PLATO IV - AN ECONOMICALLY VIABLE LARGE SCALE COMPUTER-BASED EDUCATION SYSTEM

D. L. Bitzer and D. Skaperdas

University of Illinois
Urbana, Illinois

I. INTRODUCTION

For the past eight years a computer-based teaching system called PLATO (an acrynom standing for Programmed Logic for Automatic Teaching Operations) has been under technical development and educational testing at the University of Illinois. The present system, PLATO III, has accumulated over 50,000 student contact hours of teaching in a variety of subjects.

It will be shown that the computer, usually considered too expensive to be economically viable as the central control element in a large-scale educational system, is actually inexpensive even when used in sophisticated ways by the student. The main factor that discourages the use of computers for large-scale teaching is the unavailability of inexpensive graphic terminals. Recognizing this factor, the University of Illinois initiated a research and development program aimed at developing a low cost graphic terminal. A detailed discussion of the teaching pedagogies presently used and the new devices under development is not possible in this paper but can be found in the references. The purpose of this paper is to give a more general picture of a proposed economically viable, large-scale, computer-controlled teaching system.

II. THE PLATO TEACHING SYSTEM

In 1960 the first PLATO teaching system[1] consisted of a single student station connected to ILLIAC I, a medium-speed computer constructed at the University of Illinois. The second model, PLATO II, had two student stations connected originally to ILLIAC I and then later to a Control Data Corporation 1604 computer[2]. This model was used to study the problems encountered with multiple student use. The present model[3], PLATO III, utilizes the CDC 1604 computer as a central control element for teaching 20 students simultaneously while allowing each student to proceed independently. Some of the areas from which lesson material tested on the PLATO system has come are geometry, arithmetic, algebra, chemistry, biology, library science, electrical engineering, and maternity nursing. Many of the courses[4] were developed to test the capability of the teaching system; thus, the method of presentation of these courses ranges from drill and practice strategies to inquiry strategies in which the students determine the data they require. Many are based upon combinations of tutorial presentation and inquiry teaching presentation. Students have ranged in age from pre-schoolers through graduate students. In most courses the major emphasis was upon developing critical thinking skills, where students are taught to ask appropriate questions, answer well-formulated questions, gather data, perform critical experiments and select and evaluate pertinent information.

In most PLATO teaching programs the students work independently of each other, although the system can provide inter-student communication. Existing teaching strategies permit the teacher to do on-line testing and editing of lesson material. One important feature of the PLATO system is its ability to keep complete records on each student's performance. Each student's request (the key pushed, who he is, and the time) is automatically recorded on magnetic tape which can then be processed to yield statistical data for educational and system evaluation. These stored records show that on the average each student generates approximately 1000 requests each hour. On the basis of 50,000 student contact hours, over 5×10^7 total requests are available for statistical analysis.

The design features for the proposed PLATO IV system are based on this statistical information. A block diagram of the present PLATO system is shown in Fig. 1. Each student's teaching station consists of a cathode-ray tube which displays video data and a keyset for communicating with the central computer. An outstanding feature of this system is the superposition of the video images from the random-access slide selector (static information) on each CRT. Information stored in the slide selector is of the type ordinarily found in a textbook. The dynamic information display consists of a computer-controlled electrostatic storage tube assigned to each student station. Diagrams, symbols and words are plotted in a point-by-point fashion on a student's storage tube. Superposition of the slide and storage tube video images on a student's CRT display enables the student to do such things as fill in the blanks on the slide in response to questions.

III. THE PROPOSED TEACHING SYSTEM

The Computer-based Education Research Laboratory's (CERL) proposal for a large-scale computer-based teaching system capable of controlling up to 4000 student terminals simultaneously was prompted by two factors. One was the wide acceptance of an increased teaching load on the present PLATO system, and the other was recent technological developments which would make such a system economically feasible. On the basis of CERL's experience with early PLATO systems, certain design philosophies for the proposed system have been formulated. First, each student terminal

National Electronics Conference Dec, 1968

requires a keyset and a display, both connected to an inexpensive data transmission system which can also drive optional equipment such as random-access audio devices, reward mechanisms, movie films, lights, and so forth. Second, each student terminal must be capable of superimposing randomly-accessed color slide images and computer-generated graphics. Third, the system should be controlled by a large-scale, centrally-located computer rather than many small computers located at the classroom sites. This decision is based upon social and administrative factors as well as on system economics. Semiconductor large-scale integration techniques may some day make the use of small computers as effective as large ones, but the added human expense of operating a computer center does not promise to scale as effectively. It is our opinion that the initial low cost of a single terminal will permit tightly-budgeted public school systems to economically incorporate computer-based teaching into their programs. The number of terminals could be increased or decreased as the needs of the school system dictate. Fourth, the cost per student contact hour for the proposed system must be competitive with equivalent costs of traditional teaching methods at grade schools, high schools and colleges.

IV. COMPUTER EVALUATION

Statistical records of over 5×10^7 requests on PLATO indicate that the average request rate per student is approximately one request every four seconds. These records also show that average computer execution time per request for the CDC 1604 is less than 20 milliseconds, equivalent to executing approximately 1000 instructions. The request rate probability density function versus computer execution time is approximately an exponential curve; therefore, student requests requiring the least amount of computer time occur most frequently. For example, the simple and rapidly-processed task of storing a student's keypush in the computer and writing the character on his screen represents 70 per cent of the requests. On the other hand, the lengthy process of judging a student's completed answer for correctness, completeness, spelling, etc. occurs only 7 per cent of the time.

Several existing large-scale computers can perform about 4×10^6 instructions per second. Even if we double the number of instructions needed to 2000 per student request, it is seen that these large-scale computers require an average processing time of only 500 microseconds per request. Allowing a safety factor of two to insure excellent system response time, the system can accept an average of 1000 requests per second. This safety factor implies that the computer will be idle approximately 50 per cent of the time. However, the computer time not utilized in processing the student requests can be effectively used for other purposes. Since the average student request rate is 1/4 of a request per second, the system can handle up to 4000 students simultaneously allowing one millisecond to process a request. Assume that the student input arrival time is Poisson distributed (a reasonable assumption for 4000 independent student stations), and that the request rate probability density function versus computer execution time is approximately exponential (PLATO statistical records substantiate this). For an average computer execution time of 500 microseconds and an average request rate for 4000 students of 1000 requests per second, it is determined from queing theory[2,7] that the expected waiting time that elapses before the computer will accept a given student's request is approximately 500 microseconds. The probability that the student must wait for as long as a tenth of a second is negligible. Hence, the probability of a student's request queue becoming long, or of the student experiencing a noticeable delay is very small.

Each student needs to be assigned approximately 300 words of extended core memory to be treated individually. The maximum used in any teaching strategy has been 600 words per student. Let us allow on the average 500 words (fifty bit) for each student for a total of 2×10^6 words for 4000 student terminals. Our data shows that 20 per cent of the computer instructions refer to these words individually assigned to the students. Therefore, the system must be capable of rapidly transferring data between the slower extended core storage and the high-speed core memory. Some existing computers are capable of transferring data at 10^7 words per second, requiring only 50 microseconds to transfer the data each way between the memory units. This transfer time is acceptable.

The peak data rate from the computer to each student station is limited to 1200 bits per second to permit data transmission over low-grade telephone circuits, a system feature made possible by the use of the plasma display panel discussed later. For 4000 stations the worst case data rate would be about 4.8×10^6 bits per second, well within the present state of the art for buffering data out of a computer.

Summarizing the computer requirements, therefore, the central computer requires about 2×10^6 words of extended core memory capable of high-speed transfer rates to the main computer memory, it must have an execution time of at least 4 instructions per microsecond and be capable of transmitting data at a rate of 4.8×10^6 bits per second. There should be a sufficiently large memory (64k to 128k words) in the central processing unit for storing lessons (1k to 2k words per lesson) and for the various teaching strategies. Several existing computers meet these requirements.

V. TERMINAL EVALUATION

The economic feasibility of the proposed teaching system is dependent upon the newly-invented plasma display panel (or equivalent device) now under development at the University of Illinois and other laboratories. This device combines the properties of memory, display and high brightness in a simple structure of potentially inexpensive fabrication. In contrast to the commonly-used cathode ray tube display, whose images must be continually regenerated, the plasma display retains its own images and responds directly to the digital signals from the computer. This feature will reduce considerably the cost of communication distribution lines. The plasma display is discussed in detail in the listed references.[8,9,10] Briefly, it consists of a thin glass panel structure containing a rectangular array of small gas cells (about .015 inches in diameter and .006 inch thick) at a linear cell density of about 40 cells per inch (see Fig.2). Any cell can be selectively ignited (gas discharge) or turned off by proper application of voltages to the orthogonal grid structures without influencing the state of the remaining cells. The plasma panel is transparent, allowing the superposition of optically projected images.

A schematic of a proposed student terminal using the plasma display is shown in Fig. 3. The display will be approximately 12 inches square and will contain 512 digitally addressable positions along each axis. A digitally-addressable slide selector and projector will allow prestored (static) information to be projected on the rear of the glass panel display. This permits the stored information to be superimposed on the panel which contains the computer-generated (dynamic) information. The projector will contain an easily-removable 4-inch square film plate containing at least 256 color images. Based upon models now being tested, a low-cost image selector with less than 0.2 sec. random access time is anticipated.

Data arriving from the computer via a telephone line enters the terminal through an input register. As previously stated, data rates to the terminal will be held to 1200 bits per second. Assuming a word length of 20 bits, the terminal could receive data at 60 words per second. With proper data formats data rates will be adequate for the applications envisaged. For example, packing three character codes per word will permit a writing rate of 180 characters per second, which is a much faster rate than that of a good reader. In addition, continuous curves can be drawn at rates greater than 300 points per second. The keyset will provide the student with a means of communicating with the computer.

VI. DATA DISTRIBUTION

In situations where a large number of students are located at considerable distances from the central computer, costs can be lowered drastically by use of a coaxial line instead of numerous phone lines. For example, the cost for a 4.5 mc coaxial line is approximately \$35 per month per mile, whereas the corresponding rate for a 3 kc telephone line is approximately \$3.5 per month per mile. The coaxial line can handle at least 1500 channels on a time-shared basis, each channel consisting of 1200 bits per second. Hence, for an increase in line cost of a factor of 10 over that of a single channel, an increase of a factor of 1500 in channel capacity can be obtained. Data to remote locations will be transmitted by a coaxial line to a central point; from this point local telephone lines rented on a subscriber's service basis would transmit the proper channel to each student terminal. A block diagram of a proposed distribution system to several remote terminals is shown in Fig. 4.

VII. COST ANALYSIS

The main frame cost of a computer meeting the above requirements is approximately \$$2.5 \times 10^6$. The additional cost for two million words of memory and other input-output equipment is approximately \$$2 \times 10^6$. An estimate for the system software, including some course development programming, is another \$$1.5 \times 10^6$. The total of \$$6 \times 10^6$ amortized over the generally-accepted period of 5 years yields \$$1.2 \times 10^6$ per year.

Assuming that the 4000-terminal system will be in use 8 hours a day for 300 days a year, there are approximately 10^7 student contact hours per year. The system costs, excluding the terminals, is thus 12¢ per student contact hour. In order to be competitive with a conventional elementary school classroom cost of approximately 27¢ per student contact hour, the terminal costs must be limited to 15¢ per student contact hour, or to a total cost of about \$$7.5 \times 10^6$ over a 5 year period. The cost for each of the 4,000 terminals, which include a digitally-addressed graphical display device and its driver, a keyset, and a slide selector must therefore be a maximum of approximately \$1900. Present indications are that this cost can be met.

These costs, based on the above assumptions, are summarized in Chart I. The earning power of the computer for the remaining 16 hours each day and for the idle time between student requests, which would further reduce costs, has not been included.

VIII. CONCLUSION

Using newly-developed technological devices it is economically and technically feasible to develop large-scale computer-controlled teaching systems for handling 4000 teaching stations which are competitive with the cost of teaching in elementary schools. The teaching versatility of a large-scale computer is nearly limitless. Even while simultaneously teaching 4000 students, the computer can take advantage of the 50 per cent idle time to perform data processing at half its normal speed. In addition, 16 hours per day of computer time is available for normal computer use. The approximate computer cost of 12¢ per student contact hour pays completely for the computer even though it utilizes only 1/6 of its computational capacity. The remaining 5/6 of its capacity is available at no cost.

References

1. D. Bitzer, W. Lichtenberger, and P. G. Braunfeld, "PLATO: an automatic teaching device", IRE Trans. on Education, vol. E-4, pp. 157-161, Dec. 1961.

2. D. L. Bitzer and P. G. Braunfeld, "Description and use of a Computer Controlled Teaching System", Proc. of the National Electronic Conference, pp. 787-792.

3. D. L. Bitzer and J. A. Easley, Jr., "PLATO: A Computer-controlled Teaching System," Computer Augmentation of Human Reasoning (Washington: Spartan Books, Inc., ed. by Sass and Wilkinson) pp. 89-103 (1965).

4. E. R. Lyman, "A Descriptive List of PLATO Programs, 1960-1968," CERL Report X-2, May, 1968, Computer-based Education Research Laboratory, University of Illinois, Urbana, Illinois.

5. K. E. Knight, "Changes in Computer Performance", Datamation, Sept., 1966, pp. 40-54.

6. K. E. Knight, "Evolving Computer Performance 1963-1967", Datamation, Jan. 1968, pp. 31-35.

7. H. H. Goode and R. E. Machol, Control Systems Engineering, McGraw Hill Book Co., Inc., 1957, pp. 328-343.

8. D. L. Bitzer and H. G. Slottow, "The Plasma Display Panel - A Digitally Addressable Display with Inherent Memory," Proceedings - Fall Joint Computer Conference, 1966, pp. 541-547.

9. Bitzer, D. L., and H. G. Slottow, Principles and Applications of the Plasma Display Panel. Proceedings of the O.A.R. Research Applications Conference. Office of Eerospace Research, Arlington, Va. March, 1968. (also pusl in the proceedings of the 1968 Micro-electronics Symposium I.E.E.E., St. Louis, 1968)

10. Aurora, B. M., Bitzer, D. L., Slottow, H.G., and Willson, R. H. Plasma Display Panel: A New Device for Information Display and Storage. Proc. Eighth Nat. Symp. on Information Display, May, 1967.

CHART I. SUMMARY OF COSTS

Item	Total Cost in $	Cost/year in $ 5 year amortization	Cost per student contact hour
Computer and extended memory	4.5×10^6	0.9×10^6	8¢
Software	1.5×10^6	0.3×10^6	4¢
4000 student terminals	7.5×10^6	1.5×10^6	15¢
Total	13.5×10^6	2.7×10^6	27¢

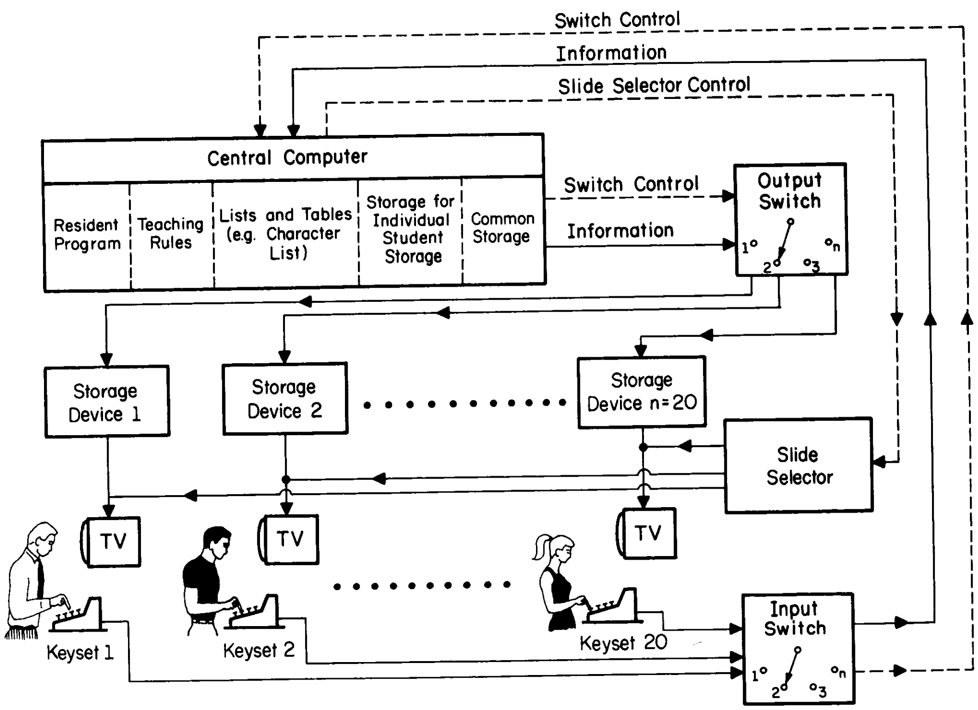

Fig. 1. Present PLATO System Block Diagram

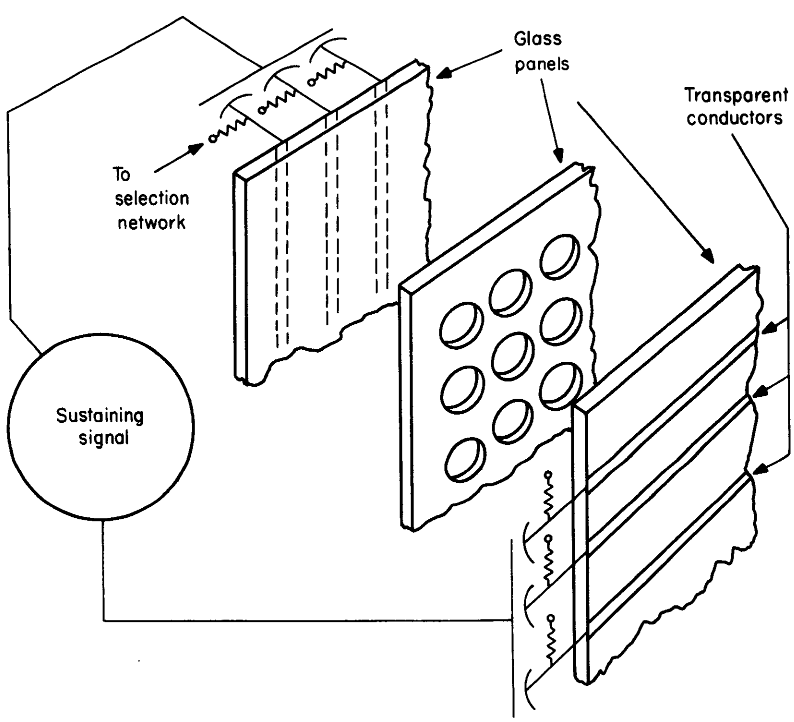

Fig. 2. Plasma Display Panel

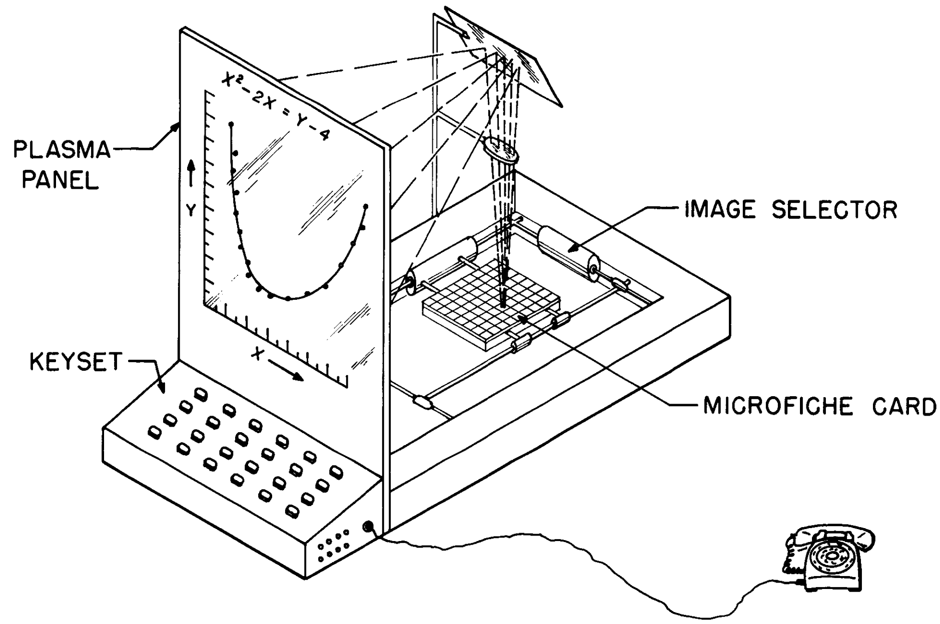

Fig. 3. Proposed Student Terminal

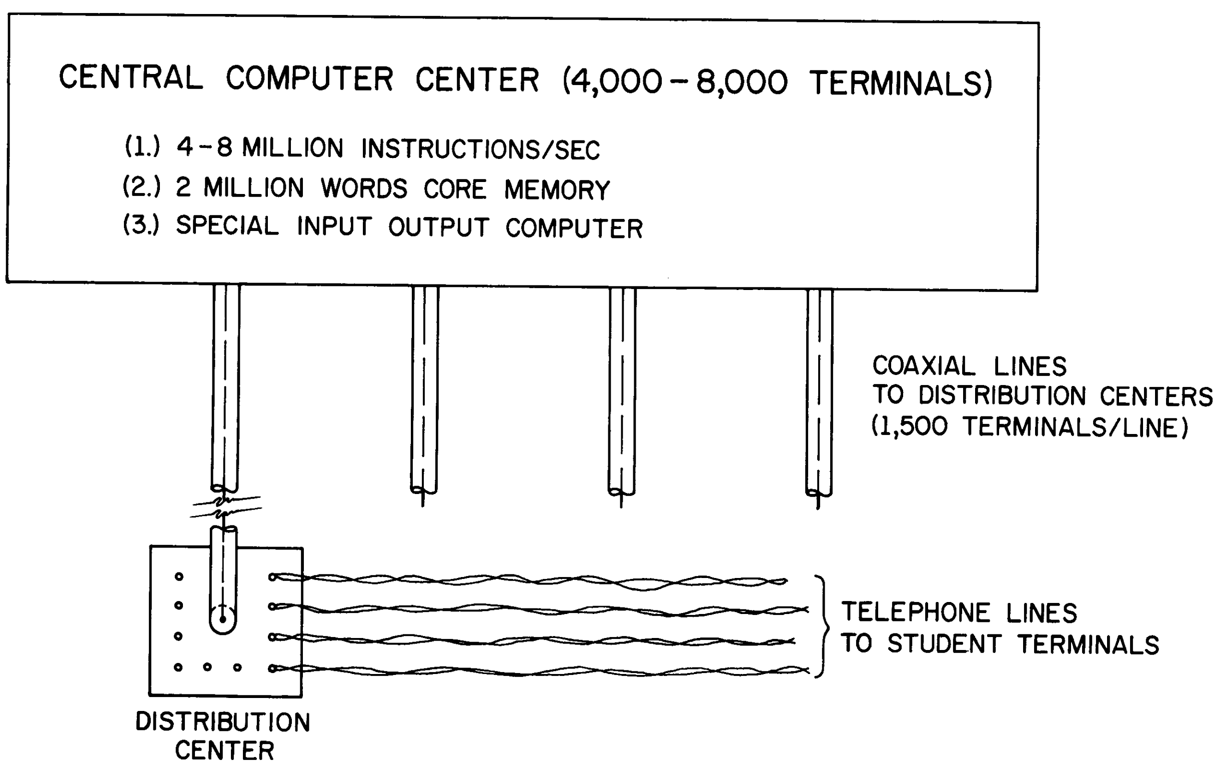

Fig. 4. Block Diagram of Proposed Distribution System