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ABSTRACT

Based upon an assessment of new applications of computer technology and upon reasonable speculation about experimental projects that seem to offer particular promise, this paper considers some of the more significant developments in computer technology and their possible effects in education in 1980. A section on hardware discusses some current possibilities and potential uses for large computers and minicomputers and examines the necessity and future of low-cost reliable terminals. The feasibility of extensible higher-level programing languages, a longer range trend toward developing simpler programing languages, and some applications for languages are discussed in a section on software. The final section on systems considers time-sharing services, advances necessary in the communications industry, and computer networks. (Author/SH)

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The perils of forecasting in high-technology areas are well-known. Many of the innovative leaps that have characterized development in the computer industry could not have been predicted well in advance; certainly an extrapolation of established trends is an unreliable guide. Therefore, the technique of this paper is based upon the assessment of new computer developments that are beginning to have impact, and upon reasonable speculation about experimental projects that seem to offer particular promise. It is feasible to present here only some of the more significant developments, and to briefly mention their possible effects in education in 1980.

Today's computer technology already suffices for many needs in education; the main problems do not lie in technology *per se*. On the campus, for example, Levien, *et al.* [1] point out that greater instructional use of computers depends upon reduced cost of computers, particular institutional arrangements, production and distribution of computer-related instructional materials, and attitudes about computers in education. Nevertheless, the changing computer technology of the 1970s will have real implications for education in the 1980s. With some exceptions (e.g., terminal design), it appears that the demand for computers in education will not significantly affect the broad course of developments in computer technology; consequently, educators and others must find ways to exploit the technology presented them.

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HARDWARE

Large Computers

"Large" as used here refers to fast, powerful computers with extensive memories, but no longer describes actual size; circuit miniaturization has generally resulted in physically smaller computers, and this trend is likely to continue. Because of the economies of scale in computing, as expressed empirically by Grosch's Law and described by Sharpe [2] and others, the future for large computers seems certain.

Of greater importance are the special features of some of the larger computers. For example, multiprogramming capabilities, together with large memories, allow a diversity of tasks to be performed essentially concurrently. This contributes to the feasibility of computer-assisted instruction, for example, by allowing many different lessons to be run simultaneously. The greater variety of systems, languages, and data files that a large computer can support also will provide expanded uses in many facets of education. Microprograms that are readily switched--an idea still in its infancy--will permit a computer to be "customized" for specific educational purposes.

The supercomputers, exemplified by the Illiac IV and the Control Data STAR [3], offer potential speeds considerably greater than those of current third-generation machines. The Illiac IV provides this capability through many parallel computing units, whereas the STAR is a "pipeline" computer that overlaps many parts of a group of computations. If either or both of these computers prove economically feasible, by 1980 their imitators and successors should see service in the educational sphere. At present, it is not well understood how to use these computers efficiently, except for certain highly structured applications.

Minicomputers

The small, general-purpose electronic computers, often called "minicomputers," should be commonplace in another decade. These computers were introduced in the late 1960s, and were a natural consequence of miniaturized circuitry. Originally priced between $10,000 and $25,000, by 1980 they may cost no more than $2000 [1]. This price would include an input unit (keyboard and tape cassette) and a small television-like display. Thus, the minicomputer will be a "personal" computer, although individual ownership will not yet be widespread. Continuing circuit miniaturization may make the minicomputer of 1980 as small and as portable as today's transistor radio.

The present speed of minicomputers--up to one million operations per second--is quite adequate for most applications; the limited memory size, usually a few thousand words, may be a handicap. The rapidly decreasing cost of high-speed memory will remedy this deficiency. The input-output problem can be solved through the use of inexpensive cassettes that contain both programs and data. The current lack of standardization should be solved in the next few years.

It is quite clear that there is considerable potential for the use of minicomputers in education. As mentioned previously, the main barriers are institutional; however, there also exist technical problems in software development (discussed below). Nevertheless, it is easy to imagine the student of 1980 spending part of each day with a minicomputer--using it for tutorial work, drill, testing, simulation, or as a sophisticated slide rule. Likewise, teachers and administrators will find it valuable for such tasks as the management of instruction and record-keeping.

Terminals

The success of computer time-sharing in the later 1960s created a demand for low-cost, reliable terminals. The adaptation of familiar communication devices--typewriter, teletype, television, and telephone--for computer terminals is an obvious trend, but developments in the 1970s may displace some of these devices as terminals.

Excessive reliance on keyboard input will probably decrease, although the keyboard will continue to be important, and children should be taught touch-typing--perhaps via computer--in the elementary school. Lightweight touch-sensitive surfaces that permit "quiet" input may replace the keyboard, although the positive action of keys is considered important by some. Menus of items in displays will become common, so that the user may initiate action merely by pointing to a desired item with a light-pen or by touching the display surface. Pictorial and handwritten information will be entered by special pens; however, the ready interpretation of such information is likely to remain expensive and difficult. The use of a limited vocabulary in spoken computer input, while technically possible in certain situations today, will probably not be widespread by 1980.

Some of the graphic terminals will be an adaptation of television and other technology, while others will depend on new developments. In the latter category is the plasma display panel, developed at the University of Illinois [4]. This panel is a thin, flat, gas-filled glass container that can display pictures without computer regeneration, although both the computer and the user can modify the display. Although such a terminal is proposed for a large computer serving thousands of users, it is also likely to see considerable use with minicomputers, provided the cost is moderate.

SOFTWARE

Powerful Languages

Powerful software is the likely result over time of powerful computers, increased demand for computing services, and a better understanding of how to build good software. For example, the ability of a computer to operate in parallel necessitates language features for describing parallel computation, which is only beginning to be understood. The 1980s should see software for effectively handling not only parallelism, but many other features that are beginning to appear in the hardware, including readily switchable microprograms, many levels of interrupts, very large memories, associative memories, and various amenities that contribute to multi-user access.

Extensible higher-level languages will probably become feasible. Users will be able to define their own language features as an extension of a parent language; because the parent language is the same, this will not sacrifice compatibility. Efficient metacompilers will also probably emerge, so that the development of compilers for specialized languages will itself be an automated function.

Author languages for the production of instructional programs will become more standardized. They will contain powerful language features, such as extensive matching capabilities for free-form English, and the provision for writing programs that adapt to the needs of individual students to a much greater degree than currently exists.

Simple Languages

The discussion above presupposes the existence of talented and willing programmers and other specialists, and indeed there should be a fair supply of such people. A longer-range trend is toward the development of programming languages so simple that little or no expertise is required to use them. An interesting forecast [5] asserts that programming will be widely taught and, except for a few computer specialists, there will be no programmers as we now know them. The use of computers via simple languages will be routinely taught in secondary schools, with the computer itself as the instructional medium in a kind of "bootstrap" operation.

These "simple languages" will be subsets of English, and programming will be no more than the straightforward enumeration of familiar declarative and imperative sentences that tell the computer what to do. If the instructions are fuzzy, the computer will ask for clarification. However, a major difficulty is that the computer interprets commands literally and the human does not necessarily convey precisely what is intended. A better feedback of how the computer interprets instructions, together with means for easy modification, would alleviate this problem.

Applications

The 1980s should see tens of thousands of computer programs as readily available as library books are now. They will probably be accessible through a nationwide data bank, retrieved over ordinary telephone lines or special lines, or simply sent on tapes or other storage media. The cost will range from free to expensive, the latter in the case of large, specialized, low-demand, high-royalty programs. Most programs will be application-oriented, designed to carry out specific types of computations in specific problem areas. The range of applications will be immense, probably including many not even imagined today. The realization of such a national computer library will depend upon many factors, e.g., language compatibility, ease of program use and distribution, communications availability and reliability, royalty arrangements, and many others beyond the scope of this paper. An overriding consideration will be cost-effectiveness. Most individuals and companies using application programs will do so only if they provide a saving and/or improvement over alternative methods.

Many applications will be in education, covering such diverse areas as computer-aided instruction (CAI), computer-managed instruction (CMI), record-keeping, and general computing. The large market for these programs should insure a high level of both quantity and quality, just as is generally the case today in the textbook market. Once again, however, the programs will have to prove themselves cost-effective. Many political problems will have to be overcome, including the present lack of acceptance of computers in all levels of education; hopefully, by 1980 most of these problems will have been faced and solved.

SYSTEMS

Time-Sharing

Time-sharing, a novelty of the 1960s, is a reality of the 1970s. It makes feasible the on-line use of computers of all sizes. Although time-sharing services are now relatively common, there is still a large untapped market associated with the use of interactive application programs of the type previously described. At present, there are hundreds of commercial firms offering time-sharing services, but it seems likely that consolidation and shakeout among these companies will result in dominance by a few large companies in 1980.

Despite the enchantment with time-sharing as a way of using computers, the concept of interactive computing may have been oversold. For example, Sackman [6] found in some experiments that computer time required to solve a given problem was significantly greater for on-line access than for batch, and that man-hours required were as great. By 1980, there should be a clear understanding of what should be done interactively and what is best left for batch processing; such studies are largely lacking at present. The economies of the situation may well force the right choices.

CAI owes its existence to time-sharing, but the promise is only slowly being realized. An interesting sign of the present times is found in a college catalog [7], offering students a choice of taking a certain course (Introduction to Information Processing Concepts) either conventionally or via CAI. The CAI course costs 40 percent more ($145 versus $105), but includes computer time and the possibility of using any off-campus terminal to which the student may have access. By 1980, this kind of arrangement should be common.

Communications

The communications industry was hardly prepared for the extensive tie-ins of computers with terminals and other computers that is occurring at present. Although ordinary telephone lines are used for much of this data transmission, they are often inadequate in both quantity and quality. The expected ten-fold increase in data communication in the 1970s necessitates the expansion of facilities for this purpose.

For local communication, special data lines will come into use. The germ of this idea is already present in cable television (CATV), which can bring a broad-bandwidth channel into homes, businesses, and schools. Such a channel--or even part of one--can be used to link a terminal with a central computer. At present, of course, CATV is a one-way transmission, but in the 1980s a two-way transmission is likely.

For long-distance communication, upgraded telephone circuits will continue to be used, but other facilities will also be constructed. Microwave networks will be built specifically for data transmission.

Earth satellites will be used partly for data communication, but the extent of this is very difficult to predict.

The impact upon education of these advances in computer communications will be considerable. They will permit the previously discussed hardware and software advances of 1980's computers to be brought directly to administrators, teachers, and students. If communication costs become sufficiently low, "equal computer opportunity" is a possibility for all of the nation's schools.

Computer Networks

Experimentation has already begun with networks of computers. The most ambitious current project, the ARPA Network [8], links about twenty computers, located primarily at universities across the country. The purpose is to give each network member access to all specialized facilities--both hardware and software--located throughout the network. By 1980, such networks should be relatively common, although most will probably be regional.

Another approach to computer networks involves small, local computers for most needs, but with the capability of tying-in with larger, remote computers when required. This involves a blend of several ideas--minicomputers, time-sharing, and remote communications--and, in the future, may well be a common way of organizing and distributing computing power.

CONCLUSION

This paper has dealt with a perception of computing technology in 1980. Some readers may think that, because many of the predictions are based upon present developments, they will come about considerably sooner than 1980. Others may be dismayed that few really blue-sky ideas are included. It should be remembered that this paper has concentrated on those developments that are likely to be in fairly common use; for this criterion to be met, time, money, and demonstrated need are all necessary.

The infusion of these ideas into education is an exciting prospect. The growing public concern for better education, together with the increasing willingness of those holding the pursestrings to try new ideas in education, should insure that at least some of the innovations in computer technology will be used to enrich and improve the educational process.

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