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Fifth-generation computing as the next stage of a new medium

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ABSTRACT

Computer systems provide a new technology that is very significant to human society and culture. However, computer science operates primarily within the technology and does not aid an understanding of the sociocultural impact of the computer as a mind-tool. This paper proposes to regard computers as providing a new medium for communication that can encode expertise and reproduce it through conversation. This model may be used to analyse the potential long-term effects of computer systems by analogy with the effects of past media developments on our sociocultural system. In particular, the Japanese fifth-generation computer development program may be seen as completing just those aspects of computer technology necessary to enable it to compete with other media.

INTRODUCTION

It has become common to speak of *conversational* interaction with a personal computer since the term was first used in the early days of interactive systems.[1] In recent years computing has been regarded as being part of a range of *electronic media.*[2] However, the analogy between people-people conversation and computer-people conversation has not been systematically developed. The analogy has not been explored between the use of computers to present information and experience and the use of other media such as books and television.

This paper presents a discussion of computing as providing a new medium.[3] The conversational and media analogies are shown to have formal foundations. Computing is identified as providing a two-way interactive medium for providing experience of worlds through simulation. This simulation can include that of other people and hence provide access to their encoded expertise.

What is particularly significant about this viewpoint is the light it throws on the objectives of current fifth-generation computer developments.[4] Computing provides a new medium with the unique property of being *two-way* and *interactive* with an encoded message, but the technology is currently limited. The logic behind the fifth generation may be seen as that of overcoming precisely those limitations of computers through which they lag behind other media.

CONVERSATION IN OUR SOCIETY AND CULTURE

From an early age people speak to one another. Conversation is a natural activity in every person's daily life. 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 tools and technology have been developed solely to enhance the capabilities to carry on conversations.

Human beings are already remarkable for their immense capability to learn from experience. They are able to adapt to a range of climates, environments, and societies as no other animal species can. However, the advantages of the human species' learning capabilities are amplified immensely by their 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 civilization. To take advantage of it, mechanisms have been developed 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 ability 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 capability of learning from experience and from conversation. New media provide new extensions to everyone and radically affect our and our societies' modes of existence.[5,6,7]

PROGRAMS ARE TWO-WAY CONVERSATIONS

Books and television are one-way media. They are not able to support two-way conversations. They do not allow an interaction with the author of the book or with the events being portrayed. Correspondence through letters may be regarded as being a conversational form of a book. Discussion on a telephone or videophone may be regarded as being a conversational form of radio or television. Some computers have been added to this range of mechanisms for extending human conversations. They are remarkable in enabling the interaction with a program similar to the interaction with a person.

Computer programs are a way to extend interaction through time and space. When listening to a gramophone record one can imagine being at a live concert hearing the artist perform. When reading a book one can imagine the words spoken by the original author. If the book is a narrative, one can imagine the author playing the part of the character telling the story. Similarly, in a dialog with a computer program one can imagine interaction with the programmer who wrote it. Unlike the performer or the author, the programmer is able to provide responses to interventions, in some way to interact although he or she may be far distant or dead.

Computers enable the recording and dissemination of not only passive information but active processes with which the recipient can interact. For example, a model can be programmed of a chemical system so that persons without access to the materials and equipment required to create it can still experiment with that system. They are not told about it through a description of the experience, but rather it is made

available 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 another person or a simulated world depends on the technology and our capability to use it. Both of these are subject to continuing improvement.

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. The player is a fighter pilot in a world of enemy aircraft who must fight aerial battles using skill in control of craft and weapons. The player has free access to an elaborate pinball machine with a wide range of exotic features of varying difficulty. The player is an athlete attempting various feats of skill and endurance. The player is a coach for a football team who must define its strategy; if the same winning strategy is used too long then the opponents will acquire a defense against it. The player is a businessman setting up a company in a world with certain raw materials, manufacturing processes and a population with defined, but unknown, consumption 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 now available on low-cost computers. Some later games take into account moral concepts such as *good* people becoming less cooperative if *bad* actions are undertaken. This could be significant to the teaching impact of the games since the early ones incorporated a simple model of life in which everything in sight was taken or killed and most other entities in the game were enemies. This is similar in its morality to the western film genre that 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 writer's task is the same for the book, the play, and the computer program, and he or she may well be able to generate a script that can cope with varying behavior on the part of some or all of the 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 or her most outlandish behavior is somehow absorbed and accepted by the others without a marked deviation from the plot, or that the character played meets his or her demise through an unfortunate accident!

If the personalities and behavior of characters in a novel are simulated then we can also think of simulating ourselves, 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 on some subject. When I write a book I present 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[8] 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,[9] one of the best known expert systems, was designed to make a diagnosis and suggest therapy for patients with microbial infections. The expertise embedded in MYCIN is encoded as a set of rules of this 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 gastro-intestinal 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 revised when they fail to give the correct diagnosis. A very interesting later development is TEIRESIAS,[10] a system designed to help clinicians develop MYCIN's rules. This uses metalevel reasoning about the operation of MYCIN and the likelihood of rule structures to guide the clinician.

The ultimate metalevel expert system currently is AM,[10] a program that searches for *interesting* conjectures in mathematics using rules of this 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. 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 with decision-making powers that do not apply to its subcommittees below a certain size has an interesting property, that of requiring a quorum. Its subcommittees 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.

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 expertise, 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 expertise 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 expertise of an accountant for use by an ordinary businessman. An auditor evaluating such a program may expect to be able to ask it exactly the questions he or she 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 that enable it to answer such questions, then it is inadequate in exactly the same way an accountant would be who could not answer that question; it is a simulation of a poor accountant.

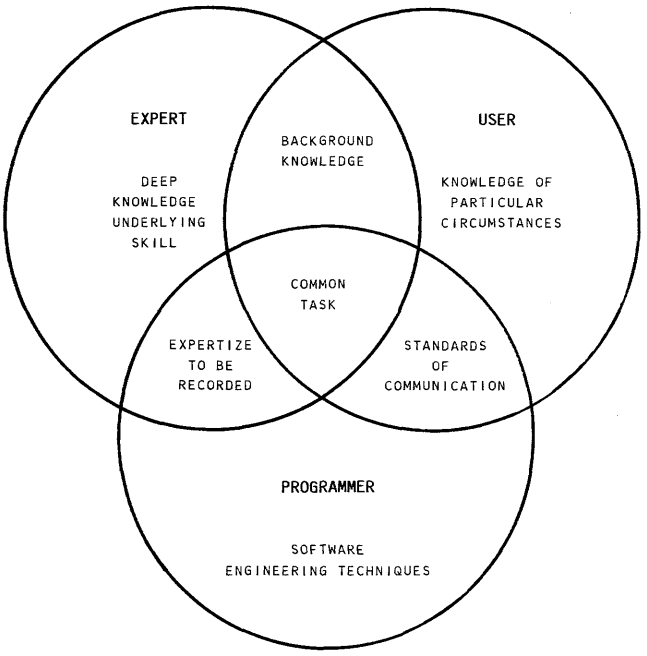

Figure 1—Relations between expert, programmer and user.

EXPERT, PROGRAMMER, AND USER

One of the peculiarities of computer systems is the role of the programmer. We can now see his/her task as being that of encoding expertise in such a way that it is accessible to another person through a computer. The diagram of Figure 1 shows how the interaction between expert, programmer, and user in using the computer to carry expertise 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 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 that 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 or she is using the program that will modulate the 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 an exercise separate 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 dialogue, independent of subject matter, can be considered. The programmer may well be setting up the computer to do something that the expert himself cannot do—communicate his skill so that it can be applied by another.

Finally, there is an area of overlap between expert and user that need not concern the programmer. It is one of common background knowledge in the profession, whereby the user is applying the expertise 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 that 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.

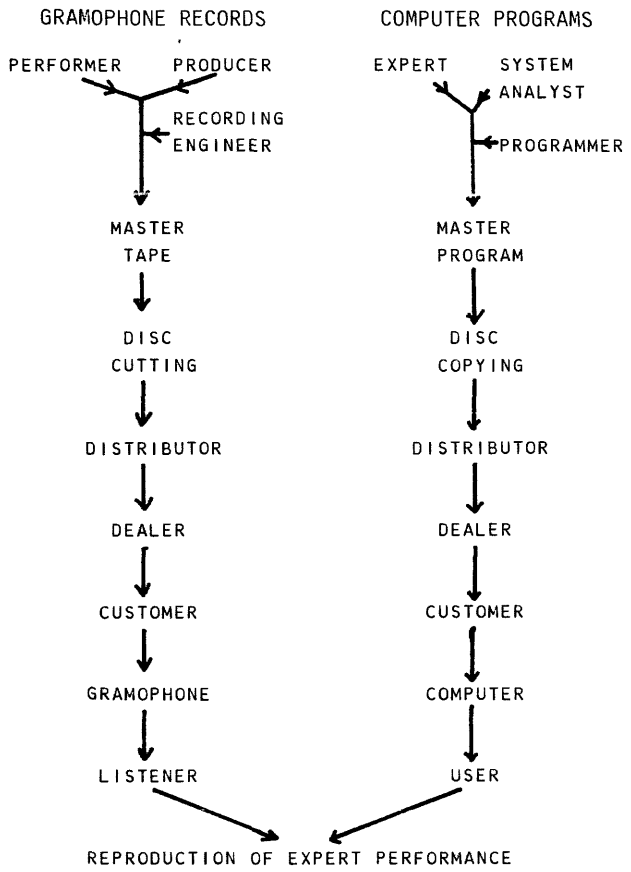

Figure 2—The recording chains for gramophone records and computer programs.

Figure 2 shows how the close analogy between computing and another medium, the gramophone, appears when this discussion is extended to include the remaining processes whereby programs for personal computers reach their users. The recording chain for computer programs and that for gramophone records are in one to one correspondence. This analogy underlies the growth of the personal computing industry, in which specialist software stores mimic record stores and in which computers and programs have taken their place alongside record players and disks in department stores. New media are marketed by analogy with the old.

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 that faithfully reproduces all of its behavior that I have observed. However, will my program produce behavior that I have never observed when interaction is made in ways that I have never 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 it is now known. The personal computers of today already provide an impressive new conversational medium for entertainment, education, and business. However, they cannot yet compete with television in their audio and video facilities. We mainly converse with them by typing at keyboards, not through speech. They can give access to vast stores of information, but they are not able to process it as knowledge. These limitations severely restrict the scope of the new medium as it is now, and it is precisely these limitations that the Japanese fifth-generation computer development program addresses.[3] Fifth-generation computers, if the objectives of the program are met, may be characterized as providing a two-way, interactive medium with the audiovisual facilities and knowledge processing to replicate all capabilities of the most advanced current one-way media.

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 that allow for new applications that change the fabric of society itself. Unless there is an awareness of these two processes going on as computers enter this culture, there will be no understanding of what is happening to individuals and to 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.

The emphasis of the computing industry has tended to be, not unnaturally, upon computers themselves. There is 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 there has been an uncertainty about how to regard computer technology; this is not surprising, since the use and understanding of it are still at an early stage. Everyone is a computer primitive. 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 expertise and making it available through conversation. Fifth-generation developments will enhance the facilities of that medium to equal and then exceed those of our previous media.

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