system is determined by the time it takes to do the keystrokes," wrote Card, Moran, and Newell (1980b, p. 397). Modeling was extended to a range of cognitive processes but remained most useful in helping to design for nondiscretionary users, such as telephone operators engaged in repetitive tasks (e.g., Gray, John, Stuart, Lawrence, & Atwood, 1990). Its role in augmenting human intellect was unclear.

CHI and human factors moved apart, although "Human Factors in Computing Systems" remains the CHI conference subtitle. They were never closely integrated. Most of the cognitive psychologists had turned to HCI after earning their degrees and were unfamiliar with the human factors research literature. The Human Factors Society did not again cosponsor CHI and its researchers disappeared from the CHI program committee. Most CHI researchers who had published in the annual Human Factors conference and the *Human Factors* journal shifted to CHI, *Communications of the ACM,* and the journal *Human–Computer Interaction* established in 1985 by Moran and published by Erlbaum, a publisher of psychology books and journals.

The shift was reflected at IBM T.J. Watson Research Center. John Gould and Clayton Lewis (1983) authored a CHI '83 paper that nicely defined the CHI focus on user-centered, iterative design based on prototyping. Watson cognitive scientists helped shape CHI, but Gould's principal focus remained human factors; he served as HFS president four years later. Symbolically, in 1984, Watson's Human Factors Group faded away and a User Interface Institute emerged.

CHI researchers, wanting to be seen as doing "hard" science or engineering, adopted the terms "cognitive engineering" and "usability engineering." In the first paper presented at CHI '83, "Design Principles for Human–Computer Interfaces," Donald Norman (1983, p. 1) applied engineering techniques to discretionary use, creating what he called "user satisfaction functions" based on technical parameters. Only years later did CHI loosen its identification with engineering.

Workstations and Another AI Summer

High-end workstations from Apollo, Sun, and Silicon Graphics appeared between 1981 and 1984. Graphics researchers no longer had to congregate in heavily financed labs (notably MIT and Utah in the 1960s; MIT, New York Institute of Technology [NYIT], and PARC in the 1970s). These workstations were too expensive to reach a mass market, so graphics research that focused on photorealism and animation did not directly influence HCI more broadly.

The Xerox Star (formally named Office Workstation), Apple Lisa, and other commercial GUIs appeared; but when the first CHI conference was held in December 1983 none was succeeding. They cost too much or ran on processors that were too weak to exploit graphics effectively.

In 1981, Symbolics and LMI introduced their workstations optimized for the Lisp programming language favored by most AI researchers. The timing was fortuitous. In October of that year, a conference on Next Generation Technology was held in the National Chamber of Commerce auditorium in Tokyo; and in 1982 the Japanese government announced the establishment of the Institute for New Generation Computer Technology (ICOT) and its ten-year Fifth Generation project focused on AI. AI researchers in Europe and the U.S. sounded the alarm. Donald Michie at Edinburgh saw a threat to western computer technology, and Ed Feigenbaum from Stanford wrote:

> The Japanese are planning the miracle product. … They're going to give the world the next generation—the Fifth Generation—of computers, and those machines are going to be intelligent. … We stand, however, before a singularity, an event so unprecedented that predictions are almost silly. … Who can say how universal access to machine intelligence—faster, deeper, better than human intelligence—will change science, economics, and warfare, and the whole intellectual and sociological development of mankind? (Feigenbaum & McCorduck, 1983, pp. 8–9, 287)

At the same time, parallel distributed processing or neural net models seized the attention of researchers and the media. Used to model a wide range of phenomena including signal detection, motor control, and semantic processing, neural nets represented conceptual and technical advances over earlier AI work on perceptrons. They were of particular interest because the new generation of minicomputers and workstations supported simulation experiments. Production systems, a computer-intensive AI modeling approach with a psychological foundation developed at CMU, also gained wider use in research.

These developments triggered an artificial intelligence gold rush. As with actual gold rushes, most of the money was made by those who outfitted and provisioned the prospectors, although generous government funding again flowed to AI researchers. The European ESPRIT and U.K. Alvey programs invested over $200M per year starting in 1984 (Oakley, 1990). In the U.S., funding for the DARPA Strategic Computing AI program alone, begun in 1983, rose to almost $400M in 1988 (Norberg & O'Neill, 1996). Investment in AI by 150 U.S. companies was estimated at about $2B in 1985 (Kao, 1998).

The unfulfilled promises of the past led to changes this time around. General problem solving was emphasized less, domain-specific problem solving was emphasized more. Terms such as *intelligent knowledge-based systems*, *knowledge engineering*, *expert systems*, *machine learning*, *language understanding*, *image understanding*, *neural nets*, and *robotics* were often favored over *AI*.

In 1983, Raj Reddy of CMU and Victor Zue of MIT criticized the mid-1970s abandonment of speech processing research, and soon funds were again plentiful (Norberg & O'Neill, 1996, p. 238). Johnson (1985) estimated that 800 corporate employees and 400 academics were working on natural language processing research in 1985. Commercial natural language understanding (NLU) interfaces to databases such as AI Corporation's Intellect and Microrim Clout appeared.

AI optimism is illustrated by two meticulously researched Ovum reports on speech and language processing (Engelien & McBryde, 1991; Johnson, 1985). In 1985, speech and language product "revenue" was $75 million, comprising mostly income from grants and investor capital. That year, Ovum projected that sales would reach $750 million by 1990 and $2.75 billion by 1995. In 1991, sales were under $90 million; but hope springs eternal, and Ovum forecast $490 million for 1995 and $3.6 billion for 2000.

U.S. corporations banded together, jointly funding the Microelectronics and Computer Technology Corporation (MCC). U.S. antitrust laws were relaxed to allow this cooperation. MCC embraced AI, reportedly becoming the leading customer for both Symbolics and LMI. MCC projects included two parallel NLU efforts, work on intelligent advising, and CYC (as in "encyclopedic," and later spelled Cyc), Douglas Lenat's ambitious project to build an encyclopedic common-sense knowledge base that other programs could consult. In 1984, Lenat predicted that by 1994 CYC would be intelligent enough to educate itself. Five years later CYC was reported to be on schedule and about to "spark a vastly greater renaissance in [machine learning]" (Lenat, 1989, p. 257).

Knowledge engineering involved human interaction. This could have brought AI closer to HCI, but AI researchers interested in representation and reasoning were frustrated by the difficulty of eliciting knowledge from experts. The latter non-discretionary activity created opportunities for HF&E, especially in Europe, where funding directives encouraged work that spanned technical and behavioral concerns. *International Journal of Man-Machine Studies* became a major outlet for both HF&E and AI research in the 1980s.

AI interaction with CHI was limited. CHI '83 and CHI '85 had sessions on speech and language, cognitive modeling, knowledge-based help, and knowledge elicitation; but in general, AI technologies did not succeed in the marketplace and were often directed at non-discretionary users. Before it disappeared, AI Corporation's primary customer for the database interface Intellect was the government. Few AI researchers and developers worried about interaction details. For example, they loved powerful tools such as EMACS and UNIX and forgot the painful weeks that were required to learn badly-designed command languages.

1985–1995: Graphical User Interfaces Succeed

> There will *never* be a mouse at the Ford Motor Company.
> —High-level acquisition manager (personal communication, 1985)

Graphical user interfaces were a disruptive revolution when they succeeded commercially, as were earlier shifts to stored programs and to interaction based on commands, full-screen forms, and full-screen menus. Some people were affected before others.

GUIs were particularly attractive to new users. Their success immediately affected the CHI field. However, only after Windows 3.0 succeeded in 1990 did GUIs influence the government agencies and business organizations that were the focus of HF&E and IS researchers. By 1990, the technology was better understood and less disruptive. The early 1990s also saw the maturation of local area networks and the internet, leading to a second transformation: computer-mediated communication and information sharing.

CHI Embraces Computer Science

Apple launched the Macintosh with a 1984 Super Bowl ad aimed at office work, but sales did not follow and in mid-1985 Apple was in trouble. Then Macs appeared with four times as much random access memory (RAM), sufficient to manage Aldus PageMaker, Adobe Postscript, the Apple LaserWriter, and Microsoft's Excel and Word for Macintosh as they were released. The more powerful Mac Plus arrived in January, 1986. Rescued by hardware and software advances, the Mac succeeded where the many commercial GUIs before it had not. It was popular with consumers and became the platform for desktop publishing.

Even within CHI, GUIs were initially controversial. They had disadvantages: an extra level of interface code increased development complexity and created reliability challenges; they consumed processor cycles and distanced users from the underlying system that, many believed, experienced users would eventually have to learn. Carroll and Mazur (1986) showed that GUIs confused and created problems for people familiar with existing interfaces. An influential essay on direct manipulation interfaces (Hutchins, Hollan, & Norman, 1986, p. 119) concluded, "It is too early to tell" how GUIs would fare. GUIs could well prove useful for novices, they wrote, but "we would not be surprised if experts are *slower* with Direct Manipulation systems than with command language systems" (p. 121). Because most prior HCI research had focused on expert use, this valid insight seemed significant. However, first-time use was critical in the rapidly expanding consumer market. Hardware and software advances overcame other difficulties. GUIs were here to stay.

The effects within CHI were dramatic. Active topics of research, including command naming, text editing, and the psychology of programming, were quickly abandoned. More technical topics such as user interface management systems became significant. At a higher level, psychology gave way to computer science as the driving force in interaction design.

Researchers had been engaged in establishing a comprehensive, theoretical, psychological framework based on formal experiments (Barnard, 1991; Carroll & Campbell, 1986; Long, 1989; Newell & Card, 1985). Such a framework was conceivable for constrained command- and form-based interaction, but could not be scaled up to design spaces that included color, sound, animation, and an endless variety of icons, menu designs, and window arrangements. The immediate mission was to identify the most pressing problems and satisfactory rather than optimal solutions. Rigorous experimentation, the principal skill of cognitive psychologists, gave way to quicker, less precise assessment methods. And to explore the dynamically evolving, unconstrained design space required software engineering expertise.

As a result, the late 1980s saw an influx of computer scientists into the CHI community. HCI entered the curricula of many computer science departments. Computer scientists working on interactive graphics saw CHI as a natural home, as did software engineers interested in interaction and some AI researchers working on speech recognition, language understanding, and expert systems. In 1994 ACM launched *Transactions on Computer-Human Interaction*. Some computer scientists brought with them knowledge of the early pioneering work that was unknown to many cognitive scientists.

Early PCs and Macs were not easily networked, but as local area networks spread, CHI's focus expanded to include collaboration support. This brought it into contact with efforts in MIS and office automation research.

Human Factors and Ergonomics Maintains a Non-Discretionary Use Focus

HF&E research continued to respond to the needs of government agencies, the military, aviation, and telecommunications. Government is the largest consumer of computing, with heavy use for census, tax, social security, health and welfare, power plant operation, air traffic control, ground control for space missions, military logistics text and voice processing for intelligence, and so on.

Most users in these settings are assigned technology. The focus is on skilled use. Small efficiency gains in individual transactions can yield large benefits over time. For routine data entry and other tasks, improvements that may not influence discretionary users can make a difference. After CHI formed, the Human Factors Society undertook a study to see how it would affect membership in its Computer Systems

Technical Group and found an unexpectedly small overlap (Richard Pew, personal communication, September 15, 2004).

Research funding in HF&E responded to governmental concerns and initiatives. Government agencies promoted the development of ergonomic standards, in part to help with the problem of defining system requirements for competitive bidding while remaining at arm's length from the potential developers who better understand technical possibilities. Compliance with standards could be specified in a contract.

In 1986, Sid Smith and Jane Mosier published the last of a series of government-sponsored interface guidelines (Smith & Mosier, 1986). Some 944 specific design guidelines were organized into sections titled Data Entry, Data Display, Data Transmission, Data Protection, Sequence Control, and User Guidance. The authors recognized that GUIs would expand the design space beyond the reach of an already cumbersome, comprehensive set of guidelines that did not cover icons, pull-down or pop-up menus, mice button assignments, sound, animation, and so on. Requirements definition shifted to specify predefined interface styles and design processes rather than features to be built from scratch.

DARPA's heavily funded Strategic Computing program set out to develop an Autonomous Land Vehicle, a Pilot's Associate, and a Battle Management system. All raised human factors research issues. These systems were to include interactive technologies such as speech recognition, language understanding, and heads-up displays. People might avoid these technologies when given a choice, but pilots, those guiding autonomous vehicles, and officers under stressful conditions might have no better alternative. Speech and language technologies might also have civilian uses: by translators and intelligence analysts, or when a telephone system provides no alternative, a disability limits keyboard use, or hands are otherwise occupied.

Information Systems Extends Its Range

Although graphical user interfaces were not quickly adopted by organizations, business graphics was important in a research field focused on managerial use. Remus (1984) contrasted tabular and graphic presentations, Benbasat and Dexter (1985) added color as another factor, and many studies followed. The concept of cognitive fit between task and tool was introduced in this context to explain apparently contradictory results in the literature (Vessey & Galletta, 1991). Studies considered online and paper presentation. In practice, color displays were rare in the 1980s; most managers dealt with printed reports.

Involvement of internal end-users in the development process was actively discussed, but rarely practiced outside of sociotechnical and participatory movements (Friedman, 1989). Hands-on managerial use was atypical, but it was central to group decision support systems research, which emerged from decision support systems and evolved into group support systems. Computer-supported meeting facility research was conducted in the mid-1980s in several laboratories (e.g., Begeman, Cook, Ellis, Graf, Rein, & Smith, 1986; Dennis, George, Jessup, Nunamaker, & Vogel, 1988; DeSanctis & Gallupe, 1987). Jay Nunamaker's group at the University of Arizona explored approaches to brainstorming, idea organizing, online voting, and other meeting activities (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1997). These systems were too expensive to be mass-market products—they were directed at decision makers, with key research in schools of management rather than computer science departments or software companies. This became a major IS contribution to Computer Supported Cooperative Work (CSCW).

The Technology Acceptance Model (TAM) introduced in F. D. Davis (1989) gave rise to considerable IS research. TAM focuses on perceived usefulness and perceived usability to improve "white collar performance" that is "often obstructed by users' unwillingness to accept and use available systems" (p. 319). "An element of uncertainty exists in the minds of decision makers with respect to the successful adoption," wrote Bagozzi, Davis, and Warshaw (1992, p. 664). This managerial view of individual behavior was influenced by Davis's exposure to some early CHI usability research.

High interest in TAM showed that the IS focus, in which hands-on use was primarily non-discretionary operation, data entry, and data retrieval, was shifting as hands-on use spread to white-collar workers who could refuse to play. Contrast IS with CHI: Consumers choose technologies that they perceive to be useful, so CHI assumes perceived utility and rarely considers utility at all. TAM researchers considered utility more important than usability. CHI focused on usability a decade before TAM, albeit more on measures of actual usability than measures of perceived usability. Perception was a secondary user satisfaction measure to CHI researchers, who believed (not entirely correctly) that measurable reduction in time, errors, questions, and training would, over time, translate into positive perceptions. Acceptance is not in the CHI vocabulary. A discretionary user chooses or adopts, rather than accepts.

The *Harvard Business Review* published "Usability: The New Dimension of Product Design" (March, 1994). In concluding that "user-centered design is still in its infancy," it made no mention of CHI (p. 149). The communities remained largely isolated.

Collaboration Support: OIS Gives Way to CSCW

In the late 1980s, three research communities focused on small-group communication and information sharing: (1) office automation/office information systems (discussed previously); (2) IS researchers focused on tools to support organizational decision making could apply them to group decision making more generally as computing costs declined; and (3) the proliferation of LAN networks encouraged some CHI researchers to move from individual productivity to a quest for so-called "killer apps" to support teams.

Although the OA/OIS field had led the way, it declined and largely disappeared in this period. The minicomputer, platform for most of OIS research, did not survive competition from PCs and workstations. The concept of "office" or group was problematic: organizations and individuals are persistent entities with goals and needs, but small groups often have ambiguous membership and shift in character as members join or depart. People with a need to communicate through technology often fall under different budgets, complicating technology acquisition decisions unless the technology is available organization-wide.

The rapid shift was reflected in terminology use. First, *automation* fell out of favor; in 1986, ACM SIGOA shifted to SIGOIS (Office Information Systems) and the annual AFIPS OA conferences ended. By 1991, the term *office* followed: *Transactions on Office Information Systems* became *Transactions on Information Systems*; *Office: Information and People* became *Information Technology and People*; "Conference on Office Information Systems" became "Conference on Organizational Communication Systems."

The AI summer, a contributor to the OA/OIS effort, ended when AI failed to meet expectations: Massive funding did not deliver a Pilot's Associate, an Autonomous Land Vehicle, or a Battle Management System for the military, or automated offices for enterprises. CHI conference sessions on language processing had diminished earlier, but sessions on modeling, adaptive interfaces, advising systems, and other uses of intelligence in interfaces increased through the late 1980s before declining in the 1990s. AI research did not disappear, but funding became scarce, employment opportunities dried up, and conference participation dropped off.

Building on a 1984 workshop (Greif, 1985), the 1986 Computer Supported Cooperative Work conference brought together researchers from diverse disciplines interested in issues of communication, information sharing, and coordination. Participants came primarily from IS, OIS, CHI, distributed AI, and anthropology. Four of thirteen CSCW program committee members and many papers were from schools of management, with similar numbers from OIS.

The field coalesced in 1988. *Computer-Supported Cooperative Work,* edited by Irene Greif (1988), was published, and SIGCHI sponsored the North American CSCW conference that would be held biennially. A European CSCW series (ECSCW) was initiated in 1989. With heavy participation from computer and software companies, North American CSCW had a small-group focus on networked individuals working on PCs, workstations, or minis, whether in an organization or linked by proliferating ARPANET, BITNET, or other networks. European participation was from academia and government agencies and focused on organizational users of technologies, as did the IS and OIS communities.

Scandinavian influences, described in the next section, influenced both camps.

Many IS researchers shifted participation to other conferences and a series of less selective bi-annual Groupware conferences that started in 1992. Their newsletter, *Groupware Report,* listed many relevant conferences but not CSCW. The Collaboration Technology track of HICSS (the annual Hawaii International Conference on System Sciences) became a major IS pre-journal publication arena, with some participating in the Organizational Computing Systems (1991–1995) and GROUP (1997–present) descendants of the Conference on Office Information Systems.

CSCW has been challenged by the pace of technology change. In 1985, supporting a small team was a technical challenge; ten years later, the web had arrived. Applications that provided awareness of the activity of distant collaborators was a celebrated achievement in the early 1990s; several years later, dark linings to the silver cloud arose in the form of privacy concerns and information overload. Major phenomena were identified—a productivity paradox in which IT investments were not returning benefits, health effects of internet use on young people—that were not visible in data collected and reported only a few years later. European CSCW had focused on development of IT in large organizations, which shifted to the use of commercial software. North American CSCW found that collaboration could not be supported one team at a time, that organizational context was important. With organizational behavior and theory thriving in other venues, CSCW welcomed ethnographers who studied technology use, a group marginalized in traditional anthropology departments.

CSCW remains a strong research area that has attracted a broad swath of HCI researchers. Content ranges from highly technical work to thick ethnographies of workplace activity, from studies of instant messaging (IM) dyads to scientific collaboratories involving the activities of hundreds of people dispersed in space and time.

Sociotechnical and Participatory Design

Pre-dating this period were experiments in employing design methods to involve systematically specific people who would interact with a resulting system, typically non-discretionary users of systems developed by a large enterprise for its own use. Sociotechnical design (Bjørn-Andersen & Hedberg, 1977; Mumford, 1976) took a managerial perspective, whereas participatory or cooperative design, rooted in the Danish trade union movement, focused on empowering the eventual users (Nygaard, 1977). These efforts became widely influential following the publication of the proceedings of a 1985 conference held in Aarhus, Denmark (Bjerknes, Ehn, & Kyng, 1987). Scandinavian influences also appeared in human factors (e.g., Rasmussen, 1986). The greatest resonance, though, was between Scandinavian and CHI researchers. In spite of cultural differences and differences in the contexts of development (in-house vs. commercial product) and use (non-discretionary vs. discretionary), they shared a focus on empowering hands-on users. They also, on balance, shared the perspective of a generation growing up in the1960s, unlike the World War II generation that dominated HF&E and IS.

Library and Information Science: An Unfinished Transformation

Research universities have always supported prestigious professional schools, but the prestige of library schools declined as the training emphasis shifted to higher-paid IT and software engineering professions. Between 1978 and 1995, fifteen American library schools were closed (Cronin, 1995). Most of the survivors were rechristened Library and Information Science. Computer technology was unquestionably changing librarianship, requiring new curricula and faculty with different skills.

The changes did not go smoothly or as anticipated. Forced multidisciplinarity is never easy. Traditional library studies had largely dismissed technology, arguably a reasonable reaction to the cost and limitations of new technologies. But, in line with Moore's Law, costs decreased and many of the limitations disappeared with a speed that left little time to prepare. Young information scientists were not interested in absorbing a century of work on indexing, classifying, and providing access to complex information repositories; their eyes were fixed on a future in which many past lessons would not apply—and those that still applied would likely have to be relearned. The conflicts are exposed in a landmark 1983 collection, *The Study of Information: Interdisciplinary Messages* (Machlup & Mansfield, 1983). In the book, Rayward described the different views and argued that there had been some convergence. His essay is followed by commentaries attacking him from both sides.

In a series of meetings beginning in 1988, new deans at Pittsburgh, Syracuse, Drexel, and subsequently Rutgers discussed approaches to explaining and managing multidisciplinary endeavors. In spite of this progressive effort, Cronin (1995, p. 45) describes the library and information science camps as still very much at loggerheads and in a "deep professional malaise" that might require librarianship to be cut loose in favor of stronger ties to cognitive and computer science. In the early 1990s, a handful of universities dropped "library," becoming schools of information (see Figure 8.2). More would follow.

1995–2010: The Internet Era Arrives

How did the spread of the internet and emergence of the web affect the different HCI research threads? CHI researchers were relatively internet savvy. Although excited by the prospects, they took this change in

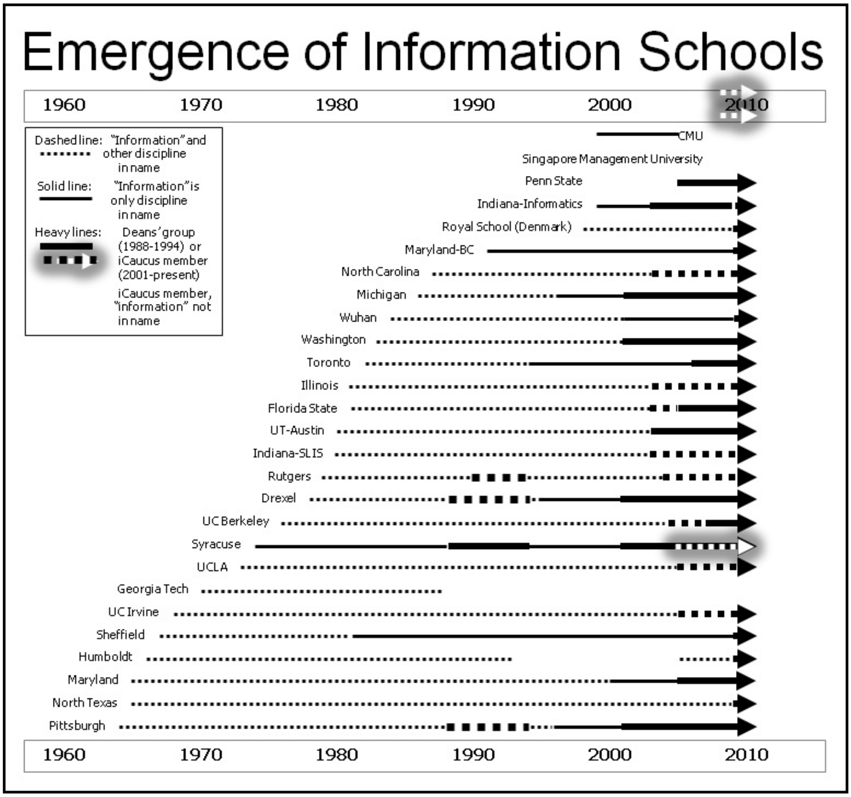

Figure 8.2 Emergence of Information Schools.

stride. Over time, the nature of research, development, and use evolved. The internet and web were not disruptive to human factors and ergonomics, either. The web was initially a return to a form-driven interface style; and for a few people it was a locus of routine work. However, the web had a seismic impact on information systems and information science, so this section begins there.

The Formation of AIS SIGHCI

Computer users in organizations were no longer almost slaves devoted to maximizing computer use—screen savers vied with Solitaire to be the main consumer of processor cycles. Embrace of the internet created more porous organizational boundaries. Employees downloaded free software such as instant messaging clients, music players, and weblog tools inside the firewall in spite of IT concerns about productivity and security. These are not the high-overhead applications of the past. Another change is that home use of software reduced employee patience with poor interactive software at work. In addition, managers who were hands-off users in the 1980s became late adopters in the 1990s, and are now hands-on early adopters of some technologies.

Significant as these changes are, the web had a more dramatic effect on IS research. Corporate IT departments had focused on internal operations; suddenly, organizations were creating web interfaces to external vendors and customers. Discretionary users! The internet bubble revealed that our understanding of these phenomena was limited, but online marketing, services, and business-to-business systems remained important when the bubble burst. The web became an essential business tool. In handling external customers IT professionals and IS researchers were in much the same place CHI had been 20 years earlier, whether they realized it or (most often) not.

In 2001, the Association for Information Systems (AIS) established the Special Interest Group in Human–Computer Interaction (SIGHCI). The founders defined HCI by citing 12 works by CHI researchers (Zhang et al., 2004, p. 148) and made it a priority to bridge to the CHI and the information science communities (Zhang, 2004). Although SIGHCI's charter includes a broad range of organizational issues, published work emphasizes interface design for ecommerce, online shopping, online behavior "especially in the internet era," and effects of web-based interfaces on attitudes and perceptions (p. 1). Eight of the first ten papers in SIGHCI-sponsored journal issues cover internet and web behavior.

In 2009, *AIS Transactions on Human–Computer Interaction* was launched. The shift from an organizational focus to the web and broader *end-user computing* is documented in an article appearing in it: Zhang, Li, Scialdone, and Carey's (2009) analysis of the IS literature related to HCI from 1990 to 2008.

The effort to bridge to CHI foundered, as had previous efforts between CHI and human factors, office information systems, and IS within CSCW. This will be discussed further.

Digital Libraries and the Evolution of LIS

By 1995, a wave of change had occurred (Figure 8.2). Digital technology was in the LIS curriculum. Familiarity with technology use was a prerequisite for librarianship. Overall, though, innovative research had not kept pace with professional training (Cronin, 1995).

Use of the internet grew exponentially, but in 1995 it was still a niche activity found mainly on campuses. In the mid-1990s, Gopher, a convenient system for downloading files from around the internet, attracted attention as a possible springboard for indexing distributed materials. Wells's (1938) "world brain" seemed within reach. Then the web hit, transforming all aspects of information—acquisition, management, access—at an accelerating pace. Between 1994 and 1999, two NSF/DARPA/NASA/National Library of Medicine/Library of Congress/National Endowment for the Humanities/FBI research initiatives on digital libraries awarded about $200M in today's dollars. This with other investments galvanized the research community.

By 2000 about ten schools (or equivalent units) had information as the sole discipline in their name; today it is twice that. In 2001, a new series of "deans meetings" formed, with original members Syracuse, Pittsburgh, and Drexel joined by Michigan, Berkeley, and the University of Washington, all of which are now information schools. In 2005, the first annual "iConference" drew participants from nineteen universities with information programs. The "iCaucus" now has 27 dues-paying university members. Some are transformed library schools, some had closer ties to information systems or computer science, and others formed recently. Collectively, they include HCI researchers from HF&E, IS, and CHI.

Within these schools, conflicts in academic cultures are addressed on a regular basis. The conference is not yet very visible. One could challenge the implication in Figure 8.2 that a shift from LIS to a field simply called "information" is well underway. Many faculty consider themselves to be "a researcher in {X} who is located in an information school," where X could be library science, HCI, CSCW, IS, communication, education, computer science, and perhaps others. It is too early to say how it will evolve. We can say that information has become, and will remain, a significant player in human–computer interaction.

Human Factors and Ergonomics Embraces Cognitive Approaches

In 1996, the Human Factors and Ergonomics Society formed a new technical group, Cognitive Engineering and Decision Making. It quickly became the largest technical group in the society. A decade earlier this would have been an unlikely development: Senior human factors researchers disliked cognitive approaches; it was in the CHI field that *cognitive engineering* was used in this sense (Norman, 1982, 1986).

Even more astonishing a decade earlier would have been the fact that in 2005, Human Performance Modeling was a new, thriving technical group in HFES, initiated by Wayne Gray and Dick Pew, CHI participants in the 1980s. Card, Moran, and Newell (1983) had introduced human performance modeling to reform the discipline of human factors from the outside. Work had continued, focused on expert performance (e.g., a special issue of *Human–Computer Interaction,* Vol. 12, Number 4, 1997). Today the reform effort has moved within human factors, still focused largely on non-discretionary use.

HF&E to a large degree shaped government funding of HCI. The U.S. National Science Foundation Interactive Systems Program—subsequently renamed Human–Computer Interaction—was described:

> The Interactive Systems Program considers scientific and engineering research oriented toward the enhancement of human–computer communications and interactions in all

> modalities. These modalities include speech/language, sound, images and, in general, any single or multiple, sequential or concurrent, human–computer input, output, or action. (National Science Foundation, 1993, online)

One NSF HCI program manager reported that his proudest accomplishment was doubling the already ample funding for natural language understanding. Even after NSF established a separate Human Language and Communication Program in 2003, speech and language research continued to draw heavy funding support in the HCI and accessibility programs, and lighter support in AI and other NSF programs. Two subsequent NSF HCI program managers emphasized *direct brain interfaces* or *brain-computer interaction*, using brainwaves, implants, or other means. NSF program managers rarely attended CHI conferences, where there was little work on speech, language, or direct brain interaction. Whether or not these technologies prove useful, they will not appear soon in discretionary use situations in many homes or offices. A review committee noted that a random sample of NSF HCI grants included none by prominent CHI researchers (National Science Foundation, 2003).

Human factors research on computer use has dispersed. HCI issues now appear in most HFES technical groups, from telecommunications to medical systems, even as the Computer Systems Technical Group has declined in size.

CHI Evolves, Embraces Design

The steady flow of new hardware, software features, applications, and systems ensures that initial use and early adoption of digital technology is always present, important to technology producers, and generating new research issues. CHI has tracked this flow of innovation, generally picking up an innovation when it first attracts a wide audience.

As an application matures, use may become routine. Many people now must use email and word processing, for example. Such technologies receive less attention as CHI directs its gaze to discretionary use of the moment: instant messaging, blogging, collaboration technology, web design, ubiquitous computing, mobile computing, social computing, and so on. New technologies raised new issues, such as privacy, and encouraged new methods, such as ethnography. At a more abstract level CHI shows continuity: continued exploration of input devices, communication channels, information visualization techniques, and design methods.

The growing participation in an internet that steadily became more reliable and higher bandwidth through the mid-1990s increased the focus on real-time communication technologies and quasi-real-time technologies such as email. The web temporarily slowed this, however, by shifting attention to indirect interaction via static sites.

The web was like a new continent. First came explorers, posting flags here and there. Then came attempts at settlement, in the form of virtual worlds research and development. Few of these early pioneers survived; there was little to do in virtual worlds other than games and simulations. But more recently some people, primarily young people, shifted major portions of their work and play online, relying on online information sources, digital photo management, social software, digital documents, online shopping, multiplayer games, and so on. And this is reflected in CHI research topics.

The web curtailed research into self-contained personal productivity tools. In spite of high development and maintenance costs, representing knowledge in application software was appealing when external information resources were limited. With so much information available online today, including the ability to find knowledgeable people, static knowledge representation is less useful. In contrast, adaptive systems that build and maintain local knowledge can play a greater role. Steady progress in machine learning is influencing productivity tools—although implausible forecasts have not disappeared.

To the psychologists and computer scientists who formed CHI, interface design was a scientific and engineering undertaking. Focused on performance, they assumed that people eventually choose the most efficient alternatives. Because human discretion involves aesthetic preferences, and invites marketing and non-rational persuasion, this view could not be sustained when computing costs came down. But the engineering orientation held on longer in CHI than in SIGGRAPH, where aesthetic appeal motivated much research. CHI researchers labeled the study of enjoyment "funology" (Blythe, Monk, Overbeeke, & Wright, 2003, p. 1), lest someone think that the researchers were too relaxed about it.

Visual designers participated in graphical interface research early on. Aaron Marcus began working full time on computer graphics in the late 1960s. William Bowman's (1968) book *Graphic Communication* was a strong influence on the Xerox Star, for which the designer Norm Cox's icons were chosen (see Bewley, Roberts, Schroit, & Verplank, 1983). However, graphic design was usually seen as secondary (Evenson, 2005). In 1995, building on working group meetings at previous conferences, SIGCHI initiated Designing Interactive Systems (DIS), a biennial conference drawing a few visual designers and many systems designers. In 2003, SIGCHI, SIGGRAPH, and the American Institute of Graphic Arts (AIGA) initiated the Designing for User Experience (DUX) conference series that fully embraces visual and commercial design.

The evolution of CHI is reflected in the influential contributions of Donald Norman. A cognitive scientist who introduced the term *cognitive engineering,* he presented the first CHI '83 paper. It defined *user satisfaction functions* based on speed of use, ease of learning, required knowledge, and errors (Norman, 1983). His influential 1988 book *Psychology of Everyday Things* (*POET*) (Norman, 1988) focused on pragmatic usability. Its 1990 reissue as *Design of Everyday Things* reflected a field refocusing on invention. Fourteen years later he published *Emotional Design: Why We Love (or Hate) Everyday Things*, stressing the role of aesthetics in our response to objects (Norman, 2004).

Design's first cousin, marketing, has been poorly regarded in the CHI community (see Marcus, 2004). However, website design forces the issue. Site owners often wish to keep users on a site, whereas users may prefer to escape quickly. Consider supermarkets, where items that most shoppers want are positioned far apart, forcing people to traverse aisles so other products can beckon. CHI professionals usually align themselves with end-users, but when designing for a site owner, they face a stakeholder conflict. This was not true in the past: Designers of individual productivity tools had negligible conflict of interest with prospective customers. Marketing is likely to find a place in CHI because marketing is concerned primarily with identifying and fulfilling consumer needs.

Looking Back: Cultures and Bridges

In spite of a significant common focus and a dynamic environment with shifting alliances, the major threads of human–computer interaction research—HF&E, IS, LIS, and CHI—have not merged. They have not even interacted much, although not for lack of effort to build bridges. The Human Factors Society co-organized the first CHI conference. CSCW sought to link CHI and IS. AIS SIGHCI tried to engage with CHI.

Even within computer science, bridging proved difficult. Researchers interested in interaction left SIGGRAPH to join CHI rather than work to bridge the two. Twenty years later another opportunity arose as advanced graphics processing became available for use in design on standard platforms. The DUX conference series was cosponsored by the SIGS, but was discontinued after three meetings. In AI, SIGART and SIGCHI cosponsor the Intelligent User Interface series, but participation has remained outside mainstream HCI. We can identify some of the obstacles to greater interaction.

Discretion Is a Major Variable

HF&E and IS arose before discretionary hands-on use was widespread, whereas CHI made that its focus. HF&E and IS researchers examined organizational as well as technical issues; CHI generally avoided domain-dependent work. As a consequence, HF&E and IS researchers did share journals; for example, Benbasat and Dexter (1985) published in *Management Science* and cited five *Human Factors* articles. These three fields moved quickly to focus on general populations, whereas information science only slowly distanced itself from supporting specialists.

User motivation affects methods. HF&E and CHI were shaped by psychologists trained in experimental testing of hypotheses about behavior. Experimental subjects agree to follow instructions for an extrinsic reward. This is a good model for nondiscretionary use, but not for discretionary use. As a symbolic if cosmetic change, CHI researchers relabeled subjects to be *participants*, which sounds volitional. But they discovered that formal experimental studies were often overkill for their purposes, and that lab studies in general are more likely than ergonomics studies to require confirmation in real-world settings.

The same goals apply—fewer errors, faster performance, quicker learning, greater memorability, and being enjoyable—but the emphasis differs. For power plant operation, error reduction is key, performance enhancement is good, and other goals are less critical. For telephone order entry takers, performance is critical: testing an interface that could shave a few seconds from a repetitive operation requires a formal experiment.

In contrast, consumers often respond to visceral appeal and initial experience. In assessing designs for mass markets, catching obvious problems can be more significant than striving for an optimal solution. Less rigorous studies, such as discount usability or cognitive walkthroughs (Nielsen, 1989), can be enough, with more time-consuming qualitative approaches, such as contextual design or persona use (Beyer & Holtzblatt, 1998; Pruitt & Adlin, 2006), providing a deeper understanding of users when new circumstances arise. Unlike HF&E, CHI largely abandoned its roots in scientific theory and engineering. This did not impress HF&E researchers or theory-oriented IS researchers. The controversial psychological method of verbal reports, developed by Newell and Simon (1972), was applied to design by Clayton Lewis (1983; Lewis & Mack, 1982, p. 387) as "thinking-aloud." Perhaps the most widely used CHI method, it led some in the other fields to characterize CHI people as wanting to talk about their experiences instead of doing research.

Academic, Linguistic, and Generational Cultures

The traditional academic culture of the sciences is that conferences are venues for work in progress and journals are repositories for polished work. HF&E, IS, documentation, and library science all followed this practice. In contrast, CHI and other U.S. computer science disciplines shifted to conference proceedings as the final destination of most work. Outside the U.S., computer science retained more of a journal focus, arguably due to the absence of professional societies that archived conference proceedings (Grudin, in press). Information science is divided, drawing as it does on researchers from both camps. This circumstance impedes communication across disciplines and continents. Researchers in journal cultures chafe at CHI's rejection rates; CHI researchers are dismayed by the relatively unpolished work at other conferences.

CHI conferences are selective, accepting only about 20 percent of submissions. With a few exceptions, HF&E and IS conferences have acceptance rates of about 50 percent or more. On the other hand, CHI journals receive fewer submissions and have higher acceptance rates (see Grudin, 2005). Many CHI researchers report that journals are not relevant, and I estimate that as little as 10 percent of work in CHI-sponsored conferences reaches journal publication. In contrast, an IS track organizer for the Hawaii International Conference on System Sciences estimated that 80 percent of research there progressed to a journal (Jay Nunamaker, HICSS-38 presentation, January 2004).

A linguistic divide also set CHI apart. HF&E and IS used the term *operator*; in IS, *user* could be a manager who used printed computer output, not a hands-on *end-user*. Within CHI, *operator* was demeaning, *user* was always hands-on, and *end-user* seemed a superfluous affectation. In HF&E and IS, *task analysis* generally refers to an organizational decomposition of work, a broad analysis that can consider external factors; in CHI, it was a cognitive decomposition, such as breaking a text editing move operation into select, cut, select, paste. In IS, *implementation* meant deployment of a system in an organization; in CHI, it was a synonym for development. *System, application*, and *evaluation* also had markedly different connotations or denotations. Significant misunderstandings and rejections resulted from failure to recognize these distinctions.

Different perspectives and priorities were reflected in attitudes toward standards. Many HF&E researchers contributed to the development of standards, believing that standards contribute to efficiency and innovation. A view widespread in CHI was that standards inhibit innovation. There are elements of truth in both views, and positions may have converged as internet and web standards were tackled. However, the attitudes reflected the different demands of government contracting and commercial software development. Specifying adherence to standards is a useful tool for those preparing requests for proposals, but compliance with standards can make it more difficult for a product to differentiate itself.

A generational divide also existed. Many CHI researchers grew up in the 1960s and 1970s, and did not appreciate the prior generation's orientation toward military, government, and business systems, or the inability of HF&E and IS "man-machine interaction" researchers to adopt gender-neutral terminology (still occasionally occurring). Only in 1994 did *International Journal of Man-Machine Studies* become *International Journal of Human–Computer Studies*. Such differences affected enthusiasm for building bridges and exploring literatures.

Competition for resources was another factor. Computers of modest capability were extremely expensive for much of the time span we are considering. CHI was initially largely driven by the healthy tech industry; the other fields were more dependent on competing for government funding, which waxed and waned. Demand for researchers outstripped supply, as well. HCI tended to prosper in AI winters, starting with Sutherland's ability to use the TX-2 for the first graphics research when AI suffered its first setback and recurring with the emergence of major HCI labs during the severe AI winter of the late 1970s. Library schools laboring to create information science programs had to compete with computer science departments, some of which awarded faculty positions to graduates of master's programs due to the short supply.

Greater interdisciplinarity is intellectually seductive. More might be learned by looking over fences. But perhaps a better metaphor is the Big Bang—digital technology as an explosion dispersing effort in different directions, forming worlds that at some later date might discover one another and learn how to communicate, or might not.

Looking Forward: Trajectories

The future of human–computer interaction will be varied, dynamic, and full of surprises. Nevertheless, observations about the past and present state of the field may help us anticipate developments.

Discretion—Now You See It, Now You Don't

We exercise prerogative a great deal when buying online, more at home than at work, and not at all when confronted by a telephone answering system. We have more choice when young and healthy than when constrained by injury or aging. Software that was discretionary yesterday is indispensable today. The need to collaborate forces shared conventions.

Consider a hypothetical team that has worked together for twenty years. In 1990, one member still used a typewriter, others chose different word processors. All exchanged printed documents. One emphasized by <u>underlining</u>, another by *italicizing*, a third by **bolding**. In 2000, group members could share documents digitally—and thereby had to adopt the same word processor and forms of emphasis. Choice was curtailed; it could only be exercised collectively. Today, it often suffices to share documents in portable document format (PDF), so in 2010, the team can again use different word processors. Perhaps tomorrow I will be able to personalize my view, and see in italics what you see as bold.

Shackel (1997, p. 981) noted this progression under the heading "From Systems Design to Interface Usability and Back Again." Early designers focused at the system level; operators had to cope. When the PC merged the roles of operator, output user, and program provider, the focus shifted to the human interface and choice. Then individual users again became components in fully networked organizational systems. Discretion evaporates as to whether to use a technology that has become mission-critical, as email did for many people in the 1990s.

The converse also occurs. Employee discretion increases when one can download free software and demand capabilities enjoyed at home. Managers are less likely to mandate the use of a technology that they use and find burdensome. Even in the military, language processing systems appealed to military officers—until they themselves became hands-on users:

> Our military users … generally flatly refuse to use any system that requires speech recognition. … Over and over and over again, we were told "If we have to use speech, we will not take it. I don't even want to waste my time talking to you if it requires speech …" I have seen generals come out of using, trying to use one of the speech-enabled systems looking really whipped. One really sad puppy, he said "OK, what's your system like, do I have to use speech?" He looked at me plaintively. And when I said "No," his face lit up, and he got so happy. (Forbus, 2003; see also Forbus, Usher, & Chapman, 2003)

As familiar applications become essential and security concerns curtail openness, one might expect discretion to recede. But Moore's Law (broadly construed), competition, and the ease of sharing bits may guarantee that a steady flow of unproven technologies will reach us.

Ubiquitous Computing, Invisible HCI?

Norman (1988, pp. 185–186) wrote of "the invisible computer of the future." Like motors, he speculated, computers would be present everywhere and visible nowhere. We interact with clocks, refrigerators, and cars. Each has a motor, but there is no human–motor interaction specialization. A decade later, at the height of the Y2K crisis and the internet bubble, computers were more visible than ever. We may always want a multipurpose display or two, but part of Norman's vision is materializing.

With computers embedded everywhere, concern with interaction is everywhere. Perhaps HCI itself will become invisible through omnipresence. As interaction with digital technology becomes part of everyone's research, the three major HCI fields are losing participation.

Human Factors and Ergonomics

David Meister, author of *The History of Human Factors and Ergonomics,* stresses the continuity of HF&E in the face of technology change:

> Outside of a few significant events, like the organization of HFS in 1957 or the publication of Proceedings of the annual meetings in 1972, there are no seminal occurrences … no sharp discontinuities that are memorable. A scientific discipline like HF has only an intellectual history; one would hope to find major paradigm changes in orientation toward our human performance phenomena, but there are none, largely because the emergence of HF did not involve major changes from pre-World War II applied psychology. In an intellectual history, one has to look for major changes in thinking, and I

> have not been able to discover any in HF. (personal communication, September 7, 2004)

Membership in the Computer Systems Technical Group of HFES has declined sharply; technology use is stressed in other technical groups, such as Cognitive Engineering and Decision Making, Communication, Human Performance Modeling, Internet, System Development, and Virtual Environment. Nor can Aging, Medical Systems, or other technical groups avoid "invisible computers."

Information Systems

As IS thrived during the Y2K crisis and internet bubble, other management school disciplines—finance, marketing, operations research, organizational behavior—become more technically savvy. When the bubble burst and enrollments declined, the IS niche was less well defined. The research issues remain significant, but this cuts two ways. With the standardization and outsourcing of IT functions, web portals and business-to-business attract more attention. These have economic and marketing elements, making it natural to outsource HCI functions to other management disciplines.

Computer–Human Interaction

This nomadic group started in psychology. It obtained a place at computer science banquets, often bestowed grudgingly. CHI, lacking a well defined academic niche, ties its identity to its conference. Participation peaked in 2001. Specialized conferences thrive. As technologies appear and attract a critical mass at an ever-increasing pace, researchers can start new conferences or blog their findings. For example, soon after the web emerged, WWW conferences included papers on HCI issues. Now there are conferences on ubiquitous, pervasive, accessible, and sustainable computing, agents, design, emerging technologies, and emerging markets. HCI is an invisible presence in each. High conference rejection rates and a new generational divide could accelerate this dispersion of effort.

Information

The first iConferences were marked by active discussion and disagreement about directions. Faculty from several disciplines worked to create pidgin languages. Since then, many assistant professors were hired and graduate students enlisted. Their initial jobs and primary identities are with Information. They are likely to creolize the pidgin languages.

Cronin (1995) proposed that information access, in terms of intellectual, physical, social, economic, and spatial/temporal factors, is the focus of the field. Information is acquired, through sensors, from human input, and flows and aggregates and is transformed over networks including the web. Information visualization is also critical, as is the information management that increasingly each of us must handle for ourselves, choosing what to keep locally, what to maintain in the cloud, and how to organize it and ensure its accessibility at a later time.

In speculating about the future, Cronin cites Wersig (1992, p. 215) who argued that concepts around information might function "like magnets or attractors, sucking the focus-oriented materials out of the disciplines and restructuring them within the information scientific framework." There is evidence for this in a migration of HCI faculty to information schools. On the other hand, the rise of specialized programs—biomedical informatics, social informatics, community informatics, information and communication technology for development (ICT4D) presents a countervailing force. Information, like HCI, could become invisible through ubiquity.

From talking with the younger generation, my sense is that the generals may still be arguing over directions, but the troops are starting to march. It is not clear where they will go. The annual conference is fragile; the generals are busy with other matters but reluctant to turn over command. In any case, in the long term, Information will be a major player in human–computer interaction. Design and Information are active HCI foci in 2010. Design activity is compensating for past neglect. Information is being reinvented.

Conclusion: The Next Generation

Until revoked, Moore's Law will ensure that digital landscapes will provide new forms of interaction to explore and new practices to improve. The first generation of computer researchers, designers, and users grew up without computers. The generation that followed used computers as students, entered workplaces, and changed the way technology was used. Now a generation has grown up with computers, game consoles, and cell phones. They absorbed an aesthetic of technology design while communicating with IM and text messaging. They are developing skills at searching, browsing, assessing, and synthesizing information. They use digital cameras and blog, acquire multimedia authoring talent and embrace social networking sites. They are entering workplaces, and everything will be changed once again.

However it comes to be defined and wherever it is studied, human–computer interaction will for some time be in its early days.

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