HCI in the Next Millennium: Supporting the World Mind

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ABSTRACT This presentation uses *three worlds*, *collective stance* and *learning curves* perspectives to analyze developments in human-computer interaction. It argues from historic data that the human interests have remained unchanged over at least five millennia, and may be expected to have the same basis during the next millennium. It concludes that we are still at a very early stage in the development of HCI, and that the major impact of the technology on our societies is yet to come. To understand the issues involved we will need greater understanding of the operation of our societies, their economies, politics and cultures, and how these evolve under the influence of environmental factors including advances in information technologies.

1. INTRODUCTION

Interact'99 falls in a year which is the 50th anniversary of EDSAC, the first stored program digital computer (Williams, 1985); the 40th of the first paper on HCI (Shackel, 1959); the 30th of the first issue of the *International Journal of Man-Machine Studies* (Chaplin, Gaines and Gedye, 1969); the 20th of Visicalc, the first spread-sheet program (VisiCalc, 1984); and the 10th of the proposal for a World Wide Web of hypertext documents (Berners-Lee, 1989). In another decade what will we remember of 1999, what will be the issues of 2009, and what will be the challenges and opportunities of computing and HCI in the next millennium?

I welcome this opportunity to look back on the evolution of computing and HCI, and forward to the growing role of computing in human society. The editor of a journal is an impresario continually seeking new 'acts', the innovative performers of tomorrow who will challenge the envelope, surprise us with their ideas and achievements, and create the cultures of the future. In this article I will share with you perspectives on the future of computing and HCI that drive my anticipations of what will be reported in the *International Journal of Human-Computer Studies* in the next millennium.

As one browses through the first three decades of IJHCS and later journals that developed in its wake, it is apparent that the HCI literature to date has been largely focused on the interaction between the individual person and the computer system. In recent years the development of groupware has led to papers on systems in which the technology mediates the activities of a team, but the focus is still largely on individual cognitive issues such as situational awareness. Similarly, the development of the Internet and World Wide Web has led to papers on various aspects of computer-mediated communication, but the focus is largely on supporting the individual to interface to community resources.

My argument in this presentation is that these foci of attention must, and will, change to model the larger unit as a composite human entity whose processes interact with computing technologies. The *team*, the *special-interest community*, and *humanity at large*, are the relevant systems to consider in designing, modeling and understanding the next generation of human-computer interaction (Gaines, Chen and Shaw, 1997). Studies of individual interaction will continue but they will be greatly enriched by situating that interaction in the social, organizational, political, economic and cultural situations within which that interaction plays a role.

2. BACKGROUND AND ISSUES

There are many papers that address the role of information technology in organizations, particularly in the management literature, but they tend do so on the basis of organizational design rather than organizational emergence. They assume that the structure of the organization is pre-defined as are the roles within it, and the focus of interest is on the application of information technology to support those roles and that organization.

This is a valid approach to organizational analysis but it does not address some of the most important impacts of computing in recent years where organizational structures have emerged that did not previously exist, or where the operation of existing communities has changed through the effective use of the Internet and web. What is needed is a framework for the emergence of social structures through the process of interaction where the definition and maintenance of an organization is an ongoing process embedded in the interaction, not an externally defined precursor of that interaction.

The framework exists in various literatures, such as: philosophy of *three worlds* (Popper, 1968); the *group mind* (Bar-Tal, 1990); *reflexive sociology* (Bourdieu and Wacquant, 1992); *economic sociology* (Granovetter and Swedberg, 1992); *social network theory* (Burt, 1992); but not in what are normally regarded as the foundations of HCI.

I suggested in a keynote address at the 1978 System, Man and Cybernetics conference in Tokyo (Gaines, 1978) that the distinctions made by Popper in defining '3 Worlds', the physical, the mental, and the mediating products of the mental, were fundamental to the analysis of HCI. I later used that framework to analyze person-computer interaction in distributed systems (Gaines, 1988a), computer-aided knowledge acquisition (Gaines, 1989), and the support of scholarly communities on the Internet (Gaines, Chen and Shaw, 1997).

The original presentation focused on computers as vehicles to explore Popper's 'World 3', the mediating products of the human mind, and is useful in modeling developments in simulation, artificial intelligence and electronic journals (Gaines, 1993). However, the massive growth of discourse on the Internet may be viewed as computer networks providing vehicles to explore Popper's 'World 2' of mental processes, and draws attention to the need for deeper models of communities of discourse. A useful perspective from which to examine such communities is a *collective stance* (Gaines, 1994) in which humanity is viewed as a single adaptive agent recursively partitioned in space and time into sub-systems that are similar to the whole. In human terms, these parts include societies, organizations, groups, individuals, roles, and neurological functions (Gaines, 1987).

A third framework is needed for computers as a physical technology in 'World 1'. For this I will use a model of the generational infrastructure of information technology as a set of tiered learning curves (Gaines and Shaw, 1986) that was developed as an outcome of the studies of 5th generation computing (Gaines, 1984b) underlying my Interact'84 presentation (Gaines, 1984a). In particular, it can be used to model the convergence of communications and computer technologies and the growth of the web (Gaines, 1998).

This presentation will make use of the *three worlds*, *collective stance* and *learning curves* perspectives to explore potential future development in human-computer interaction. In particular, I shall argue from historic data that the human interests and resultant collective dynamics underlying socio-cultural phenomena have remained unchanged over at least five millennia, and hence may reasonably be expected to continue to operate during the next millennium.

In HCI studies it is the 'C' that is changing rapidly while the 'H' remains fundamentally unchanged although the 'I' may lead to the emergence of variant socio-cultural configurations.

I will conclude that we are still at a very early stage in the development of HCI, that the major impact of the technology on society is yet to come, and that to understand the design issues involved we will need much greater overt understanding of the operation of our societies, their economies, politics and cultures, and how these evolve under the influence of environmental factors including the development of information technologies.

Let me pause in this rather dry academic discussion and give an experiential perspective that serves to illustrate the major issues. While preparing this presentation in early April 1999 I attended a performance of Brahms' *German Requiem* and reflected on how many of the issues noted above were instantiated through that experience:-

First, there were no computers involved in the performance. There are many major aspects of our lives that are yet unaffected by computer technology.

Second, the capability of people to coordinate a complex activity involving the skilled activities of a large team of individuals was very apparent. The choir, soloists, and orchestra came together in a social unity constructed for a particular task that only existed for this performance.

Third, the social activity involved a wider socio-economic context of an audience paying to attend, the payment of those taking part, payment for the hall and associated staff, marketing activities, and so on. It was situated in an even wider social environment that provided for the building and management of the concert hall, car park, associated transportation facilities, paid employment for the audience that left them with the disposable income to attend, and so on.

Fourth, the basis of the performance was the product of a long-dead composer from another country who had composed it as a response to the death of his mother. There were links across space and time to another social unit.

Fifth, the words of the requiem were themselves reminders of the essential short-term embeddedness of the individual in the collective, "*the grass withereth and the flower fadeth.*" The components of humanity are short-lived and fragile, and much of our socio-cultural system derives from this.

Sixth, a requiem was appropriate to a time when planes from my countries were currently bombing buildings in the capital city of another country and fellow humans who might have been friends and colleagues were dying. Warfare has played a major role in human interests throughout recorded history.

Seventh, the troops of the country being bombed were reported to be robbing the refugees fleeing their homes. Crime has played a major role in human interests throughout recorded history.

Eighth, the media that was now full of war reports had recently been equally full of reports of the puerile sexual behaviors of the leader of the nation leading the bombing. Sexual desires have played an equally major role in human interests throughout recorded history.

Ninth, as a scholar I could model all this and see its relevance to related social phenomena involving the Internet, including its use to support hate literature, criminal activities, pornography and scholarship. Reflection on its own nature has been one of the most distinctive features of human life throughout recorded history. Modeling and designing human-computer interaction on a social scale requires an understanding of issues that go far beyond the cognitive psychology of the individual.

3. LOOKING BACK TO INTERACT'84

What were the HCI issues 15 years ago when Brian Shackel and I had the pleasure of providing the two keynote addresses at Interact'84, the first major IFIP conference on human-computer interaction? Five more Interact conferences have been held in the UK, Germany, The Netherlands, Norway and Australia, with attendance at Interact'93 in Amsterdam exceeding 1500 participants from 32 countries. It is fitting to pay tribute to IFIP Technical Committee 13 on Human-Computer Interaction which, under the leadership of Brian Shackel, has supported HCI activities world-wide. We owe a profound debt of gratitude to those who have worked in IFIP and TC13 on our behalf.

My presentation at Interact'84 was entitled *from ergonomics to the fifth generation* (Gaines, 1984a) and focused on HCI within the context of the Japanese 5G initiative. It is salutary in this presentation concerned with forecasting trends in HCI to note how few outcomes have resulted from that initiative, or from the others it stimulated in other countries, despite the enthusiasm at the time. One lesson from a life of research, and from the study of the history of scholarship, is that the majority of what any of us do is evanescent and will have no lasting impact. Each of us plays a minor role in the accumulation of knowledge and would not be missed if we did not play that role.

However, the *community* of scholarship of which we are part does generate lasting outcomes, and some members of that community will be remembered for their parts through a fairly erratic process of attribution (Brannigan, 1981). History tends to focus on the 'breakthroughs', neglecting the majority of research activity, which was fun, challenging, frustrating and rewarding, but had little dramatic impact. However, major changes arise out of that amorphous soup of forgotten research, often through a serendipitous process, and it is important to model this in forecasting. I will exemplify this through significant cases in this presentation.

Brian Shackel's presentation at Interact'84 was entitled *designing for people in the age of information* (Shackel, 1984) and posed some interesting questions about the expected state of the art by the end of the millennium: *the passing of paper; the reduction of writing; the victory of voice; the wired society; the expert in the system?*

The evidence of my ever-expanding bookcases and piles of documents is that paper is not yet obsolete. However, major changes are occurring. In my role as a university bureaucrat the majority of communication is through email, and when I receive the rare written memo I reply by email. One impact of this is upon filing systems where electronic archives of email provide a readily searchable corporate memory. Last year also I dropped most of my paper journal subscriptions by subscribing to the electronic versions, achieving major reductions in costs and needs for filing and storage.

Handwriting has been largely replaced by keyboarding but voice entry has had singularly little impact despite continuing research efforts dating from the 1950's. James Martin's (1978) *wired society* has arrived in the late 1990's and is having a major impact on our lives. In my day to day research I am continuously connected to a range of information resources on the Internet including library catalogues, abstracting services, electronic journals, bookstores and an ongoing flow of email from various list servers. One reason the use of paper has not stopped for me is that, with thousands of bookstores on the web, it is often quicker to order a book through the web than to request it through inter-library loan. The digitization of the entire corpus of written literature will be a major undertaking in the next millennium. The major impediments are issues of copyright and effective mechanisms for electronic commerce rather than the technologies of digitization *per se*.

Expert systems development was another exciting research area in the 1980's, stemming from the promise of artificial intelligence in the fifth generation era but failing to achieve its apparent potential. The social need that such systems targeted in terms of access to expert knowledge has been addressed instead by the access to human expert knowledge through the Internet. The *wired society* has to large extent obviated the need for the *expert in the system* by providing access to a network of human experts through list servers and newsgroups.

I can claim to have foreseen the significance of Internet communities some 28 years ago: *"If fifty percent of the world's population are connected through terminals, then questions from one location may be answered not by access to an internal data-base but by routing them to users elsewhere—who better to answer a question on abstruse Chinese history than an abstruse Chinese historian."* (Gaines, 1971). This remark arose out of my experience with developing operating systems for time-shared computers where a common bug was for console buffers to be switched and for one user to receive material intended for another. In the days before the widespread usage of email, it struck me that such serendipitous communication might not be entirely a bad thing!

4. COMPUTERS IN THREE WORLDS

In 1968, as we planned the first issue of IJHCS, Karl Popper was publishing his seminal paper proposing that *"thoughts in the sense of contents or statements in themselves and thoughts in the sense of thought processes belong to two entirely different 'worlds'…If we call the world of 'things'—of physical objects—the first world and the world of subjective experience the second world we may call the world of statements in themselves the third world (...world 3)…I regard books and journals and letters as typically third-world objects, especially if they develop and discuss a theory…I regard the third world as being essentially the product of the human mind. It is we who create third-world objects. That these objects have their own inherent or autonomous laws which create unintended and unforeseeable consequences is only an instance of a more general rule, the rule that all our actions have such consequences."* (Popper, 1968)

Popper later included the computer in this framework, noting that *"human evolution proceeds, largely, by developing new organs outside our bodies or persons…instead of growing better memories and brains we grow paper, pens, pencils, typewriters, dictaphones, the printing press, and libraries…the latest development (used mainly in the support of argumentative abilities) is the growth of computers."* (Popper, 1972)

Human agents interact with each of the three worlds through: *perception* and *action* to predict and control the reality of the physical World 1; through *comprehension* and *explanation* to understand and persuade the community of the mental World 2; through *derivation* and *creation* to use and create representations in the mediational World 3.

Computers, like books, span all three worlds: depending on major developments of physical technologies in World 1; involving the expression of human intentions in World 2 as programs represented in World 3; and storing and managing products in World 3 (Gaines, 1988a). Unlike books, computational products can be active, supporting dynamic processes that *generate* presentations rather than merely store them. Computers add data processing, modeling, simulation, hypertext links, and so on, to the repertoire of World 3 products.

Computers amplify human capabilities in World 1 through their instrumentation/control capabilities. Galison (1997) documents modern science's dependence on technologies to explore World 1. We have noted the dependence of developments in genetic engineering on the learning curves of computer technologies (Gaines and Shaw, 1986).

Computers amplify human capabilities in World 2 through their communication capabilities. The convergence of computer and communications technologies to the Internet and World Wide Web is a technological advance with major social impact (Gaines, 1998), and governments have recognized it as a major economic driver (Gore, 1995).

Computers amplify human capabilities in World 3 through their mediational capabilities. The digital media is able to encode any arbitrary entity so that it can be represented, processed and communicated in a computer system (Negroponte, 1995).

5. A COLLECTIVE STANCE

Popper also models the evolution of the agent as taking place in all three worlds through the same process of inwardly developed trial and the elimination of error. *"On all three levels—genetic adaptation, adaptive behaviour, and scientific discovery—the mechanism of adaptation is fundamentally the same…inherited structures are exposed to certain pressures, or challenges, or problems…variations of the genetically inherited or traditionally inherited instructions are produced by methods which are at least partly random. On the genetic level, these are mutations and recombinations of the coded instructions. On the behavioural level, they are tentative variations and recombinations within the repertoire. On the scientific level, they are new and revolutionary tentative theories…The next stage is that of selecting from the available mutations and variations: those of the new tentative trials which are badly adapted are eliminated."* (Popper, 1994)

These notions of how changes occur in the worlds are critical to understanding and forecasting human developments including the evolution of computers and their applications. Learning is a directed process based on presuppositions that can block progress (Gaines, 1976). However, the introduction of randomness can bypass the blocks (Gaines, 1971), and the resultant product will be selected not only in terms of the originating intention but also for any other value it may have—that is, serendipity is rife (Roberts, 1989).

Such phenomena have fascinated me through my career. The first computer I developed at ITT in 1965 was a *stochastic computer* that simulated an analog computer digitally by using random pulse trains in the manner of neurons (Gaines, 1967). It interested me thereafter to find problems that could be solved simply through random processes compared with insolubility or complexity with deterministic processes (Gaines, 1969b). My experience with using linear describing functions to model the highly nonlinear human controller and the artifacts this produced (Gaines, 1969a) led to an interest in the distortions of empirical theories caused by incorrect presuppositions (Gaines, 1976). I also became interested in the intrinsic positive feedback processes of learning processes, that one advance tended to lead to another and that exponential growth was common until curtailed by some limiting process (Gaines, 1988b).

In recent years I have integrated these concepts in a model of Worlds 2 and 3 which adopts a *collective stance* to World 2 and models the human species as a single adaptive organism recursively partitioned in space and time into sub-organisms that are similar to the whole (Gaines, 1994). These parts include societies, organizations, groups, individuals, roles, and neurological functions.

The organism adapts as a whole through adaptation of its interacting parts, leading to distribution of tasks and functional differentiation of the parts. The mechanism is one of positive feedback from parts of the organism allocating resources for action to other parts on the basis of those latter parts' past performance of similar activities. Distribution and differentiation follow if performance is rewarded, and low performers of tasks, being excluded by the feedback mechanism from the performance of those tasks, seek out alternative tasks where there is less competition.

World 3 phenomena, such as meaning and its representation in language and overt knowledge, arise as byproducts of the communication, coordination and modeling processes associated with the basic exchange-theoretic behavioral model. The model links to existing analyses of human action and knowledge in biology, psychology, sociology and philosophy, and is used to analyze the role of information technology in supporting activities in the lifeworld of World 2.

6. HUMAN INTERESTS

Human interests is the term conventionally used to capture the underlying dynamics of World 2. In general, technology will play a significant role if it supports these collective interests. I will first provide evidence for my sweeping statement in Section 2 that human interests have not changed throughout recorded history by a series of anecdotes that illustrate how the phenomena of the Internet have been instantiated in various past societies.

Let us commence with the intellectual experiments of the Greek enlightenment around

500BC that gave us: *argumentation*; *persuasion*; *utopian wishes*; *Greek language*; *empirical psychology*; and *rational reconstruction* as foundations for our own knowledge processes (Solmsen, 1975). We have come to idealize Pericles and Athens at that time as providing the foundations for democracy and scientific thought. However, detailed social histories of the period tell a story of *hetaireiai*, special-interest groups based on kinship, religion, military affiliation, employment, pleasures, and so on, that vied in the assembly to present their interests in developing the law (Connor, 1971). Legal, financial and marital corruption were rife, and the intellectual tools that we value were developed as ways of both managing and manipulating it as well as for more idealistic purposes. These are the same phenomena and same interests that the Internet and web address today.

Greek language is of particular interest because the written form was developed to allow the works of Homer to be transcribed (Powell, 1991). Writing technology substituted for an oral technology based on formulaic use of hexameters that provided communal storage for stories in the society of bards (Hobart and Schiffman, 1998). We see the mediation of Internet technology providing similar written capture for discourse in the special-interest communities using list servers. What was previously *cultural software* (Balkin, 1998) becomes captured in the archives of those servers, and newcomers can attune to the group through the archives without having to participate in the discourse.

The invention of writing led to a major industry in books. Around 250AD Origen was reckoned to have published some 6,000 books in his attempt to recreate accurate copies of Christian literature from the many versions extant. His extensive annotations and cross-references may be the earliest examples of hypertext linkage. His tracing the texts not only to biblical sources but also to earlier pagan literature led to Pope Anastasius condemning his works in 400AD, and the Council of Constantinople pronouncing them anathema in 533AD—censorship took longer to operate in those days! Nevertheless much of his work survives and is a basis for modern biblical scholarship (Constable, 1995).

The printing press revolutionized book production in the mid 15th century, having not only the intended effect of making it easier to propagate the bible and the established order, but also the serendipitous effect of making it easier to publish texts attacking that order. Eisenstein (1979) sees the book as a foundation for modern scholarship supporting *standardization*, *dissemination* and *fixity*. However, Johns' (1998) detailed studies of the book during the scientific revolution shows otherwise, that it was a very difficult to obtain a definitive copy of a book and that piracy of incorrect editions was rife. The issues of spurious and incorrect materials on the Internet today were problems with books then, and Johns gives modern examples suggesting they continue in scholarly publications today.

Writing also led to massive use of correspondence. Jardine (1996) notes that Datini, a Renaissance Venetian merchant, exchanged 125,549 letters with his factors or agents between 1364 and 1410. She also gives interesting examples of early pornography, that the works of Titian were sold for sexual titillation in the bedroom, and that the owners wanted to ensure that they were anonymous. She documents the commercial aspects of the book trade as a major business for both authors and printers, who were often at loggerheads. Hampson (1968) throws further light on the book trade during the Enlightenment, noting that book prices increased by a factor of five or more when they were banned.

One of the most interesting correspondents during the scientific revolution was Henry Oldenburg who came over as an ambassador from Bremen to Oliver Cromwell and stayed in London through the Restoration becoming a confidant of Robert Boyle and the first secretary to the Royal Society. Much of his massive correspondence survives (Hall and Hall, 1965) and has been the foundation of a range of studies of the scientific revolution and the role of the Royal Society. His world-wide correspondence with scholars of the seventeenth century can be modeled as if he were a human list server and shows patterns of discourse similar to those on the Internet today. The main different is in the time scales since his correspondence with Europe had a cycle time of some 6 months and that with America some 6 years.

Oldenburg used correspondence to support himself financially. He concludes a letter to Boyle in 1664 with the postscript: *"Sr, give me leave to entreat you, yt in case you should meet with any curious persons, yt would be willing to receave weekly intelligence, both of state and litterary news, you would doe me the favour of engaging them to me for it. The Expences cannot be considerable to persons yt have but a mediocrity; Ten lb. A yeare will be the most will be expected; 8. or 6. will also do the business."* His newsy letters became the *Transactions of the Royal Society* which he hoped would bring him £100 a year but, as he complains to Boyle, brought in rather less. What we see as the first scientific journal started as a commercial newsletter, driven by similar economic issues to those of how to charge for Internet information.

Shapin (1994) provides one of the most profound analyses of the Oldenburg correspondence and other documents and activities of that time in terms of the networks of trust underlying scholarship and science. His model generalizes not only to the modern scholarly community but also to communities in general on the Internet. The basis of trust in the intentions of those participating, how it is monitored and managed, is one of the most important issues for any communications technology supporting human communities.

7. ADVANCES IN TECHNOLOGY

Information technology is a recent invention whose rapid growth has had a major impact on age-old human interests. In 1959, as Brian Shackel at EMI published his paper on computer ergonomics, I was changing a semiconductor diffusion furnace at ITT to operate with boron rather than phosphorus in order to experiment with the new Bell Laboratory process for making planar transistors. Production processes for silicon transistors at that point involved etching the silicon away from the transistor. The new process created the transistor as an island in an area of non-conducting silicon so that we could put multiple coupled transistors on the same slice of silicon and create integrated circuits.

The number of transistors on an integrated circuit chip has increased exponentially by nine orders of magnitude since the first planar transistor in 1959, a growth curve commonly termed Moore's law after a joking prediction made by Gordon Moore, a cofounder of Fairchild Semiconductor. In 1964 when he made the prediction, 20 on a chip allowed the first flip-flop to be integrated; in 1972, 5,000 allowed the first 1 Kilobit memory (Intel 1103) and microcomputer (Intel 4004) to be integrated; in 1980, 500,000 allowed major central processing units to be integrated. The projected limit as we enter the next millennium is some 10,000,000,000 million devices on a chip as quantum mechanical effects become a barrier to further packing density on silicon planar chips.

The substitution of integrated circuits for discrete components radically accelerated the evolution of computers. The decrease in costs and increase in reliability made it possible to develop computers with greater storage capacity and processing power that also had mean times between failures that allowed them to be used in an interactive mode. For example, in 1968 I was able to develop the MINIC I computer using 74N TTL circuits to a full commercial product in some 6 months. In those days as well as the circuit design one also developed the microcode, wrote the operating system, developed the compilers and programmed the early applications.

My first interactive system on MINIC was a 12-bed patient monitoring system for the intensive care ward at University College Hospital. It had 1Kbyte of main memory, a 64Kbyte storage drum, and provided graphic output on temperature, respiratory rate and heart rate, over a period of time for a patient selected by the physician. The major market for MINIC, however, was not this type of intended application but rather the programmed control of machine tools where its microprogram allowed cost-effective control of the servo loops. This success in an area of which I knew nothing is another example of the serendipity that is prevalent in the development of technology and ideas.

The mention of computer architectures, programming and interaction in the example above is a reminder that the learning curve of integrated circuits was not the only factor in the evolution of computing. The nine orders of magnitude increase in the number of transistors on a chip has depended on the use of the computer to support the design and fabrication of such circuits. This is an example of a positive feedback loop within the evolution of computers, that the computer industry has achieved a learning curve that is unique in its sustained exponential growth because each advance in computer technology has been able to support further advances in computer technology.

Such positive feedback is known to give rise to emergent phenomena in biology (Ulanowicz, 1991) whereby systems exhibit major new phenomena in their behavior. The history of computing shows the emergence of major new industries concerned with activities that depend upon, and support, the basic circuit development but which are qualitatively different in their conceptual frameworks and applications impacts from that development. For example, programming has led to a software industry, human-computer interaction has led to an interactive applications industry, document representation has led to a desktop publishing industry, and so on.

Each of these emergent areas of computing has had its own learning curve (Linstone and Sahal, 1976), and the growth of information systems technology overall may be seen as the cumulative impact of a tiered succession of learning curves. Each curve is triggered by advances at lower levels, and each supports further advances at lower levels and the eventual triggering of new advances at higher levels (Gaines, 1991).

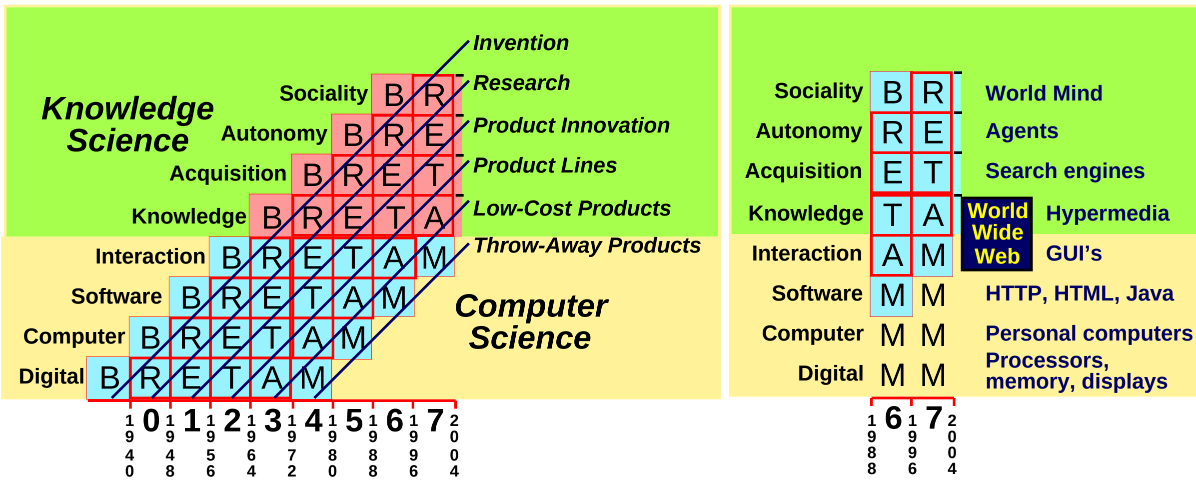

Figure 1 The infrastructure of information technology (left) and its role in the World Wide Web (right)

It has also been noted in many disciplines that the qualitative phenomena during the growth of the learning curve vary from stage to stage (Gaines and Shaw, 1986). The era before the learning curve takes off, when too little is known for planned progress, is that of the inventor having very little chance of success but continuing a search based on intuition and faith. When an inventor makes a *breakthrough*, his or her work is *replicated* at research institutions world-wide. Experience gained leads to *empirical* design rules with little foundation except successes and failures. As enough empirical experience is gained it becomes possible to model the basis of success and failure and develop *theories*. The theoretical models make it possible to *automate* the manufacturing processes. Once automaton has been put in place effort can focus on cost reduction and quality improvements in a *mature* technology.

Figure 1 left shows a tiered succession of learning curves for information technologies in which a breakthrough in one technology is triggered by a supporting technology as it moves from its research to its empirical stage. The initial sequence of technologies is those of *computer science*: digital circuits; computer architecture; software engineering; and human-computer interaction; followed by those of *knowledge science*: knowledge representation; knowledge acquisition; autonomous agents; and socially organized agents.

Also shown are trajectories for the eras of *invention*, *research*, *product innovation*, *long-life product lines*, *low-cost products*, and *throw-away products*. One phenomenon not shown on this diagram is that the new industries can sometimes themselves be supportive of further development in the industries on which they depend. Thus, in the later stages of the development of an industrial sector there will be a tiered structure of interdependent industries at different stages along their learning curves.

8. THE GROWTH OF THE INTERNET

The *Request for Comments* (RFC) that answers the question "What is the Internet?", offers three different definitions (Krol, 1993): *a network of networks based on the TCP/IP protocols; a community of people who use and develop those networks; a collection of resources that can be reached from those networks*—which nicely characterizes the net in Worlds 1, 2 and 3.

The Internet came into being through serendipity rather than design in that the intentions and aspirations of their originators had little relation to what they have become. The Eisenhower administration reacted to the USSR launch of Sputnik, the first artificial earth satellite, in 1957 with the formation of the Advanced Research Projects Agency (ARPA) within the Department of Defense to regain a lead in advanced technology. In 1969 ARPANET (Salus, 1995) was commissioned for research into networking with nodes at UCLA, UCSB and the University of Utah. By 1971 ARPANET had 15 nodes connecting 23 computers and by 1973 international connections to the UK and Norway had been created.

Use of ARPANET by the scientific and engineering communities grew through the 1970s and in 1984 the National Science Foundation funded a program to create a national academic infrastructure connecting university computers in a network, NSFNET. In 1987 the net had grown to such an extent that NSF subcontracted its operation to Merit and other commercial providers, and in 1993/1994 the network was privatized and its operation taken over by a group of commercial service providers.

Email on the Internet commenced in 1972, news distribution in 1979, gopher in 1991, and web browsers with multimedia capabilities in 1993. Existing use encouraged further use leading to exponential growth in the number of connected machines of 100% a year. The growth to over one million nodes, the growing commercial usage of the Internet, and the multimedia capabilities of the web in the 1993/1994 period combined to persuade government and industry that the Internet was a new commercial force comparable to the telephone and television industries, and the concept of an *information highway* came into widespread use.

9. THE GROWTH OF THE WEB

The need for better technologies to manage the growth of human knowledge was recognized before the advent of the computer. Wells promoted the concept of a "*world brain/mind*": "*Encyclopaedic enterprise has not kept pace with material progress. These observers realize that the modern facilities of transport, radio, photographic reproduction and so forth are rendering practicable a much more fully succinct and accessible assembly of facts and ideas than was ever possible before.*" (Wells, 1938)

Bush proposed a technological solution based on his concept of *memex*, a multimedia personal computer: "*There is a growing mountain of research. But there is increased evidence that we are being bogged down today as specialization extends… The difficulty seems to be not so much that we publish unduly in view of the extent and variety of present-day interests, but rather that publication has been extended far beyond our present ability to make real use of the record.*" (Bush, 1945)

Martin's model of a "*wired society*" in 1978 comes closest to forecasting many aspects and impacts of the information highway: "*the technology of communications is changing in ways which will have impact on the entire fabric of society in both developed and developing nations.*" (Martin, 1978)

However, attempts to make available the wired society at the time of Martin's seminal work were presented in terms of greatly exaggerated expectations. For example, Fedida and Malik presented Viewdata as having the potential to have major social and economic impacts: "*We believe that Viewdata is a major new medium according to the McLuhan definition; one comparable with print, radio, and television, and which could have as significant effects on society and our lives as those did and still do.*" (Fedida and Malik, 1979)

Ten years after Viewdata, in 1989 Tim Berners-Lee presented CERN with a proposal for managing its documents effectively that over the next decade became through a series of serendipitous processes the World Wide Web as we know it today: "*We should work toward a universal linked information system, in which generality and portability are more important than fancy graphics techniques and complex extra facilities.*" (Berners-Lee, 1989)

The web was slow to emerge as a viable technology and in the early 1990's the gopher protocol that had been developed for campus-wide information services was rapidly coming into use as a way of sharing structured databases of documents (Anklesaria, McCahill, Lindner, Johnson, Torrey and Alberti, 1993). However, in November 1992 Marc Andreessen joined the *www-talk* list server that Berners-Lee had established in October 1991 asking: "*Anyone written code to construct HTML files in Emacs? I'm hacking something up; let me know if you're interested*", and the development of the web began to change as Marc moved into the development of what became the *Mosaic* browser and eventually *Netscape* and *Internet Explorer*.

Tracking the development of the web is simple since the email correspondence that Marc used to discuss the design of Mosaic remains available through the email archives of the *www-talk* list—the modern equivalent of Oldenburg's correspondence.

Unfortunately, librarians have been slow to realize the value of archiving list servers and data is being lost that is invaluable to the study of the significant human activities now taking place through the Internet. The web provides a reflexive technology through which we can understand not only the growth of the web but also the wide range of human knowledge processes it now mediates.

Examination of the *www-talk* archives illustrates serendipity in the design of Mosaic. Features incorporated for one purpose proved even more valuable for unforeseen purposes. A major example is the discussion about where the search terms text box should be placed in the browser window. Marc got annoyed with all the suggestions and complaints and decided to embed it in the document being viewed. At 3am on 19th August 1993 he mailed to the list: *"You may be happy to know that I have before me a Mosaic running a quite revised HTML widget, thanks to Eric's kamikaze work ethic, that includes the following features…(BTW, this also means that putting widgets -- e.g., Motif text entry fields, etc. -- inside the HTML widget suddenly got a lot simpler and therefore should be arriving soon.)"* The embedding of HCI widgets in documents was revolutionary in allowing them to be used as graphic user interfaces and radically changed the nature of the web as web browsers became universal interface.

The BRETAM tiered learning curves infrastructure of Figure 1 brings together the various phenomena of convergence in an integrated model which has the potential both to explain the past and forecast the future of the web. The relevant learning curves in Figure 1 are the lower four: digital electronics; computer architecture; software; and interaction. The *product innovation* trajectory passes through the last of these in the fourth generation, 1972-1980, and led to the premature development of Viewdata and to Martin's detailed forecasts of the potential for a wired society. However, the mass market potential for wired society technology at costs comparable to other mass media such as the telephone and television is dependent on the cost reductions possible in the post-maturity phase of the learning curves leading to *throw-away products*. This trajectory passes through the interaction learning curve in the current seventh generation era, 1996-2004, and it is this that has made the information highway economically feasible.

The analysis of product opportunities arising from the existence of the information highway involves the upper learning curves of the BRETAM model—knowledge representation and acquisition, autonomy and sociality. Knowledge representation and processing encompasses all the media that can be passed across the web, not just the symbolic logic considered in artificial intelligence studies but also typographic text, pictures, sounds, movies, and the massive diversity of representations of specific material to be communicated.

The significance of discourse in the human communities collaborating through the Internet has been underestimated in the stress on 'artificial' intelligence in computer research. Knowledge need not be machine-interpretable to be useful, and it can often be machine-processed, indexed and enhanced without a depth of interpretation one might associate with artificial intelligence.

There are socio-economic problems with the web in that much represented knowledge is owned by copyright holders who seek some financial reward. Technologically it is important to develop ways of charging for access to knowledge at a low enough rate to encourage widespread use at a high enough volume to compensate the knowledge provider. The knowledge-level problem for the information highway is not so much representation and processing but rather effective trading.

10. CONCLUSIONS—THE FUTURE

Those of us who can no longer function without access to the resources of the Internet may sympathize with an earlier insight into human relations with the previous generation of technology: *"Leave us to ourselves, without our books, and at once we get into a muddle and lose our way - we don't know whose side to be on or where to give our allegiance, what to love and what to hate, what to respect and what to despise. We even find it difficult to be human beings... and are always striving to be some unprecedented kind of generalized human being...Soon we shall invent a method of being born from an idea."* (Dostoyevsky, 1864)

How prophetic this seems today, but also how one sided—the *underground man* has surrendered to despair, to be an unwilling passenger in World 3, not an architect, a builder, or even a free-wheeling traveler. The positive side of Dostoyevsky's insight is that technology may play a role in enriching our humanity, particularly in extending our access to the network of ideas since much of what we value has always been 'born from an idea'.

In this article I have shared with you perspectives on the future of computing and HCI that drive my anticipations of what will be reported in the *International Journal of Human-Computer Studies* in the next millennium. Whereas the foundations of HCI for the past 30 years have been cognitive psychology, I would see the future as having a broader basis in sociology, economics, anthropology, politics, and other models of the lifeworld. Perhaps cognitive psychology will come to encompass these communal aspects of humanity. However, I doubt that any systematic framework is possible that captures the nature of humanity.

We are essentially open systems, open to experience and open to our own processes of redesign. We can choose to exhibit whatever social theories interest us, although some may be rather more comfortable than others. I sympathize with Castoriadis's (1987) emphasis on the *imaginary institution of society*, and with Bourdieu's emphasis that reflexive sociology is *not* a system because its fundamental postulate is that no system can describe the lifeworld (Bourdieu and Wacquant, 1992).

Let me conclude with another quotation: *"It is our duty to remain optimistic…The future is open. It is not predetermined and thus cannot be predicted—except by accident. The possibilities that lie in the future are infinite…all of us contribute to it by everything we do: we are all responsible for what the future holds in store."* (Popper, 1994) This is a nice prescription on which to end.

There is joy and creativity in being optimistic, and it is a state of mind, not a response to circumstances. All interesting developments in HCI were created in a spirit of optimism (as were many of the failures, but they were the stepping stones to success). This quotation also makes my title and theme a tautology—you and your systems will not be able to avoid contributing to the world mind. What matters is how effectively you and others learn from the experience of making that contribution.

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