dumb systems can be of considerable use. Their uses are encouraged when, in the short run, they benefit their users, while the harm they cause to others is remote and largely invisible. Moreover, architects of systems that initially appear to function well are usually richly rewarded until and often even long after their systems' faults have become obvious and the harm they have done has become irreversible. This last observation holds true even for systems that have nothing directly to do with computers: witness, for example, the fate of the coterie of American "statesmen" who led America into the Vietnam war.

On the other hand, the impressive number of comprehensible though large computer systems that exist in the scientific domain, in chemistry, physics, mathematics and astronomy, teach us that incomprehensibility is not a necessary property of even huge computer systems. The secret of their comprehensibility is that these systems are models of very robust theories. One can tell when they go wrong, for example, because the errors they then produce result in behaviour that contradicts their theories. What this should teach us is that the construction of reliable computer systems in the social and political sphere awaits not so much the results of research in computer science as a deeper theoretical understanding of the human condition. The limit, then, of the extent to which computers can help us deal with the world of human affairs is determined by the same thing that has always determined such limits: our ability to assess our situation honestly, and our ability to know ourselves.

Artificial intelligence

No discussion of the role computers are to play in the emergent information society would be complete without an appraisal of the state of and the hopes for artificial intelligence (AI). This must be because the ethos of so much of the rest of the computer practicum is now pervaded by the spirit – and by what little substance there is – of AI. There is talk not simply of robots but of intelligent robots, not simply of home computers but of intelligent home computers; kids in school will have AI at their disposal and even help create more of it. Dr Sidney Fernbach, previous head of the Lawrence Livermore Laboratory's Computation Centre, one of the world's largest computation facilities, invokes an absurd vision of AI's potential use in science and in education that gives an idea of what leading computer managers expect from their instruments:

> The scientist experiences and learns to understand physical phenomena throughout his entire life, but his most active years for thought are relatively few. The experiences of large numbers of scientists can be put into the data banks of computer systems, and *the computers can then be*

> *programmed to sort through all this information and come up with "original" ideas* . . . Thus far I have provided for bookkeeping functions, data retrieval, problem solving in both numeric and analytic bases, and a *reasoning system stocked with all the scientific knowledge in the world.* This latter system should not be restricted to science alone. Our educational facilities in general need to have the information in the Library of Congress at the fingertips of teachers and students. This could be the greatest educational tool in the world. [Emphases mine.]

Artificial intelligence, much like real intelligence, has been extraordinarily resistant to attempts to define it with precision. But there seems to be general agreement that however else intelligence manifests itself and whatever else it may be, a necessary property of it is that it must be able, to use Fernbach's words, to "come up with 'original' ideas". There is also a widespread consensus that the production of original ideas has much to do with the application of analogies and metaphors. As Minsky says: ". . . in analogy lies the secret of really useful learning, a way to apply something learned in one situation to a problem in a quite different area." Minsky then goes on to discuss a program written by Thomas Evans, then one of his students, "that proposed solutions to geometric analogy IQ test problems and achieved performances resembling those of teenagers – although, of course, only in this restricted microworld." Obviously, Minsky thinks this program to be of very great importance to AI. I know of few papers or books Minsky has written or talks he has given since this program was written (1964) in which he has not emphasized its importance.

This is not the place to discuss the Evans program in detail. Suffice it to say here that the program is given descriptions of two geometric figures A and B, the source figures, and a small set of target figures, say C, D, E and F. The problem is to select one of the figures D, E, or F such that C is to the selected figure as A is to B. A and B may be related in that, for example, some subfigure of A, A1, is *above* another subfigure of A, A2, while in B the corresponding subfigure B1 is to the *right* of B2. The possible relations between the subfigures of A are above, left, and inside. A2 may also be smaller or larger than A1, or it may be rotated or reflected or be some combination of these relationships. Given that the set of possible relationships of subfigures to one another is very small, it is possible to specify rules that govern how source figures are transformed. The program's problem then becomes to find a rule that transforms C into one of the target figures, such that that rule most closely resembles the rule that transformed A1 into A2 in the original problem statement.

A metaphor is fundamentally a borrowing between and intercourse of thoughts, a transaction between contexts.[6] The extent of the creative

analogical reach of a metaphor is always surprising. Its power to yield new insights depends largely on the richness of the contextual frameworks it fuses, on the potential mutual resonance of disparate frameworks. Newton fused the contextual framework consisting of the behaviour of everyday objects in the material world, like apples falling to the ground, with that of the solar system, and produced the remarkable idea that the moon is falling to Earth.

Do the processes embodied in Evan's program have much to do with whatever processes may exist for coming up with original ideas by the use of analogy and metaphor? This is an extraordinarily important question in view of the stress Minsky places on Evans's program, for in effect Minsky claims that Evans's program and those that have followed the general methods it pioneered are achievements in a progression that terminates in the realization of true computer creativity. We recognize that the firecracker of the ancient Chinese was such an achievement in the progression of technologies that led to the moon landings, but that mountain climbing, no matter how much nearer it brings the climber to the moon, can never be such a step. The question then is whether the kind of analogy programs on which Minsky appears to be betting so heavily are more like firecrackers than like mountain climbing.

The answer seems to me to be obvious. Truly creative thought, to the extent that it is based on analogical and metaphorical reasoning – and it is a very large extent – gains its power from the combination of hitherto disparate contexts. The act of creation is that of selecting from among the infinitude of similarities shared by every pair of concepts precisely those two frameworks that shed the maximum illumination on one or both of them. The A1 community will readily agree that the analogical reasoning programs A1 has produced so far are *given* the relevant criteria of similarity they need – that is, the two frameworks that are to be fused. This is not to criticize the quite clever programs produced to date; it is rather to illustrate on what profoundly and fundamentally misguided bases some of the most crucial concepts of A1 are built.

Conclusion

The computer in its modern form was born from the womb of the military. As with so much other modern technology of the same parentage, almost every technological advance in the computer field, including those motivated by the demands of the military, has had its residual payoff – fallout – in the civilian sector. Still, computers were first constructed in order to enable efficient calculations of how most precisely and effectively to drop artillery shells in order to kill people. It is probably a fair guess, although no one could possibly know, that a very considerable fraction of computers devoted to a single purpose

today are still those dedicated to cheaper, more nearly certain ways to kill ever larger numbers of human beings.

What then *can* we expect from this strange fruit of the human genius? We can expect the kind of euphoric forecasting and assessment with which the popular and some of the scientific literature is so abundantly filled. This has nothing to do with computers per se. It seems rather to be characteristic of a peculiarly American tradition of thought. We have seen many other examples of it, and these may be instructive. Americans thought that universal schooling – not to use the term education – would lift the masses by their bootstraps and ensure a happy, prosperous, democratically governed society. This dream was realized in substance; that is, almost all American youngsters are today forced to attend school during the whole of their adolescence. But the American primary and secondary school has become not a centre of learning, not even a centre where elementary reading and writing can be taught. It has become, as I noted earlier, a minimum security prison in which millions of children and adolescents are contained for a considerable fraction of each of their days. Government reports document that America's young people are largely functionally illiterate. As a university professor, I can testify that not many youngsters recruited from among the best and the brightest can compose a single paragraph of standard English prose. As for democratic governance, a recent Health, Education and Welfare Department study revealed that nearly half the sampled high school graduates did not know that their representatives in the Congress were elected, let alone who they are or what terms of office they serve. Other examples of dreams that have been realized in a technical sense but have spawned disasters in place of the social bounties they foretold can be cited from medicine, urban planning and architecture, mass transportation, and so on.

We can also expect that the very intellectuals to whom we might reasonably look for lucid analysis and understanding of the impact of the computer on our world, the computer scientists and other scholars who claim to have made themselves authorities in this area, will, on the whole, see the emperor's new clothes more vividly than anyone else. They will shout their description in the most euphoric terms. Some of us will find their accounts unrealistic, not because of mere differences of opinion but because their accounts are plainly silly. For example, the distinguished Princeton professor of public and international affairs Robert Gilpin writes:

> ... in order to exercise power, a nation must be able to process vast amounts of data. The classic case in point is the Arab petroleum boycott against the West following the October 1973 Arab-Israeli war. Without sophisticated data-processing capabilities, the Arab oil producers *could*

> *not* have kept track of Western oil tankers, refinery output, and all the other information needed to enforce the embargo. Moreover, given the complexity of the oil industry and the potential for cheating by Cartel members, it is doubtful if the Organization of Petroleum Exporting Countries (OPEC) would remain intact without the benefit of electronic data processing. [Emphasis mine.]

Oil tankers spend weeks at sea. An old-fashioned clerk with a quill pen could keep track of them on the back of a few large envelopes. And there have been effective cartels since at least the rise of modern capitalism, long before there were any electronic computers.

It is not necessary to credit computers for accomplishments with which they have nothing to do. They can be realistically credited with having made possible some easing of the lives of some people. Modern airline reservation systems, for example, have made it easier for me to travel. Herbert Simon believes that computers are raising the level of expertness in decision making on complex matters. I would suggest, however, the Admiral Moorer might be asked his opinion on that point. There is no question that computers have helped enormously to extend our vision of our corner and even the farther corners of the universe: I have in mind both that computers have radically transformed many aspects of astronomy and that without computers spaceflight, hence the dramatically symbolic picture of the earth floating in space, would have been impossible. Many other examples could be given of how and in what ways the computer has done some good. But some questions are almost never asked, such as: Who is the beneficiary of our much-advertised technological progress and who are its victims? What limits ought we, the people generally and scientists and engineers particularly, to impose on the application of computation to human affairs? What is the impact of the computer, not only on the economies of the world or on the war potential of nations and so on, but on the self-image of human beings and on human dignity? What irreversible forces is our worship of high technology, symbolized most starkly by the computer, bringing into play? Will our children be able to live with the world we are here and now constructing? Much depends on answers to these questions.

Notes

1 United States Congress, House Committee on Banking and Currency. Hearings before the Subcommittee on Urban Growth, 7 October 1970, 91st Congress, 2nd session, pp. 205–65.
2 *New York Times*, 10 August 1973.
3 "The Wide World of Watergate", *Newsweek*, 20 August 1973, p. 13.
4 "Toward an Intelligence beyond Man's", *Time*, 20 February 1978, p. 59.

5 "Steps toward Artificial Intelligence", in Edward A. Feigenbaum and Julian Feldman (eds), *Computers and Thought* (McGraw-Hill, New York, 1963), p. 447.
6 I. A. Richards, *The Philosophy of Rhetoric* (Oxford University Press, Oxford, 1936), p. 93.

A Reply to Weizenbaum

Daniel Bell

To invoke an old Russian proverb, Mr Weizenbaum is knocking down an open door. He sets up a confrontation between the "technologist" and the "humanist" and, having recently made the crossover, he is angry and harsh with those who seemingly do not share his new enthusiasm. More regrettably, he adopts the tactic and even the tone of the heresy hunter to sniff out – usually by pouncing on statements taken out of context – technological hubris and to berate this attitude as being morally blind. That is a pity. Since I share many of Mr Weizenbaum's concerns, I wish he had written with a pen, not a large paintbrush.

In his thick strokes, Mr Weizenbaum fails to make some necessary distinctions. The first centres on the understanding of the word *knowledge*. Mr Weizenbaum, like any tyro in epistemology, begins with the statement that "acts", "experimental results", and "reasoned judgements" are themselves determined by the observer's organizing principles. He seems to think that such a statement necessarily disproves the idea of objective knowledge. But this is to confuse the source of knowledge with its validity. Would he have us believe that all knowledge is completely relative? That there is *no* basis for deciding which knowledge is better than other knowledge? He points out, quite understandably, that much knowledge is tacit knowledge. But the scientist-philosopher who did most to establish the idea, Michael Polanyi, then went on to assert most emphatically that tacit knowledge becomes translated into public knowledge by the process of open discourse – debate, testing and evaluating – which is the very process of science, what Polanyi has called "the republic of science".

Since Mr Weizenbaum does not follow through with the logic of his own argument, it is not clear what he is driving at. He would seem to be saying that what everyone knows may be knowledge, and it is only the