thereby solve a class of decision problems of far greater scope than those considered in [4] since within the accuracy of the machine (for example, modulo 2^{-39} on the interval from -1 to 1 on the University of Illinois computer) all convergent power series may be considered as polynomials. Thus a decision method for all functions that may be represented by convergent power series in a finite set of real variables may now be possible within the accuracy of the machine used. Even though the result obtained is modulo 2^{-39}, for example, and therefore is not a precise theoretical result, such a decision method would have very wide application—both practical and theoretical.

Added in proof. Since the present paper was submitted, A. Seidenberg has shown that the results obtained by Tarski's decision machine may also be obtained in algebraic geometry. See "A New Decision Method for Elementary Algebra," *Annals of Mathematics*, vol. 60, 1954, pp. 365–374. Although the two methods appear equally suitable for human calculation, Seidenberg's method provides new hope for the construction of a decision machine.

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THE FIRST CONFERENCE ON TRAINING PERSONNEL FOR THE COMPUTING MACHINE FIELD*

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1. The nature of the conference. This conference, which was held in Detroit, Michigan, June 22–23, 1954, was sponsored by Wayne University with the cooperation of the Association for Computing Machinery, the Industrial Mathematics Society, and the local chapter of the Professional Group on Electronic Computers of the Institute of Radio Engineers. The details were arranged by Professor Arvid W. Jacobson, director of the Wayne University Computation Laboratory, with the help of his staff. The purpose of the conference was to discuss

(a) manpower requirements in the computer field,

* The full proceedings of this conference have been published and are available from the Wayne University Press, Detroit 1, Michigan. The cost is $5.00.

(b) educational programs for training computer personnel, and
(c) possibilities for cooperation among business, industry, government agencies, and educational institutions in solving the manpower problem.

The program consisted of four groups of invited addresses and two panels, followed in each case by extensive discussion from the floor. The speakers represented a wide range of organizations of the kinds just mentioned.

That such a conference was opportune hardly needs emphasis, for the shortage of competent candidates for positions in the computer field is becoming increasingly critical as the demand for computers grows. Not too widely recognized is the fact that this problem is of importance to the entire mathematical fraternity. However, although many mathematicians have scorned computer art, most of us recognize that it has added a whole new dimension to research in engineering and in the physical and the social sciences. Perhaps many of us have felt that, much as we might like to do so, we cannot adequately prepare our students for participation in this field for lack of a machine. However, the speakers indicated repeatedly that *the most important educational requirements for work in the computer field may be met even by those who have no expensive equipment*. It is the purpose of this report to outline the details of conclusions such as these, to list the constructive actions suggested, and to call attention to the opportunities, existing and future, for employment in this field.

2. Manpower needs in the computer field. At present, computers are most extensively used for engineering calculations, next for scientific research calculations, and only to a relatively small extent for the processing of business data. In all of these areas, and especially in the third, as machines are built that better meet existing and developing needs, and as potential users learn what these new tools for data-processing can do, the demand for the machines expands at an accelerating rate. This of course creates a corresponding demand for a variety of trained personnel. Present indications are that this demand will reach dramatic proportions within a decade.

Employees in this field who require mathematical training may be grouped into the following classifications.

(A) Employees of the computer manufacturer (who may also use computers).
   (1) Machine design men, trained in electronics, mathematics, information theory, the logical design of computers, *etc*. Such men are most difficult to find. Usually they grow up in the company. (Manufacturers of telephone switching systems, industrial control systems, and other computer-like devices also need men with these qualifications for work in their research and development organizations, so that a broad basic training rather than one governed solely by computer considerations is indicated. The same observation applies to the next category of employee as well.)

(2) Electronic circuit designers. These will be trained principally by departments of electrical engineering. Many more will be needed than men of the first type.
(3) Technical salesmen, educated in special fields of application, experienced in the use of the machines they sell, and able to communicate effectively with the prospective user. Many of these will be mathematics majors or minors.
(4) Training staff for the manufacturer's own employees and for those of his customers. Again, many of these will be mathematics majors.
(5) Assembly and maintenance workers. For a large proportion of these, high school training will be adequate.

(B) Employees of the computer user (who may also build computers).

(1) Professional computer staff to develop program libraries, to do numerical analysis, to develop better methods of using machines, to reduce data and formulas to computable form, *etc.*
(2) Applied mathematicians with computer experience to assist research workers in various fields in formulating their problems properly for computation. Teams of this kind have proved to be especially effective in research.
(3) Programmers.
(4) Maintenance workers.

In the first two of these categories, advanced mathematical training is required; in the last two, a high school education is often sufficient but intelligence and reliability are essential. In all categories, ***the premium is on people who are above average in personality, mental ability, and education.*** The more education a candidate for employment has, the greater are his opportunities to find a responsible position with a high salary.

Currently there is a shortage in all the above classes except perhaps in the case of programmers. The shortage is in part due to the fact that potential employees are not aware of the good salaries, the opportunities to advance, the interesting work, and the pleasant associations characteristic of the field. However the shortage will continue even when this knowledge is more widely circulated, simply because there are not enough students now receiving the necessary instruction at the various levels.

A related problem is that the present number of mathematics teachers is too small to take care of the future training need. Moreover, because of the salary differential, we can expect future graduates to be attracted increasingly to positions other than teaching. In fact, teachers themselves have often been attracted to such positions, and in the long run, the problem of finding teachers will be more critical than that of finding students. The public will thus be faced increasingly with the necessity of making teaching more attractive to able candidates in order to preserve the quality of the schools.

3. Educational institutions and the manpower need. Clearly, the greatest responsibility for meeting this manpower need falls on the educational institutions. The primary considerations, as they were developed by the various speakers of the conference, appear to be these:

(1) The ultimate effect of the computer will be to increase leisure time by accelerating the increase in output per man-hour characteristic of our technology. Too much emphasis on vocationalism and too little emphasis on the liberal aspects of education would tend to destroy the benefits of this leisure, and would be a serious disservice to democracy.

(2) Even from the point of view of effective participation in computer work, specific machine training must not be allowed to replace fundamental scientific education. Neglected education is a handicap that may never be overcome, but machine operation can always be learned on the job in a few months. The rapidity with which machines become obsolete lends emphasis to this point.

(3) No extensive introduction of new mathematics courses is indicated. However, the existing courses need to recognize in a realistic way the importance of computation in the scientific and industrial activities of our time, to train students to think in terms of many variables, *etc.* Thus, significant changes in emphasis and point of view are in order.

(4) Education should be designed to challenge the student's best abilities and particular emphasis should be placed on courses and methods of teaching which require creative thinking in the learning process rather than imitation and drill alone. Indeed, what the student needs most from his schooling is a basic foundation of principles by whose aid he can continue his learning throughout his years of employment and thus keep abreast of changing technology.

(5) There should be a far-reaching re-emphasis on mathematical modes of thought and analysis at all levels of the educational process.

As mentioned previously, these primary goals require no expensive machinery for their attainment.

Comments directed to specific educational levels were also made. At the *high school level*, these included the following:

(6) Experience shows that able high school graduates can easily be trained to perform some of the more routine tasks of computing such as programming, for example, thereby releasing more highly trained staff for work in which advanced training is necessary.

(7) The interests of high school students are typically dormant and need stimulation and encouragement. This can be done by emphasizing the importance of computation in their mathematics courses, by introducing computer "literature" into high school libraries, by providing experience with desk machines, by competitions and prizes, *etc.*

(8) An emphasis on accuracy and checking is vital. "Getting the method right" isn't enough: a computing machine does just what it is told to

do, and one error in programming may cause it to make thousands of errors a minute.

(9) The vocational high schools can provide good preparation for maintenance work on computers through training in shop work, electronics, mathematics, *etc.*

Comments directed primarily at *the college level* included these:

(10) Numerical analysis, though difficult, is the most important single mathematical course needing to be introduced into the curriculum. However, the approach must be up-to-date: much of the classical material on computation is obsolete.

(11) Training in abstract mathematics (such as algebra at the Birkhoff-MacLane level, for example) is most valuable for those who will analyze problems and reduce them to mathematical form prior to computation and especially for those who will design logical machines.

(12) Consideration should be given to introducing basic logic, number systems other than decimal, and vectors and matrices, all of which are fundamental in modern computer mathematics, into the program of the freshman year, or even into the high school program. Mathematical induction, the "soul of programming," deserves a special emphasis.

(13) The subject of finite approximation procedures should be introduced wherever possible (for example, in studying integration) because such procedures are used in computing with machines, which cannot pass to the limit.

(14) Experience with desk calculators is important because it gives a "feel" for computation and should precede training with electronic computers.

(15) The student expecting to enter the computing field should develop an interest in, and obtain experience with, applications, since an essential qualification is the ability to communicate with the engineers and scientists who provide the problems.

(16) There is a wide gap between the undergraduate's mathematical training and what the graduate school or industry will require of him. More attention must be given to improving his mathematical preparation.

(17) It was repeatedly emphasized that a broad, thorough training in mathematics, appropriately oriented with respect to computation and applications, is the best training for mathematical work in the computer field, and that only a general familiarity with what the machines can do is prerequisite to such employment. Most of the specialized training may be left to graduate courses or may be obtained on the job.

Considerable regret was expressed by a number of speakers that many mathematicians view the whole science of computation as being somewhat beneath their consideration. Indeed, this attitude was felt to have constituted a serious impediment to progress in view of the influence exerted by such mathematicians on graduate students. The following comments are directed to *the graduate level* and are in part an answer to this attitude:

(18) The rewriting of analysis in a form adapted to the computer is a far from trivial problem and will require years for its completion.

(19) The mathematical analysis of an applied problem and its reduction to computable form is often not trivial either, even though only elementary mathematics may be involved.

(20) Besides numerical analysis, the qualitative theory of differential equations (as opposed to the search for closed solutions), the effect of higher order terms that no longer need to be neglected in analyzing physical problems, practicable existence theorems and tests, the theory of errors, the theory of systems, an abstract theory of digital control processes, and the development of quantitative methods of research in the social sciences, were all cited as important areas for mathematical investigation.

(21) Graduate students are attracted to staffs with lively, current problems. Thus there will be an inadequate supply of applied mathematicians until more mathematicians in the universities become active in that kind of research. In fact, the sets consisting of the mathematics which is taught, the mathematics which is the object of research, and the mathematics which the world needs, have too limited an intersection.

(22) In institutions having a computer, special lectures and special courses may be given to inform students and staff in other departments about the nature of the computer, what it can do, what it should not be expected to do, how it can aid their research, and how it should be programmed for this purpose. In this way, the computer can be used to exert a beneficial, unifying influence on the university.

Some of these observations, as well as those made earlier concerning the type of training that is essential, indicate that the interests of the pure mathematician, the applied mathematician, and the computer specialist are not so divergent as might once have appeared.

4. Non-educational employers and the manpower problem. The observation of those familiar with the recruiting problem was that "Ph.D.'s are hard to find and harder to recruit" for positions in the computing field. This is partly due to the relatively small number of possible candidates, and partly due to an unwillingness to accept nonacademic employment because of anticipated loss of freedom of research, limited vacation time, routine type of work, and so on, for which the considerably better pay does not always seem to be adequate compensation. As Ph.D.'s in such employment are increasingly provided with semiprofessional and nonprofessional aid to help with the more routine procedures, and as nonacademic research organizations take on a more academic flavor, it will become progressively easier to recruit such personnel. In fact, a real problem may ultimately be to induce enough Ph.D.'s to stay in teaching positions.

Some specific ways in which nonacademic employers can help to increase the supply of highly trained personnel are these:

(1) Funds should be given to schools for the purpose of setting up computation laboratories.
(2) Scholarship funds should be provided for promising students.
(3) Students should be given summer positions during their period of schooling and part-time work in winter where that is feasible.
(4) Consultation opportunities should be provided for teachers. This will make it easier for them to stay in teaching, where their services will benefit many employers rather than just one.
(5) Endowed professorships, fellowships for further study, funds for visiting professorships, and temporary positions in business, industry, or government, should be provided for the teachers also.
(6) Industry should allow near-by schools without computers to use its machines on a part-time basis and provide significant problem material as a means of giving practical experience to both students and staff.
(7) Interest, goodwill, and inspiration should be created by providing informative lectures, orientation programs, appropriate literature, *etc.*, in schools and colleges.
(8) Through cooperation with and support of appropriate agencies (such as this conference, for example), non-academic employers can aid in the study of the needs for training and research and in the formulation of policies and plans for handling the problems that arise.

Many forward-looking companies and certain government agencies (the National Science Foundation, for example) are already active in the above ways. Their help has been widely appreciated by students and teachers throughout the country. It is to be hoped that other companies will soon follow suit.

Clearly not all the funds for such activities can come from the computing machine manufacturers. Indeed, other companies stand to gain much in the long run from sharing in these responsibilities in order to advance computer art.

An outstanding example of this sort of shared responsibility is to be seen in the Wayne University Computation Laboratory, which derives advice and support from some twenty companies in the Detroit area. Because of this cooperation, the Laboratory is enabled to make a unique contribution to the economic life of the community as well as to give its students particularly valuable training.

There is no reason why similar laboratories could not be set up in many other universities. Indeed, this should be done, for in this area as in others, the universities must serve as the primary sources of new talent and new ideas. Moreover, theirs is also the responsibility of helping to ensure that the potentialities of these new machines will be used only for the preservation and advancement of the values of our free, democratic society.

5. Conclusion. An important feature of these meetings was the enthusiasm of the speakers for what the computer and related devices can now do and will do in the future. The automatic office, the automatic factory, and better systems of communication, as well as better computers, were indicated as being well on the way toward realization. Moreover, in all these developments, *mathematics* will play an important role. Whether or not we as *mathematicians* exercise any significant influence thereon depends on the extent to which we are willing to cooperate in the education of workers in this field. If we are unwilling to recognize the rising importance of applied mathematics and computation, much of our present responsibility will of necessity be taken over by other departments of our universities and by industrial training programs. On the other hand, there is much to be gained, for all concerned, from mutual respect and cooperation.

AN EXPERIMENT WITH TELEVISION

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"Of myself I say nothing, but in behalf of the business which is in hand I entreat men to believe it is not an opinion to be held but a work to be done."—Francis Bacon

1. Introduction. This is a report on a semester's experience with a mathematics program on a commercial network, concerned not so much with the program itself as with the powerful means at our disposal, for our purposes. I say "our" not only in the wide sense of national concern with an educational dilemma, if not disaster, in mathematical training but also in the special sense of mathematicians, with all that implies of the specialist's jealous concern for his own field of knowledge. Fifteen weeks convinced me that the best we can manage—best in a mature professional sense even in so supposedly esoteric a field as pure mathematics—pays off in that unknown general public at the receiving screen of a television camera in precisely the ways we want and need.

The program called *University of the Air* which has just completed its fourth year over Philadelphia's Channel 6 is a joint undertaking of WFIL and some twenty-five institutions of the Delaware Valley region, ranging from Rutgers and Lehigh through Philadelphia's varied list to Lincoln and the University of Delaware. Individual faculty members or departments submit to the studio's educational director suggested plans for a fifteen-week "course," October through January or February through May, to be developed in either a seventeen or twenty-seven minute period once a week. Ten courses are selected for each semester and the lecturers supply outlines from which the studio compiles a semester syllabus, announced at each talk and sent out for twenty-five cents. In this way, five mornings a week from 11:15 to 12:00, subjects ranging from Chemistry of the Body and Folk Art to T. S. Eliot have been presented, with sufficient response to warrant the studio's continuing the plan even with an allocated