Conference Paper

The State of the Art—(b) Computers in British Universities

by A. S. Douglas

INTRODUCTION

Until about two years ago only three Universities in the United Kingdom actually possessed computers—that is, electronic digital general-purpose computers—namely, Birkbeck College, London, Cambridge University, and Manchester University. These computers were developed and built in the laboratories concerned, and, for various historical reasons, have become associated with different University departments in each case, that at Birkbeck being associated with Physics, that at Cambridge with Mathematics, and that at Manchester with Electrical Engineering. In all cases instruction in programming and numerical analysis has been given, but almost entirely at the post-graduate level. Internal organization has been conducted on the "open shop" principle, the policy being to train users from outside the laboratory in programming and then to assist them to work out their own programs, rather than to carry out the programming as a service for them.

RECENT INSTALLATIONS

Over the last two years, seven commercially made computers have been installed in other Universities, these comprising three Pegasus, two Mercury, and two Deuce machines. These have been distributed to some extent on a geographical basis, the two Mercurys going to the Universities of London and Oxford, the three Pegasus to Durham, Leeds and Southampton Universities, and the Deuce machines to Glasgow and Liverpool. In addition, Manchester replaced its earlier machine by a Mercury. For the majority of these installations, money has been provided from public funds through the University Grants Committee. The main object of the new laboratories is to develop the use of machines rather than carry out construction work, and this has led to an emphasis on association with Mathematical departments in the main, although some Universities, particularly those housed on more than one site (sometimes called the "schizophrenic" Universities) such as Durham and London, have set up independent organizations without direct affiliations to existing departments.

In order to achieve the maximum effect with the staff available, all the new laboratories have followed the open shop policy, which has proved so satisfactory elsewhere. In my own University of Leeds this has already been markedly successful. Over the past year we have trained more than 100 staff and research students within the University, more than half of whom have subsequently run programs on the machine. These have come from more than fifteen different University departments. Nor has the spread of knowledge and work been less encouraging elsewhere. To quote from recent information from Durham University, for instance, work was done between December 1957 and September 1958 for the departments of Botany, Chemistry, Education, Geology, Mathematics, Mechanical Engineering, Metallurgy, Philosophy, Physics, Zoology and the Royal Victoria Infirmary. Similar lists could by now be compiled for any of the other Universities with computers.

Whilst the main emphasis has still been on post-graduate training in the use of machines, there is now a tendency to lay more emphasis on suitable training at the undergraduate level. I am sure that this tendency will continue more strongly in the future. When carrying out studies in local engineering firms I have been struck by the number of straightforward numerical problems, arising in the drawing office, which are at present inadequately investigated by hand techniques. Very often this leads to costly decisions being made on inadequate data. Many such problems are suitable for a computer, but there is no knowledge, among the relevant staff, of the potentialities of these machines, and consequently the problems do not reach the machines even though they may be available locally. With the object of providing a long-term solution to this difficulty, the laboratory in Leeds has taken over from the pure mathematics department the teaching of computation to engineers, physicists, chemists and general scientists at the undergraduate level. We aim to give them all a reasonable grounding in numerical analysis and also to give them some understanding of how and when a computer can assist them in their work. I would emphasize that this is a long-term solution of the problem and will not affect matters for some years. Nevertheless I believe it to be an important step in the right direction. When the syllabus has been consolidated on the engineering side, it is our intention to take up with the departments of Economics and Accounting, ways in which the use of the machine can be introduced to their undergraduates also, to ensure the widest possible dissemination of knowledge about this important tool.

At the graduate level several Universities have followed Cambridge's lead in establishing a post-graduate diploma course, lasting one year. The courses are designed to train the expert programmers of the future by giving a thorough course in numerical analysis, logical design, and programming. At Leeds we have also introduced a data-processing option, so that students more interested in commercial work than in science and engineering can be accepted, provided their professional qualifications are suitable. Although basic numerical analysis is taught, no higher mathematics are required, and we have already awarded a diploma to an enterprising (and deserving!) partner in a local firm of chartered accountants.

In addition to these diplomas, University laboratories also accept and train research students. In Leeds, for instance, five people in the department are reading for higher degrees, and we expect numbers to increase over the next year or two. Our situation is typical of the newer installations, and these will soon become a useful source of talent. In our own case we are concentrating on some of the problems arising in the data-processing field, as well as pursuing many interesting lines of research in numerical analysis, such as the solution of partial differential equations. We have been particularly encouraged to study these large-scale problems, since we are the only University, other than Cambridge, to have magnetic-tape units attached to our computer.

Apart from teaching, research, and work for other University departments, the new laboratories have all done some work for extra-mural users, i.e. local firms willing to pay for the use of the computer. Of the older installations, only Manchester University has ever undertaken regular work of this kind in the past, although recently Cambridge has begun to accept service work. This type of work has caused a few mild flutters in the Bursarial dovecotes, since the only precedent that could be found in my University for the receipt of payment for services rendered by a department was the University farm! However, it has also raised a number of problems both with regard to the present and the future, and I would like to refer to some of these now, since they seem to me of fundamental interest and importance.

FINANCE OF FUTURE DEVELOPMENTS

One of the principal difficulties facing Universities in the future is the increasing size and capital cost of machines suitable for scientific research, such as the MUSE, the design of which is to be discussed elsewhere by Dr. Kilburn. It is clear that the Universities ought to be in the forefront of research into the use of such machines, if only in order the better to train those programmers whose task it will be to use them. Yet we cannot expect support from public funds on a scale sufficient to equip all Universities. Indeed, it will be necessary to present a strong case for the provision of more than the one very large machine which Manchester intends to have built to its own design. The question thus arises as to how training and research can best be carried out on equipment so costly that only a few industries and Government-supported departments can afford to have it.

This situation is not new; it has already been faced in the field of nuclear energy and met in various ways. Broadly speaking, there have been three approaches to the problem. The first has been the "quasi-University"; by this I mean the research department controlled or owned by a firm or by the Government, such as the Bell Telephone Laboratories, the I.B.M. Research Laboratories, Oak Ridge National Laboratory, the National Physical Laboratory and, more recently, A.E.R.E., Harwell. In most cases these laboratories began with the object of doing specific (and sometimes secret) research into problems of direct interest to the sponsors, either for political or commercial reasons. These problems have led them into more and more fundamental research, using the expensive machinery they alone can afford, and their work has thus encroached more and more on what are traditionally, and, in my view, rightly regarded as University functions. In many cases the immediate direction of the work has been excellent, and the results have been made available in the traditional University manner. However, the higher direction of the work is, and must remain, largely in the hands of governmental committees or of boards of directors, who cannot be expected to give first priority to educational needs or to foster pure scientific research for its own sake. From time to time decisions are, no doubt, made to shut down promising investigations, on the grounds that these will not further the aims of the sponsors. These aims do not and cannot always coincide with those of the Universities, whilst the decisions reached can nowadays mean the complete suppression of the research concerned for, at the least, a short but not negligible period of time. It is, therefore, in my opinion, undesirable that the operation of large-scale, expensive equipment should rest solely, or even primarily, in the hands of the quasi-University.

Another approach to the problem of efficient usage has been that of co-operative projects between several Universities. An outstanding example of this has been at Brookhaven in the U.S.A., where a number of Universities have co-operated in running and staffing a co-operative project to use the atomic pile there for fundamental research purposes. Co-operation of this kind requires careful administration and a willingness on the part of Universities to work together either on a remote site or on the site of one of them. This presents difficulties of access to the equipment, but these are not insuperable.

The alternative approach to this has been the close co-operation between one particular University and a sponsoring body, such as that existing between the University of California and the Atomic Energy Commission at Los Alamos. This has been activated to some extent by the view that fundamental research is a commodity which can be bought, that it is best provided by a University, and that the functions of a University are in no way prostituted by acceptance of research contracts, provided that these allow adequate freedom in the direction of the research and in its subsequent publication. This philosophy, whilst certainly open to argument, has, nevertheless, been widely accepted both here and in the United States in accepting support from such bodies as the D.S.I.R., O.N.R., M.O.S., U.S.A.F., and so forth.

These precedents are obviously relevant to our consideration of how best to use the new large, fast computers which will soon be available. I would myself regard with aversion the formation of new quasi-Universities in the form of National Computing Centres, by whomever sponsored. Not only, as I have suggested, are the aims of the higher management of such institutions not entirely compatible with the pursuance of fundamental research, but also there is a serious risk of research and teaching becoming divorced, owing to problems of access to the equipment. This latter difficulty also applies to any co-operative ventures designed to make a high degree of centralization palatable. Educationally, therefore, it is most desirable that a number of large machines should be directly sited in Universities. We must expect to pay something for this privilege, and I think this will have to take the form of offering service to users outside the Universities. Two important results flow from this. Firstly, the Universities must be prepared to set up and maintain suitable organizations around the machines, and to provide appropriate services under contract. Secondly, the possible "catchment areas" around the machines must be carefully studied and the distribution must be continued on a planned geographical basis. This is particularly important, since the area which can be served by one such machine is limited by practical considerations. Given a choice between a slow but local machine and a fast but remote machine, initial development will normally be done on the former, although this may be with a view to carrying out production on the latter at a later stage. The less accessible the fast machine, the stronger the tendency to do all possible jobs locally, irrespective of the cost of machine time, owing to the trouble and cost in human time in reaching the fast machine. I myself estimate that a car or train journey of greater than 2 hours' duration between the work and the machine will erect a barrier practically insuperable except in those rare cases which demand the largest and fastest machine available, or in cases where work can be conducted by correspondence only, cases which are at present few in number. This would imply the existence of at least three large machines in the United Kingdom Universities, a number which probably represents the maximum we can hope to obtain support for in the near future.

RELIABILITY

I have mentioned these matters of fundamental policy in the belief that it is appropriate at this time to give thought to them, and that everyone interested in the future both of computers and of the Universities ought to be aware of some of their implications. In doing so I realize that I have given less attention than I might to some other aspects of the work of University laboratories. In particular, I have omitted so far any remarks about reliability and maintenance of computers, a subject of much interest to us all. I cannot yet give any reliable figures for the Mercurys, which have mostly been installed very recently. I choose to give the figures for our own Pegasus because it has probably been the least reliable such machine to be installed in a University. Preliminary information indicates that the Deuce machines have behaved at least as well as the Pegasus machines.

For the first three or four months we had a few teething troubles. Discounting this period, over the year from May 1958 to May 1959 we have worked a total of 2,873 hours. Out of this, 544 hours have been devoted to scheduled maintenance, an average of about 2 hours per working day. Finding and repairing faults during scheduled operating time has never exceeded $5\frac{1}{2}$ hours in any one month (or less than 3% of the total running time) and has averaged $2\frac{1}{2}$ hours per month, or less than 1% of total running time. During the last three months of the period reviewed we have had magnetic-tape equipment, and this has not appreciably lowered the efficiency of the installation. However, it is as yet early to claim that it will not do so! I have every confidence that future machines will operate at least to these comparatively high standards of reliability, which I feel should be encouraging to those of us who have a special interest in data processing, where reliability plays an important role. I shall look forward to being able to report on the fulfilment of this and other hopes with regard to the future of University computers at a future conference.

Correspondence

The Editor,
The Computer Journal.

Sir,

In the note by Mr. Strachey in the July 1959 *Computer Journal*, the author speaks "of the concealed dangers in using algebraic coding." In our opinion, he has given one more example to show that numerical analysis is not trivial. If he understands the use of algebraic coding as blindly copying algebraic identities, he is right, but it is equally dangerous to do this in straightforward machine coding.

An experienced numerical analyst will use an algorithmic language, such as ALGOL, only as a vehicle for describing the specific numerical process he intends to have carried out. Inexperienced people must learn to recognize and eliminate potential hazards; indeed, we try to teach all of our students how to do this. Effective use of a program language requires both art and skill. We hardly consider it necessary, nor perhaps even possible, today to expect more, namely a language and translator that would take on the ingenuity of the human being.

Sincerely yours,
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