THE BANISHMENT OF PAPER-WORK

Arthur L. Samuel

(Formerly at IBM Thomas J Watson Research Centre
Yorktown Heights, New York)
Research Scientist
Department of Computer Science
Stanford University
Stanford, CA 94305

Editor's Note: In connection with the announcement of Professor Arthur Samuel as recipient of the 1983 IJCAI Distinguished Service Award, we thought you'd be interested in a prophetic article that he wrote for *New Scientist* nearly twenty years ago. It is particularly interesting to note how close to the mark he was in his predictions of the state of the art in hardware. However, in his own specialty area — learning — he underestimated the difficulty of developing systems that learn from experience. Perhaps if there were a few more Art Samuels around in 1964 he would have hit the mark on that one, too — *Bob Engelmore*

IT MAY COME AS A SURPRISE to some to be told that the modern digital computer is really quite old in concept, and the year 1984 will be celebrated as the 150th anniversary of the invention of the first computer the Analytical Engine of the Englishman Charles Babbage. One hundred and fifty years is really quite a long period of time in terms of modern science and industry and, at first glance, it seems unduly long for a new concept to come into full fruition. Unfortunately, Charles Babbage was ahead of his time, and it took one hundred years of technical development, the impetus of the second World War and the perception of John Von Neumann to bring the computer into being. Now, twenty years later and with several generations of computers behind us, we are

in a position to make a somewhat more meaningful prognosis than appeared possible in, say, 1948. We can only hope that we will not be as far off in actuality as we believe George Orwell to be, or as far off in our time scale as were Charles Babbage and his almost equally famous interpreter, Lady Lovelace

Where, then, will the computer be in 1984? Computers are not going to get much bigger; in fact, they are going to get very much smaller, that is smaller in physical size, while retaining all of their presently envisioned computational capabilities. They will, of course, have access to very much bigger memories, memories which in fact can contain the total sum of man's recorded information, but this is already technically possible today. Nor are computers going to get much faster. They may be faster by a factor of 100 or even by 1000, but not by anything like the factor of one million which has characterised the last twenty years' development. The finite velocity of light, and the discrete nature of matter and of energy, conspire to limit the attainable computational speed. Because of these limits the speed of our computers is not apt to change very much. We are learning a great deal about computer organisation, and we can expect some startling changes along these lines, but these changes will be more apparent to the computer designer than to the user.

The large changes, and they will be large, will come in the way in which computers will be used and in the extent

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to which they will permeate the entire fabric of our society. Let us try to visualise these changes.

In the first place we have good reason for predicting that two rather basic problems will by then have been solved. The first of these has to do with learning, or rather its absence. At the present time, computers do not learn from their experience. Given a new problem to be solved, no matter how similar it may be to a previously solved problem, we, as humans, must write a new set of instructions, a programme in the jargon of the trade, to specify the solution procedure. Not only this, but unless we make special arrangements to save old information, we frequently have to rewrite an identical set of instructions and even waste machine time be recomputing previously computed data. By contrast, when similar tasks are given to a human assistant, he is expected to learn from his experience; and a clerk who has failed to do so is likely to be looking for another position. This problem of machine learning should certainly have been solved well within the next twenty years, and the computer will then become a very much more useful device.

The second difficulty resides in the nature of the instructions which must now be given. The computer, today, accepts only imperative statements; it is a slave which executes our commands, and this without any ability to ask questions, volunteer information, discuss pros and cons with respect to solution methods, etc. In short, one cannot converse with a computer. Here, too, we can confidently look to a practical solution with a period short compared to twenty years.

Meanwhile, as a result of these two difficulties, we now find it necessary to employ a veritable army of people called "programmers" to write instructions for the computer. When these problems have been solved, programming as we now know it will have ceased to exist and the computer will then be a truly "intelligent" and reliable assistant.

A third current difficulty of a less basic sort will also have been solved within the next few years. It concerns the construction of simple input and output equipment for both oral and visual communication with the computer. This is already largely a problem of cost and, with time, we can expect to have extremely cheap and convenient terminals which will also be highly portable. Communication with a computer will then be easy and natural—as easy and natural as communication with an intelligent servant of the human variety.

Given computers that are perhaps 100 to 1000 times as fast as the fastest present day computers, computers with larger memories, computers which occupy perhaps one one-hundredth of the volume that they now do, computers that are much cheaper, and finally, computers which learn from their experience and which can converse freely with their masters—what can we predict?

To be completely realistic, we must postulate two quite different situations, the one in which nearly everyone has his own private computer, and the second situation in which the private ownership of computers is banned by law, but in which each person has access to a small terminal connecting

him with one or more large state-owned computers giving him most of the advantages of a small privately-owned computer, but without the opportunity for private, or perhaps some would say, clandestine operations. Capitalist countries will tend in the first direction while communist states will doubtlessly go in the second direction although even in these countries the "big brother is watching" aspect will be very much less pronounced than was predicted in 1948. Lest we of the West view this dichotomy with complacency, one must note that a trend toward the large central installation is also evident in the Western World. One might, therefore, expect that an immediate situation will develop in the West which private ownership of computers of limited capabilities which also serve as remote terminals to communicate with the centrally located computers for the solution of larger problems. Computers will in any case be as convenient to use and as readily available as the present day telephone.

Telephones, will, of course, be portable and connected via radio so that one need not be at any special location to obtain phone communication only with one's computer. Tele-video-phones via radio will be well developed although not yet in widespread use and the terminals will still be rather bulky, so that one may still have to go to fixed locations if one wishes video-communication with a computer.

Connection to a central location will be very necessary to perform another function which will, by then, be delegated to the omnipresent computer. I refer to information retrieval The entire contents of the large central files (or at least that portion which the government elects to make available) will be readily retrievable by anyone at a moment's notice. One will be able to browse through the fiction section of the central library, enjoy an evening's light entertainment viewing any movie that has ever been produced (for a suitable fee, of course, since Hollywood will still be commercial) or inquire as to the previous day's production figures of tin in Bolivia—all for the asking via one's remote terminal. Libraries for books will have ceased to exist in the more advanced countries except for a few which will be preserved at museums and most of the world's knowledge will be in machine–readable form. Perhaps it would be more correct to say, all of the world's recorded knowledge will be in this form since the art of programming computers to read printed and handwritten material will have been fully developed. However, the storage problem will make it imperative that a more condensed form of recording be used, a form which will only be machine-readable and which will be translated into human–readable form by one's computer on demand.

The consequences of this compilation and ready access to large amounts of stored information will be truly profound in many diverse fields, such for example as, agromony, jurisprudence and medicine, to name but three. But all this is another subject.

Computers will perform yet another major function—that of language translation. Not only will one be able to obtain information from the central files in the language of

one's choice, but automatic translation via the telephone will also have come into use—although perhaps not general use, because of the cost and because the gradual drift toward a universal language. It will, nevertheless, be possible to dial anywhere in the world and to converse with anyone speaking a different language with only a slight translation delay to allow for the differences in sentence structure and a word-ordering between the languages.

Perhaps we should mention teaching machines, which will have been developed to such an extent that master-computers of large capacity will be needed, each to direct many slave-teaching machines and to compile data from them. These master-computers will alter teaching methods on the basis of experience. They will up-date the material and its ideological slant as dictated by scientific advances and the changing mores of society. While it will be entirely feasible to obtain an education at home, via one's own personal computer, human nature will not have changed, and there will still be a need for schools with laboratories, classrooms and individual teachers to motivate the students.

So far, we have talked primarily about the individual user and his personal use of the computer, but the digital computer is destined to play an even bigger role in the real-time control of projects and processes. The coordination and scheduling of any large endeavour whether it be running a business, operating a factory, constructing a large building or running a government, now takes a fantastic amount of paper–work. This paper–work will cease to exist in twenty years. Instead, direct inputs and outputs to the computer will provide information, initiate the necessary processes (all computer controlled by a lesser breed of computers), and finally issue what few instructions are needed for the few people who are still involved.

Process control with the attending automation, while delegated to simpler computers, will have reached a very high degree of development so that the number of factory employees will drop precipitously. These displaced people will be going into the service industries, and a few into the design and maintenance of the machines which replace them. Science and the arts will be flourishing. The working week will have been shortened to four days, but we shall have an unemployment problem Making this due prediction will, of course, help to nullify it. Many people (including the author and his associates) are taking steps to make the transition to automated production an orderly one without socially undesirable side–effects.

Finally, a word regarding solid intellectual achievements of computers. The world draughts, chess and go champions will, of course, have met defeat at the hands of the computer, but strangely enough this will not have ended these three games either as intellectual pastimes or as professional career activities It is true that matches between people will be less common, but nearly everyone will know his precise rating as a player and he will endeavour to improve his ability by playing against his computer. Computers will have largely taken over the task of composing and arranging music, at least for popular entertainment, and many people will vie with each other in regard to the quality of mood music which their own personal computer, or personal programme can produce. As far as literature is concerned, the computer will still be a neophyte although "who-done-its" will be turned out by the million. Computers will not have contributed as much as some people have predicted, with respect to making basic contributions to mathematics and science and, somehow or other, all attempts to invest them with truly creative abilities will have failed.

There will still be a place in the world for people!