the speed of calculation is now limited by the speed of propagation of pulses down wires, in other words, by the speed of light. But the point I wish to make is that we can now calculate many thousands of times as fast as we could in 1953 and at least a million times as fast as we could three hundred years ago.

Now this change is quite extraordinary, if one compares it for example with the increase in the speed of travel. A satellite orbiting the earth or moving towards the planets is unlikely to go much faster than twenty-five or thirty thousand miles an hour. An ordinary man can usually do two and a half or three, so that the satellite is perhaps ten thousand times as fast as a walking man. The enormous increase in speed of travel has changed our world and our ideas of the potentially possible. We don't use satellites to go from Manchester to Edinburgh in a few minutes, but we hope to explore the solar system. Few people have made similarly realistic and visionary forecasts of the effect of our modern speed of computation.

The memory of machines has increased many thousand fold and so has the speed by which one can get access to the information in the stores; at the same time the cost of storing a binary digit has come down at least a hundred to one, while the reliability of the machines has increased even more dramatically!

It is in fact now quite possible to put the whole of the contents of the *Encyclopaedia Brittanica* on a largish spool of tape (this is about a thousand million binary digits), and one can imagine a computing installation which had immediately available to it a very significant part of all the information in the world in so far as it has ever been produced in print.

May I say again that few people appreciate just how powerful these machines can be when they undertake the tasks for which they were designed.

On the other hand, as I said myself about twenty years ago, a machine is unlikely to be able to answer satisfactorily such a question as this. 'If a man of twenty can gather ten pounds of blackberries in a day and a girl of eighteen can gather nine, how many will they gather if they go out together?' And it is problems like this which dominate the thinking of ordinary human beings.

But astonishing though the achievements of the engineers have been, I believe that the achievements of the mathematicians who have made it possible for ordinary human beings to use them have been even more dramatic and are even more astonishing.

When I first interested myself in the subject, there were very few programmers in the world, many of whom were outstandingly good mathematicians, and I think I knew most of them. Today there are hundreds of thousands of them and any intelligent schoolboy can learn to program a machine and solve problems which would have defeated some of the ablest men of their generation twenty years ago.

I think that there is a very close parallel between the achievements of the men who have created the languages and the compilers which made computers available to ordinary people, and the achievements of a few great mathematicians in the eighteenth and nineteenth centuries who made Newton's work accessible to ordinary mortals. That very great mathematician Euler spent many years of his life in simplifying the calculus so that it could be used by schoolboys. When Newton left the subject it was obscure and almost universally misunderstood; but Euler created the A-level mathematics which schoolboys learned when I was young, and I have always thought that his achievements were among the most important and underestimated in the history of mathematics. I believe, furthermore, that the achievements of a dozen or so men who have invented and developed the languages of computers have been equally remarkable and must rank with the most extraordinary achievements of which human beings can boast.

We have enormously powerful machines and extremely ingenious languages. What then are the problems which make us need these complicated machines?

In the first place, of course, they have revolutionised engineering calculations and have made it possible to introduce analytical mathematical techniques in the design of vastly complex structures such as aeroplanes and atomic power stations which could never have been built without them. Furthermore, it had become obvious twenty years ago that clerical work was becoming more and more expensive, more and more difficult to do and more and more necessary in modern society. Industry, banking, commerce and government depend more and more on numbers which computers can handle and which ordinary clerks no longer need to study or to process. It is no longer true to say, as it once was, that the number of clerks is increasing more rapidly than that of any other category known to the Census. I think there are more hairdressers today than there are steel makers! – but that is by the way.

However, we still have many unsolved problems. For example, the fast increasing rate of accumulating and publishing knowledge is beginning to destroy the very mechanism which was designed to foster it. There was a time when a few people wrote books and papers, and thousands of people read them and knowledge was disseminated thereby. Today more people seem to be engaged in writing books than there are who read them; the whole process of publication is getting more and more expensive and it is producing ever diminishing returns. If six people write a paper and only one man reads it, it can hardly be considered to be a profitable enterprise on the part of authors or readers, or even publishers.

The number of books in university libraries increases all the time – it seems to double every eight years or so – but the number of books which are actually read depends on the speed and devotion of individual readers. In other words, the fraction of books in a library which remains unread on the shelves increases all the time, and in some libraries it must already be well over ninety per cent. In many libraries, including our own, it would be cheaper to give away the books that the students actually read instead of keeping them on the shelves until they want them, but librarians seem strangely reluctant to accept the implications of this argument. It is analogous to arguments which suggest that it would be cheaper to *give* cars to students instead of providing them with parking spaces. The point I want to make is that the classical techniques for storing and disseminating information are collapsing as we watch them and no one has ever faced the basic problems of serendipity as a technique for uncoordinated research. Here then are problems in search of solution; in the computers and their extraordinary software we may have solutions in search of problems.

May I indulge myself in a personal reminiscence? I shall never forget one interview I had some forty years ago with that great man Professor Lord Rutherford for whom I worked in the Cavendish for three very exciting years. He came into the lab, hung his coat on the main switch and gave himself a minor electric shock, and then lit his pipe. He always dried his tobacco on a radiator before he used it, so his pipe burned with occasional explosions and bright blue flames, furthermore it emitted showers of sparks from time to time. His students were always intimidated and watched this operation very anxiously; they wondered if he would set fire to his moustache. He began in that great booming voice of his: 'The time has come, my boy, to decide if the results you are getting from your researches are really worth the price of the liquid air they are costing the Cavendish'! Rather unwillingly he decided that they might be, but ever since then I have displayed a certain scepticism about all research projects, and not only my own.

I have always hoped that your Society would concern itself with the marriage, or the liaison if you prefer it, between unsolved problems and unused solutions. How far can computers be used to study the apparently insoluble intellectual problems of the day? I have probably misunderstood your work, but I have been disheartened by some of the research in which your members are engaged. It is pressing against the limits of knowledge and this is splendid, but are you right to be so worried about problems which appear to me to be semantically significant rather than technically important, and philosophically interesting rather than economically useful? It is some years since people attempted to improve the speed of aircraft by improving the thermodynamic efficiency of horses, but I hope that our new expensive motorways will be suitable for horse-drawn traffic in a hundred years' time, when the oil runs out!

There is no doubt at all that it is extraordinarily difficult to understand the very complicated interactions and interlinkages in our own brains. It may be even that one can draw some analogy between the structure of a human cortex and that of a computer. If so it will be great fun, but will it help the design of machines or will it help to relieve the otherwise unendurable burden which scholars and administrators have to carry in these days of more and more complicated numerical analysis and more and more detailed recording of the details of our lives?

The concept of *gestalt* is hard enough to understand – why and how do humans recognise the squareness of squares, the straightness of lines, the 'e'-ness of a letter 'e', the beauty of a sunset or the charm of a melody, which was written for an orchestra and is whistled off-key by a butcher's boy? Heaven knows these problems defy solution – why therefore should one expect that they can be studied or solved or practised by computers? When Atlas was closed down last year after nearly a decade of use, it had no more intelligence than it had when first it was switched on – but it had done some astonishingly useful work in the meantime. In this life one should, I believe, play from strength and reinforce success whenever possible – I commend the idea to all of you.

LORD BOWDEN OF CHESTERFIELD
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