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The Application of Digital Computers to Social and Operational Problems; Opportunities and Needs

Environment and New Facilities - M.I.T. has long been in the forefront in the development of computing equipment and in developing ways whereby this equipment can help solve problems in a wide variety of fields. In the mid-30's Vannevar Bush built here the first differential analyzer and several faculty members, in various departments, used it to solve problems in engineering, mathematics, and physics, which could not otherwise be solved. In the past four years Whirlwind I, one of the first truly high-speed digital computers to get into operation, has been made available for more than 1/3 of its time for the solution of general scientific problems. Problems from many fields, sponsored by members of all the different departments at the Institute, have been put on the machine. The programming research staff of Whirlwind has gained experience in adapting the computer to this variety of problems and the faculty at the Institute has begun to learn, by actual doing, the ways in which the computer can help them solve their problems.

Beginning in 1957, the computing facilities at M.I.T. will be enlarged and reorganized into a Computation Center, to be devoted entirely to unclassified scientific research and education. I.B.M. is donating one of its new 704 computers with double the usual storage units and with appropriate auxiliary equipment, and will provide for the maintenance of the equipment; the Center will be housed in the new K. T. Compton Laboratory Building; according to agreement with I.B.M., the equipment will be used ten hours a day (on the "midnight shift") by I.B.M., will be available up to seven hours a day to faculty members from other colleges in New England and the remainder of the time (seven plus hours) will be available for use by students and staff of M.I.T. for basic research. The programming research staff, at present working with Whirlwind, will be transferred to the Center, to serve as a nucleus for planning machine use and for developing new techniques of machine application.

Nature of the Research - Exploitation to the full of the potentialities of a new piece of equipment can most effectively be accomplished by an advance on two fronts: the solving of specific problems and the development of techniques. In the case of computing machines, research workers in many fields should learn machine programming techniques and then proceed to use the machine to help them solve their own problems. In many cases they can develop the programs they will need for their work, but in some crucial cases they will need the help of those persons interested primarily in machine operation, who are interested more in developing machine techniques than in solving individual problems.

This division of labor has been necessary in many other scientific advances. The recent great progress in nuclear physics

has come as well from the men interested in experimental techniques, who spend their time trying to get more out of the cyclotrons they have and building new and better cyclotrons, as from those who are primarily interested in measuring nuclear cross sections and finding new particles. Even in theoretical physics one needs the analysts, who improve mathematical techniques, as well as the physicists proper, who use the techniques to devise new theories. Research into techniques does not usually have the glamour which research on specific problems has, but in really new fields of investigation the basic techniques often must be worked out before the specific problems can begin to be attacked.

Research into techniques of using digital computers is particularly important now, for the potentialities of the new machines are not well understood by others, who would be benefited by its help. For this reason we are hoping to enlarge our programming research group when the I.B.M. machine gets here, so that, in addition to helping the problem-solvers program their computations, the group can spend some time devising really new tricks. Some of this research should be into the possibilities of devising new modifications of input and output equipment so that, for example, the results of some experiment can be fed directly into the machine for detailed analysis, or so that the calculations performed by the machine can be fed directly to a high-speed typesetter, in each case eliminating one or more time-consuming and inaccurate human interventions.

We are requesting NSF and ONR for help in developing such techniques of particular use in adapting the computer to research in the physical sciences. Some of the work proposed includes:

1. Devising, writing up, and correlating a library of programs for solving standard problems, to facilitate the use of the machine by workers in the physical sciences.

2. Investigating basic programming logic, how it can be expressed in mathematical terms and how much of it can be carried out by the machine itself.

3. Development of input equipment and techniques which can connect the machine directly to the experiment, and output equipment which can display results in a more concise and understandable form.

In this way the Computation Center can cooperate in an active way with the various groups, at M.I.T. and at other New England colleges, which are carrying on research in the physical sciences.

Need for Parallel Development in the Social Sciences - The work we have proposed for support by NSF and ONR is to be primarily for applications in the physical sciences. But the potentialities of machine computers in the social sciences and in operations research has equal or greater promise. In economics, in management problems, in some aspects of psychology and in other fields, the data is large in quantity, often requiring much statistical processing and special display before its purport can be understood. Many mathematical techniques, now being developed for these subjects, require tremendous amounts of computation before they can be applied to specific problems. Although the appropriate machine techniques and the special input-output equipment have not been investigated very completely, it is already clear that they will often differ considerably from those devised for the physical sciences and should be investigated separately, in close collaboration with specialists in the social sciences. The grants requested of NSF and ONR will not support the detailed theoretical study and special equipment development which this research will require.

It is, therefore, appropriate and desirable that a request be made for a separate grant for the development of machine techniques useful for these fields. We now have, at M.I.T. and in the neighboring colleges already planning to use the Computation Center, a variety of specialists in the social sciences, who would be interested in collaborating with the staff of the Center in developing such techniques. Funds for the support of specific studies, in particular fields, can and should be requested and granted separately. But there is need to support the work of the Center's staff in devising new techniques, in adapting known techniques to new fields and in helping social scientists effectively to utilize digital computers in their studies.

Possible Directions for Research - It is not possible at present to enumerate in detail the directions this investigation of computer techniques will take. Several promising leads have already aroused interest, however:

1. A basic investigation of the machine techniques for computation in the general field of linear programming--dynamic programming--input-output analysis, which promises to be of considerable importance in economics and in operations research. The economics departments at both Harvard and M.I.T. are interested in applying such techniques to their work. Professor Orcutt at Harvard and Professor Solow at M.I.T. are on Advisory Committees to the Computation Center and will cooperate in this work. The computations are quite difficult for present equipment but it appears likely that new programs, planned to utilize the considerably greater high-speed storage of the new machine, can greatly improve the speed of solution. It is likely that fundamental improvements in techniques of solution of these problems will also prove valuable

in devising algorithms for the solution of problems of game theory, also of potential importance in these areas.

2. General studies of the use of machines in the storage and translation of information have already been started at M.I.T. A project in machine translation has already been set up, under the direction of Professor Locke of the Language Department. As it develops, it will need the help of machine programming specialists and will need the use of a machine to test its ideas. The translation project is already supported by the Rockefeller Foundation, but parallel work by the Computation Center on techniques for rapid access to large-quantity data would help this work as well as others. For example, a study of the use and operation of the M.I.T. libraries was begun last year. At present, the study is concerned with the ways the library is being used at present, but it is expected to move on to the consideration of possible improvement of library operation and extension of its use as a research tool in science and engineering. One promising direction of investigation is in the application of machine techniques to library inventorying, cataloguing, and record-keeping. Although special-purpose machines will probably be required in the end, many ideas and procedures can be developed and checked out on the general-purpose machine at the Center with the addition, perhaps, of some specially built input and output equipment. The staff of the M.I.T. Library is interested in this work, and will contribute its knowledge to its progress.

3. A digital computer can be used as an integral part of many experiments in the social sciences. It can be used to simulate certain operational situations and thus to provide data rapidly and under controlled conditions. For example, automobile traffic distributes itself through the streets of a town according to some minimization principle, on the average. It should be possible to simulate this flow on the computer, trying different assumptions as to the effective "street resistances" and measuring the resulting flow under various traffic stresses to see how closely the results check with measurements made in the Boston streets by the Traffic Study Group already in operation in the Civil Engineering Department at M.I.T. Tactical situations in warfare are already being studied by "gaming techniques" at Rand and in other military operations research groups. Similar tactical problems in various fields of the social sciences can also be studied by simplifying the situation down to some sort of "game," with more or less complicated rules, which can be played by groups of investigators, to see what are the consequences of various strategies. If the "games" are to correspond, even distantly, to some actual social situation, the rules must be quite complicated and the scoring will require a great deal of statistical computation. It has been found that only by the use of computing machines can the scoring be speeded up sufficiently so that enough games can be run through to provide

an over-all grasp of its properties. Such "gaming techniques" are closely related to the experiments of Bavelas on the behavior of task-oriented groups. The use of a properly programmed computer would provide such experiments with a powerful and flexible means of changing, controlling, and analyzing these experiments in social psychology. In this field we could work in close collaboration with the Center for International Studies at M.I.T. and with the psychology departments in several other colleges.

Proposed Budget - The three general areas of study just mentioned are examples of fields of research in computer techniques quite different from those used in the physical sciences, but ones equally important and promising. The budget for the group to work in the physical sciences will run about $100,000 a year. A group of roughly equal size would be needed for the parallel work in the social sciences. The added staff would be, in part, social scientists with an interest in computers and in part mathematicians and computer specialists with an interest in social science. The group should work together for several years. An appropriate rate and duration would be $100,000 a year for five years.

This budget would be administered by the Computation Center and would be for the support of a group, working at the Center, investigating machine techniques of particular value in the social sciences, as discussed earlier in this proposal. When other divisions, such as the Sloan School or the Economics Department at Harvard, are able to organize research or educational programs which utilize these techniques in their fields, with separate financial support, they will find a nucleus of collaborators and advisors at the Center, which can see that their program does, in fact, utilize the facilities of the Center in an effective manner.

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