COMPUTER SYSTEMS IN THE KNOWLEDGE ENVIRONMENT: A NEW MEDIUM

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ABSTRACT

Computer systems provide a new technology that is very significant in the knowlege environment, perhaps a **vehicle** with which to traverse it However, computer science operates primarily within the technology and does not aid our understanding of the sociocultural impact of the computer as a **mind-tool.** In this paper we propose to regard computers as providing a **new medium** for communication that can encode **expertize** and reproduce it through **conversation.** This model may be used to analyse the potential long-term effects of computer systems on the knowledge environment by analogy with the effects of past media developments on our sociocultural system.

INTRODUCTION

It has become common to talk of **conversational** interaction with a personal computer since the term was first used in the early days of interactive systems (Orr 1968). However, the analogy between people-people conversation and computer-people conversation has not been systematically developed. Part of the reason for this is that the analogy is too weak when applied only to the dialog between people and machines. Such dialog is superficially similar to human conversation at one level but also differs from it in many details -- it is somewhere in between the informality of people-people conversation and the formality of computer-computer protocols (Gaines & Shaw 1982, 1983a). In order to understand the computer's role in the knowledge environment we have to consider the wider analogy between other artificial aids to conversation, such books and the telephone.

This paper proposes that we consider computers as providing a new communications medium (Shaw & Gaines 1983). It is informal in that we are concerned here with exhibiting the phenomena of personal computers now and projecting this into the future, rather than providing a deep systemic model. That will involve combining a variety of forms of media models together with anthropological models of the impact of communication on the evolution of society, and then injecting into this some projections of the growing state of the art of computer technology. It is a massive endeavour that will only be of value if our conjectures based on current observations are soundly based.

In the next section we give a feeling for the key role of conversation in the evolution of our society. More formal material may be found in works such as Hahn and Simmel's (1976) **Communicative Behavior and Evolution,** Innis's (1972) **Empire and Communications,** Ong's (1974) **The history and the future of verbal media,** and our own **The Human Protocol** (Gaines & Shaw 1983b).

CONVERSATION AND CULTURE

From an early age we talk to one another. Conversation is a natural activity to us in our everyday lives. What is it? Not just communication because that may be in one direction only. Conversation is **interactive communication** that is two-way or many-way. In this sense all animals have some form of conversation. Some, such as territorial and courtship rites, can be very elaborate. However, the human species has developed the art of conversation to its highest level, employing a range of symbols and forms of expression to pass feelings, information, knowledge and skills between people. Many of our tools and much of our technology have

been developed solely to enhance our capabilities to carry on conversations.

Human beings are already remarkable for their immense capability to learn from experience. We are able to adapt to a range of climates, environments and societies as no other animal species can. However, the advantages of our species' learning capabilities are amplified immensely by our ability to receive and impart information through conversation. The child in the jungle need not feel the injury of being mauled by a tiger in order to learn to fear the animal. Instead he can be told that the animal is dangerous and he should take care to avoid it. He can also be told how to look out for the signs of new dangers.

This capability of learning indirectly from conversations rather than direct experience - and of learning how to learn by discussing learning itself - has been crucial in the development of our civilization. To take advantage of it we have developed mechanisms that enable us to communicate over time and over distance: such as the letter, the newspaper, the book, the radio, the telephone, the television, the record, the tape. The remarkable nature of books can be seen from their capability to allow those long dead to impart their feelings and knowledge to those alive now and in the future. The remarkable nature of television can be seen from its ability to bring those far away into personal contact with events as they happen. Videotapes extend that ability across time as well as space. Transcending time and space adds new dimensions to the already dramatic powers of the human capabilities to learn from experience and to learn from conversation. New media provide new extensions to ourselves and radically affect our, and our societies', modes of existence.

PROGRAMS ARE TWO-WAY CONVERSATIONS

Both books and television are one way media. They are not able to support two way conversations. They do not allow us to interact with the author of the book or with the events being portrayed. We can think of correspondence through letters as being a conversational form of a book. We can think of discussion on a telephone or videophone as being a conversational form of radio or television. Now computers have been added to this range of mechanisms for extending human conversations. They are remarkable in enabling us to interact with a program in a similar way to that in which we interact with a person. They are remarkable in enabling us to encode the expertize of a person.

We can think of computer programs as being a way of extending interaction through time and space. When I listen to a gramophone record I can imagine I am at a concert hearing the artist perform. When I read a book I can imagine that I am hearing the words spoken to me by the original author. If it is a narrative then I can imagine the author playing the part of the character telling the story. Similarly, when I enter into a dialog with a computer program I can imagine that I am interacting with the programmer who wrote it, perhaps playing some role. Unlike the performer or the author, the programmer is able to provide responses to my interventions -- in some way to interact with me although he may be far distant or dead.

With computers we can record and disseminate not just a passive encoding of information to be replayed but rather an **active process** with which the recipient can interact. For example, we can program a model of a chemical system so that someone without access to the materials and equipment required to create it can still experiment with that system. We do not tell them about it, describing our experiences, but rather pass it to them in such a way that they can generate their own experience. They make their own decisions about what to do with the equipment and materials, and the model replicates what would have happened had they done this with the actual process.

Whether simulation is adequate to replace actual experience is not an absolute question but depends on the quality of the simulation and the function of the experience. Whether the interaction with a computer program is a realistic experience of interaction with the programmer is also a question of the quality of the simulation. The programmer may not be attempting to simulate interaction with himself, but rather than with another person or a physical system. However, it seems likely that some aspect of his own personality will always intrude.

ADVENTURE GAMES

Simulation of an interesting and exciting real-world or fantasy environment is the basis of many of the games now played on computer systems in the home. You are a fighter pilot in a world of enemy aircraft and must fight aerial battles using skill in control of craft and weapons. You have free access to an elaborate pinball machine with a wide range of exotic features of varying difficulty. You are an athlete attempting various feats of skill and endurance. You are coach for a football team and must define its strategy -- if you stick to the same winning strategy too long then your opponents will acquire a defense against it. You are a businessman setting up a company in a world with certain raw materials, manufacturing processes and a population with defined, but unknown, comsumption patterns.

During recent years such games have become increasingly elaborate, involving whole worlds of activity on land, sea and air. They have also made more and more use of the rapidly improving color graphics and sound effects available now on even low-cost computers. Some later games take into account moral concepts such as "good" people becoming less cooperative with you if you undertake "bad" actions. This could be significant to the teaching impact of the games since the early ones incorporated a simple model of life, that you took or killed everything in sight and that most other entities in the game were enemies. This is similar in its morality to the "Western" film genre which has been a natural foundation for the early popular games.

There are less apparent social consequences of playing with computers. It has been found that children learn to play games more readily with computers than with other children, probably because of the lack of significant social consequences. In an ordinary game if I win then you lose. You may not like losing so much that I suffer in consequence. Most computer games do not have such overtones, and this makes them easier to learn and to play. However, they also do not teach children how to cope with social interaction as does the game playing experience of real life. There is much to be learned about the social consequences of computer systems as a new medium.

THE INTERACTIVE NOVEL

On the basis of such games we can envision a novel of the future in which the author has precisely portrayed a group of characters and a situation but in which the way the situation is played out is affected by the behavior of the 'reader'. For example, the reader may adopt the role of one of the characters and interact with the others as part of the plot. What then happens is not determined in advance but varies according to the reader's actions and the other characters' reactions to them. This interaction with the plot is not normally found even in the theatre but has been the subject of a number of unconventional experimental productions encouraging audience participation.

Much of the writers' task is the same for the book, the play and the computer program, and he may well be able to generate a script that can cope with varying behavior on the part of some or all of his characters. However, the complexities possible with an interactive novel are clearly very much greater than those with a static book. The problems of the novelist with a participant reader are not as severe as those of the chemist programming the simulation of a chemical system for there is no absolute reality against which to judge the results. The participant reader may find that even his most outlandish behaviour is somehow absorbed and accepted by the others without a marked deviation from the plot, or that the character he plays quietly meets his demise through an unfortunate accident!

If we are able to simulate the personalities and behavior of characters in a novel then we can also think of simulating ourselves and making access to us available through a computer program. The active process that the computer simulates may be not just a physical system but instead yourself in some guise, as teacher, friend, game player or expert upon some subject. When I write a book I present some of my knowledge, opinions or skills and some of the background material, experience, arguments and results supporting them. However, I cannot possibly put together in the linear sequence of a book all the answers to the questions the reader may ask, all the alternative ways of presenting the material, all the forms of additional development that might occur if we were talking together. With an

active model of at least part of me recorded in a computer program I can provide some of these variations to be generated through a later conversation between the user and my computer model.

EXPERT SYSTEMS

The simulation of people in the roles of experts on some topic as a computer program has become an important application of computers. It has generated a new industry based on creating **expert systems** (Michie 1979) to make the practical working knowledge of a human expert in a specific subject area such as medicine or geology widely available to those without direct access to the original expert. Programs now exist that have made practical achievements in medical diagnosis, interpretation of mass spectrometry results, analysis of geological survey data, and other problems where one would normally go to a human expert for advice.

MYCIN (Shortliffe 1976)is one of the best known expert systems and was designed to make a diagnosis and suggest therapy for patients with microbial infections. The expertize embedded in MYCIN is encoded as a set of rules of the form:

RULE 50
If 1) the infection is primary-bacteremia, and
2) the site of the culture is one of the sterile sites, and
3) the suspected portal of entry of the organism is the gastrointenstinal tract,
Then there is suggestive evidence (.7) that the identity of the organism is bacteroides.

Such rules involving fuzzy reasoning are obtained from specialists in microbial infections and their application to particular data is fairly simple data processing. The rules are validated through their application to many cases and revized when they fail to give the correct diagnosis. A very interesting later development is TEIRESIAS (Davis & Lenat 1982), a system designed to help clinicians develop MYCIN's rules. This uses meta-level reasoning about the operation of MYCIN and the likelihood of rule structures to guide the clinician.

The ultimate meta-level expert system currently is AM (Davis & Lenat 1982), a program which searches for "interesting" conjectures in mathematics using rules of the form:

19.
If concept C possesses some very interesting property lacked by one of its specializations S,
Then both C and S become slightly more interesting.

38.
If there are no known examples for the interesting concept X,
Then consider spending some time looking for such examples.

AM seems to embody the highest level of scientific creation -- looking for the patterns underlying knowledge. What is remarkable about AM is the very notion of what it is doing. The concept of something being interesting seems peculiarly human and certainly too vague to form the basis of a computer program. However, AM is able to exhibit not only meaningful conjectures in mathematics but also meaningful ways of arriving at them. In an application to number theory it arrives at prime numbers by considering numbers with the smallest number of factors and discovers Goldbach's conjecture, and the Fundamental Theorem of Arithmetic. It is judged by the quality of its musings as it considers what it is doing.

AM uses a few hundred such rules most of which are sufficiently general to apply to other situations. Rule 19, for example, indicates that a committee which has decision-making powers that do not apply to its sub-committees below a certain size has an interesting property, that of requiring a quorum. Its sub-committees also have an interesting property, that of being quorate. AM's rules form a good "code of curiosity" that might form the basis of a religion -- perhaps it already exists, called science. One can envision a program such as AM searching for analogies leading to interesting conjectures in general systems theory.

What is remarkable about developments such as MYCIN and AM is that they are concerned with recording what had previously been regarded as very high level human expertize, difficult to explain to another person let alone program for a computer. However, from our previous discussion it seems reasonable to regard such programs only as one further advance in recording human expertize and simulating the human

expert at work. An accountancy program for a business that keeps track of purchases and sales and prepares invoices, purchase and sales ledgers, and so on, may be seen as the recording of the expertize of an accountant for use by an ordinary businessman. An auditor evaluating such a program may expect to be able to ask it exactly those questions he would ask the accountant, for example, from what original information did you calculate this figure? If the program does not have built into it "audit trail" facilities which enable it to answer such questions then it is inadequate in exactly the same way that an accountant would be who could not answer that question -- it is a simulation of a poor accountant.

EXPERT, PROGRAMMER AND USER

One of the peculiarities of computer systems is the role of the programmer. We can now see his task as being that of encoding expertize in such a way that it is accessible to another person through a computer. This clarifies the two differing aspects of the programmer's role that have come out in this discussion: sometimes he appears to be encoding a model of himself whereas at others he appears to be attempting to encode that of another. In practice he is doing both and the final product, currently, usually shows some form of composite personality.

The diagram of Figure 1 shows how the interaction between expert, programmer and user in using the computer to carry expertize divides into various areas of overlap. First consider the three areas where there is no overlap. These are where the individuals involved do not need shared knowledge to carry out their tasks. The expert, for example a lawyer, will have deep knowledge of the principles underlying his skill on which it is based but which is irrelevant to its actual application. The programmer does not need access to this knowledge to encode the skill and neither does the user in replicating the skill. Similarly the programmer will have deep knowledge of software engineering techniques which are necessary to his task but irrelevant to either expert or user. The user also will have knowledge of the particular circumstances in which he is using the program that will modulate his use of it but will be unknown to either expert or programmer.

The overlap between expert and programmer is necessary to enable the programmer to obtain from the expert a specification of his skill. This is a form of **system analysis**, often treated as a separate exercise from actual programming. The user need not understand the skill at this level of detail in order to make use of the program. The overlap between user and programmer enables the user to carry out interaction with the program. It is where the programming of dialog, independent of subject matter, can be considered. The programmer may well be setting up the computer to do something which the expert himself cannot do -- communicate his skill so that it can be applied by another.

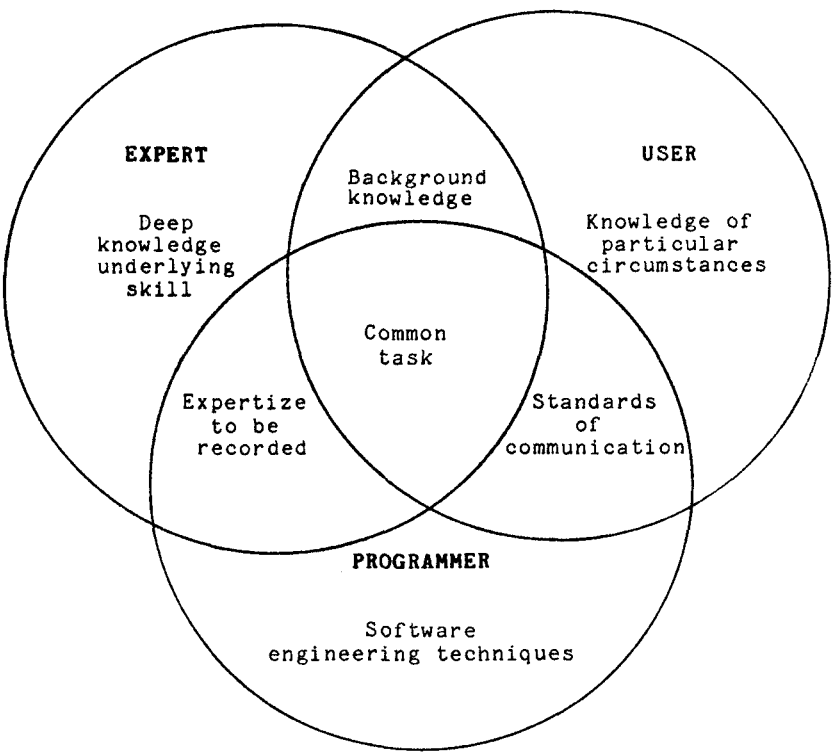

Figure 1 Programmer, Expert and User Relationships

Finally, there is an area of overlap between expert and user which need not concern the programmer. It is one of common background knowledge in the profession whereby the user is applying the expertize in the program not blindly but in a sensible way. It is this need for skill in the application of a tool that makes some professions reluctant to release their recorded skills for general use. A medical, legal or accounting textbook in the hands of a lay person may suggest courses of action which are inappropriate because of more general considerations. The results of a psychological test that can be carried out by anyone using a computer may be misinterpreted without training in interpretation. However, encoding more and more of this background knowledge is the major challenge in developing a next generation of widely applicable computer systems.

CURRENT LIMITATIONS ON COMPUTER MEDIA

The computer as a new medium for conversation is still very much in its infancy. Today's personal computers have neither the picture and sound generation capabilities nor the data storage to emulate the presentation possible with television. However, the personal computer today has greater speed, processing power and storage than the vast research machines of ten years ago and has become small enough, cheap enough and reliable enough to take its place in the home. The giant computer technologies of today are at the heart of the movie industry producing sounds and images that are as realistic as those of everyday life. It is not unreasonable to suppose that those capabilities will become available in personal computers during the next ten years.

A more severe limitation on the use of the computer to record models of active processes is our lack of understanding of them. I may know enough about a chemical system to write a program which faithfully reproduces all of its behavior that I have observed. However, will my program produce behavior which I have never observed when you interact with it in ways that I have never even contemplated?

All new media have had initial limitations and gone through phases of improvement and development. The wax cylinder gramophone could not sustain the record industry of today and neither could Baird's spinning disk support television as we now know it. The personal computers of today already provide an impressive new conversational medium for entertainment, education and business. The medium is already adequate for many significant applications and we need to understand how to use it as it is now, how to take into account its current limitations, and how to take advantages of improvements in the medium as they occur.

CONCLUSIONS

The media of communication for mankind are at the heart of our culture. Each new medium is assimilated into society and used for some of the applications of previous media. It also provides different facilities which allow for new applications that change the fabric of society itself. Unless we are aware of these two processes going on as computers enter our culture we will not understand what is happening, to our ourselves and to our society. Computers provide a new medium for communication that will be used in part to mimic those already existing but will also change profoundly our society and modes of thinking in ways that we are not able to predict.

Emphasis on our inability to predict social change has historic justification. After the change has occurred we can generally find thinkers who have discussed the possibility. However, we are not able to determine in advance which of the many thinkers and possibilities are correct. The new Republic of the French Revolution lasted only until Napoleon and that of Plato never came about. We are only now beginning to understand the role in the formation of modern society of the transition from oral to written communication.

Whether the change resulting from the use of computer media will be for good or evil is also an open question and dependent on individual circumstances and viewpoint. All change leads to opportunities for some and problems for others. Social change is often associated with strife. As value systems change, groups of people find that their particular interests are being undermined. Some of them accept this and adapt to change. Others do not and attempt to resist the change itself. To

do so they may use any of the mechanisms of persuasion open to them, including violence.

Resistance to change can be successful if there are sufficiently widespread interests at stake. Atmospheric nuclear rockets and explosions were stopped through the weight of public opinion. River and air pollution in general is on the decline. It is too early yet to determine whether the increasing use of computers will lead to strife, and whether some possible applications will be so widely unacceptable as to be rejected. Legislation associated with the use of computers is growing worldwide.

The emphasis of the computing industry has tended to be, not unnaturally, upon computers themselves. We talk of **computer science** without noticing how curious this is -- if the computer is a tool analogous to other tools this is like talking of "pencil science" or "typewriter science". In recent years the emphasis has begun to swing from the computer itself to its programs, **software engineering**, and data manipulation, **information science.** In fact we have been uncertain about how to regard computer technology and this is not surprising since our use and understanding of it are still at an early stage. We are all computer primitives. The development of expert systems and the realization that this is what we have all along been attempting to achieve, and achieving, points to one possible resolution of our dilemma. We can now see the computer as a new medium for carrying encoded expertize. When you write a computer program you are encoding the expertize of a person to make it accessible to others. You are providing the skills of the expert in traversing the knowledge environment as a vehicle for others (Gaines 1979).

This viewpoint stresses our need to understand the nature of expertize at least as much as we understand the other technologies underlying computer applications. The software and hardware are carriers and reproducers of encoded expertize. We need to understand the nature of that expertize. Perhaps the ecological analogy that gives the knowledge environment the same ontological status as the physical environment can provide us with a frame of reference with which to understand the impact of computer systems as a new medium upon our socio-cultural system. The computer in the knowledge environment offers exciting new possibilities. It also generates new, and unknown, dangers.

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