MAN-COMPUTER COMMUNICATIONS AND CAI

Steve Hunka
University of Alberta

Abstract

Computer-assisted instruction in its various forms has become evident in all segments of the educational sector including industry, universities and colleges, public schools, specialized institutions catering to the handicapped, as well as in the area of professional continuing education. This wide range of application touches upon learners of widely varying ages and capabilities, as well as widely differing subject matter and instructional strategies. Because the sole interface between the learner and the computer is the terminal, and because the use of computer-assisted instruction depends considerably upon the adequacy of the instruction as perceived by the traditional instructor, these variations place severe demands upon terminal capabilities.

Ideally, computer-assisted instruction terminals must provide to the learner, in an integrated and coordinated fashion, such capabilities as volatile and hard copy, special function keys, methods for accepting a pointing response, both static and dynamic graphics, photographic or similar high resolution images, audio, differing character sets including their magnification, and author support features. The importance of these factors varies as a function of the nature of the material taught, the instructional algorithms deemed necessary by the instructor, and the maturity of the student. Some of the most demanding constraints are imposed by the young normal child.

COMMUNICATIONS HOMME-ORDINATEUR ET EAO

Résumé

L'enseignement à l'aide de l'ordinateur (EAO), sous ses diverses formes, se manifeste dans toutes les sphères de l'éducation, y compris dans l'industrie, les universités, les collèges, les écoles publiques, les instituts spécialisés pour handicapés, de même que dans le secteur de l'enseignement professionnel continu. Il en résulte que des élèves de tous âges et de compétences très variées sont appelés à étudier de cette façon des sujets fort diversifiés, selon des méthodes pédagogiques très différentes. Étant donné que le terminal est l'unique interface entre l'élève et l'ordinateur et que l'usage de cette méthode d'enseignement dépend largement de la perception que le maître traditionnel peut avoir de son efficacité, les installations terminales doivent offrir une vaste gamme de possibilités.

Dans une situation idéale, pour répondre aux besoins des élèves qui étudient à l'aide de l'ordinateur, les terminaux doivent offrir les services suivants: affichage sur écran et documents sur papier, touches de fonctions spécialisées, possibilité d'accepter des réponses par indication, systèmes graphiques statiques et dynamiques, images photographiques ou de haute résolution, dispositifs sonores, jeux de caractères différents avec possibilité d'agrandissement, dispositifs de soutien pour les auteurs. L'importance de ces facteurs est fonction de la matière enseignée, des algorithmes pédagogiques considérés nécessaires par les enseignants et de la maturité des élèves. C'est souvent dans le cas des jeunes enfants normaux que les exigences sont les plus contraignantes.

MAN-COMPUTER COMMUNICATIONS AND CAI

Educators and learning psychologists have frequently related the use of the computer for instruction to the work of Pressy and Skinner in the area of teaching machines and programmed instruction. In fact, it is still possible today to be asked the question whether a computer instructional program is a "linear" or "branching," as if the computer was an electronic version of an old mechanical teaching machine. Considerable progress has been made during the last ten years in the use of computer assisted instruction, not as a replication of a mechanical teaching machine, but rather as a simulator of instructional activity commonly used in the classroom. Progress is still to be made since this simulation will eventually be enhanced and replaced by experience from computer-assisted instruction alone.

A variety of direct and indirect instructional activities during the last ten years have employed computers. Three terms generally referring to the application of the computer for instructional activities have become most prominent: Computer-Assisted Instruction (CAI), Computer-Assisted Learning (CAL), and Computer Managed Instruction (CMI). In sophisticated examples of CMI (Zarsky, 1973; Westrom, 1973) computing software is designed to contain a number of interrelated files containing student data, curriculum material, test material and associated scoring procedures, and a logic structure or file which coordinates the system activity as it is being used. In most cases, pre-test information which may also be held by the system, may be given to all students, and on the basis of the results, the system decides what material the student should study next. Some of the curriculum material may be printed directly by the system for the student, or the student may be directed towards some type of activity involving other sources of learning material. Clearly, the student need not even be aware that a computer interface has been made. Both CAI and CAL generally refer to the use of the computer for direct instructional activity with the student interacting with the computer through some type of computer terminal. One suspects that there is a subtle difference in the terms CAI and CAL since these separate terms continue to persist. Although CAI may be viewed as an aid to instruction, and CAL as emphasizing that the learner is being aided, whether one prefers one term over the other, little difference due to these terms can be seen in the current applications of computers for direct instructional activities.

Since most users of computers are working in a relatively high level environment in terms of intellectual activities, it is easy to assume that the whole world consists of individuals who have similar interests and capabilities. But clearly, the world is not made up of individuals who can all read, do arithmetic, and understand the elements of language necessary for accurate communication. Thus, when CAI is considered in its broadest context and outside of the confines of the large-scale computing center or the university, some demanding constraints are placed upon the interaction of man and computer. Although industry and the armed forces appear to be counting heavily upon the use of computers for instruction for manpower training, the most extensive applications of CAI have been made in the public education sector. Within this sector the students may range from kindergarten to grade twelve, from students handicapped by motor and cognitive inadequacies to those students who are intellectually very bright. The variation at the post-secondary school level is not as wide, even if the range includes a first year university student and a medical practitioner involved in a program of continuing medical education. In one way or another, CAI is being called upon to meet this wide range of students. Clearly, we must keep in mind that all learning activities of students considered in the broadest sense, is not going to involve the sophisticated interaction aimed at by those working in the area of artificial intelligence. This is not to say, however, that artificial intelligence will not make a valuable contribution to the field of CAI as time goes on. Many instructional strategies are required for effective CAI, particularly as the length of the course increases and tends to become the primary source of instruction for the student. Perhaps because of the need for computer programs to be documented, the process of documenting CAI courses has, and will continue to encourage the specification of more precise instructional strategies, crude as they may seem today. Even now these CAI strategies are more clearly articulated than those typically found in a teacher's lesson plan. Within CAI programs the following broad classes of instructional strategies have been generally accepted:

Turorial: Turorial courses are characterized by the course author designing his course to simulate an interaction between himself and the student. Reading material is presented, questions are asked, response analysis tends to follow a hierarchy beginning with correct and synonymous correct answers, wrong and synonymous wrong answers which are associated with typical misconceptions expected on the basis of the author's previous experience.

Drill and Practice: These are characterized by instructional strategies which may proceed through a predestined course of problems of fixed number, to those programs which generate, to a lesser or larger degree, their own problems based upon the student's needs. Three models can be easily identified as random, fixed, and mixed. In the random model problems are generated randomly, usually within some set of boundary values. In the fixed model, a finite set of problems are presented unvaringly to each student. In the mixed model some combination of both are used. Drill and practice programs may also have a structure which directs the student through varying levels of difficulty and problem types. Drill and practice programs are abundant in the mathematical area, but become more difficult to construct in the social sciences.

Review: The value of review both for purposes of structuring known material prior to teaching new material, and for consolidating newly learned material, has been found to enhance learning. Such reviews in some cases may restate principle ideas and concepts or they may embody other instructional strategies such as tutoring, diagnosing and testing.

Testing: One might wish to argue that since very close monitoring of a student's progress is made, and since the student must demonstrate understanding before he is allowed to proceed, there is no need for formal testing. Testing will remain an integral part of CAI even if its only function is to determine whether the student can demonstrate his newly learned skills at some time after the initial instruction. Testing can take very rudimentary forms of question and answer, or may border on complex simulations. Testing may involve a finite set of questions, be sampled from a pool of questions, or be generated individually for a student based upon accumulated date within the test itself, leading to so-called tailored testing. Testing may involve simple responses, correctly constructed sentences, numerical responses, or the manipulation of symbols or drawings.

Remediation and Diagnosis: CAI programs which are designed to diagnose and then to effect a course of remediation are in use today (Olivier, 1973). Such programs must follow some prescribed ordering of subject matter and tailored testing. Such procedures allow the system to converge upon specific deficiencies of the student and to provide, either from a finite pool or by some generating algorithm, the remediation required. The nature of the remediation can place severe constraints on the computing system. For example, in the reading area it would be more difficult to check the pronounciation of a word than to determine whether a word has been correctly spelled.

Problem Solving: Although problem solving type approaches to instruction have tended to grow up outside of CAI courses because of the inadequate interfaces between CAI languages and computing languages, problem solving remains an important part of instructional computing. To constrast typical CAI with problem solving, it is important to recognize that for most CAI instructional programs the bounds of the program are quite precisely defined. In problem solving mode, the student is usually allowed to use the computing system to solve a problem by his own methods of attack (Pappert, 1974).

Simulations: Simulations can be tremendously varied depending upon the nature of the subject matter and the purpose of the simulation. Some simulations require fast dynamic graphics to be effective, extensive computational power, or they may require only minor amounts of both facilities.

Such instructional strategies may be structured within the context of a complete course, or used as individual stand-alone components. If the strategies are to be interrelated into a complete course, further specification of instructional logic including both logical and psychological ordering of the material, must be precisely defined.

The range of subject matter used in CAI has been extremely broad (Wang, 1976; Kearsley, 1976). Those courses having the least amount of attitude content are probably the most frequently devised. The most rapid growth in course development is, however, being made in the area of medical education, the latter including tutorial, simulation, and testing strategies. Currently at The Univeristy of Alberta the following courses are operational forming a primary source of instruction for the student:

1. Cardiology: (Rossall, 1974.) An introduction to the recognition of heart murmurs including radiological and physical conditions; time about 25 hours.

2. Statistics: (Hunka, Romaniuk, Maguire, 1976.) This course covers descriptive statistics to one-way analysis of variance; average time to complete 60 hours.

3. Electrical Theory: (Petruk, 1975.) An introduction to basic electricity, average time to complete about 40 hours.

4. Fundamentals of Data Processing: An introduction to basics of computer processing and computer language; time 25 hours.

5. French: (McEwen, Robinson, 1976.) An introduction to beginning French as used at about the grade 10 level; time about 25 hours.

6. Medical Examinations: Examinations developed by the R.S. McLaughlin Examination and Research Centre for the Royal College of Physicians and Surgeons; includes simulated patient management as well as traditional examinations; time about 20 hours.

7. CAI Programming: An introduction to programming in Coursewriter for the IBM CAI system; time about 20 hours.

The courses noted above, which contributed to 23,000 hours of instruction in 1975, suggest that a wide range of subject matter has been already made operational just at one institution in Canada. Other institutions and facilities are also involved in the development of CAI courses. These institutions include Simon Fraser University, the Univeristy of Calgary, University of Manitoba, Ontario Institute for Studies in Education, Erindale College, Algonquin College, Seneca College, University of Waterloo, McGill University, the National Research Council with a number of other educational institutions using their facilities, the Armed Forces at Kingston, and the University of Quebec. In the United States, notable locations of CAI activity include the University of Illinois (Plato system), the Arden Hills, Minnesota, facility of Control Data Corporation, Ohio State University, Florida State University, Brigham Young University (TICCIT system), and the United States Navy at San Diego. The state of Minnesota has about 1,700 terminals out for various educational functions, while Philadelphia has 400, Los Angeles 550, and the city of Chicago has 1,000 terminals placed in approximately 50 elementary schools.

The delineation of important variables in man-computer communications must be viewed in the context of the factors just summarized, the wide range of students and subject matter, and the strategies of instruction. Other factors, such as the philosophy by which CAI is operationalized, is also important. At the University of Alberta we have tended to place importance upon the following additional factors:

1. A unit of CAI instruction should be a primary source of instruction for the student regardless of the length of the instructional program.

2. A major impact upon traditional methods of instruction will only be made when courses of at least 15 hours have been developed.

3. The CAI system should not be used to "back-up" the inadequacies of the computer.

4. The course material should be designed as if the instructor will not be in attendance, i.e., as if the lesson material were to be run remotely from the traditional classroom.

5. The author or instructor must perceive that the system of CAI does not degrade his instructional efforts.

6. A combination of instructional strategies must be employed, and if the same strategy is employed for long periods of time, CAI can become boring and the motivation of the student is lost. A combination of simulating good classroom practice, using unique computer capabilities, plus understanding of the factors which are required to initiate and maintain learning, are important to the design of a CAI course.

7. The analysis of performance of the students is an integral and vital step required for the improvement of the course material.

Given the factors of CAI just noted, the nature of the interface between the student and the computing system becomes paramount. This interface must be accomplished through the computer terminal. The following devices can be identified as desirable components of the terminal interface in a CAI system:

A. Output Devices:

1) the display medium
2) graphic output
3) audio output
4) image projection
5) special output signals

B. Input Devices

1) keyboard input
2) pointing response input
3) audio input
4) special input signals

A. THE OUTPUT DEVICES

Our experience would suggest that a volatile type of display medium is the most frequently desired for CAI. An exception to this occurs when it is desirable for the student to retain a copy of his interaction with the system. Such situations do exist and are probably best provided by a hard copy image of the volatile display surface. We have found that in almost all cases the impact printing terminals are too slow, particularly for the output of graphic material. In addition, their character sets are too limited and incapable of being magnified for use with small children. Hardcopy output also prevents the accumulation of new material within the context of previously displayed material.

Keeping in mind the wide range of students and subject matter which CAI attempts to handle, the desirable characteristics of a terminal, and examples of situations in which these characteristics are important, are as follows:

1) A Volatile Display Surface

Currently the emphasis is upon the use of the CRT, with some terminals as in the Plato System (Stifle, 1974) using the plasma plate. With the development of small alphanumeric sets of LEDs one is lead to predict that the LED display panel may supercede the plasma plate. However, because of costs, terminals with CRTs will likely continue for sometime since their production can take advantage of existing television manufacturing procedures. The terminal should be capable of insert mode of operation without a complete "blanking out" of the screen each time an insert is made. The latter action prohibits the user from accurately determining what has been added to a screen display, unless such a facility as highlighting can be used to indicate the addition. Terminals require the capability of providing a true subscript and superscript, upper and lower case, and variable character sets which may range from foreign language characters to those peculiar to a specific subject matter.

In many terminals it is not possible to position the cursor into any desired area of the display screen for input. Without this capability it would be most difficult to have a student complete and enter the calculations constructing a table of components such as might be required in the binomial distribution. A complicating factor, which is now only being resolved in some terminals, is the need to change the designations on the keyboard characters when a dictionary change is made. This causes a problem for the student trying to determine which keys represent each new character after a dictionary shift has been made. Indeed, the use of LEDs which illuminate the keys for the currently active characters is highly desirable.

2) Graphics.

Graphics are definitely required since we have found that every major course we have makes extensive use of graphics. All these graphics are not necessarily definable by a mathematical function, for example, the diagram of a heart. Thus, capability is required to access each dot of the display surface if a dot type generation is being used. Frequently, it would be desirable to have dynamic representations presented to the student, as for example in an illustration of harmonic motion. Unfortunately, too many terminals used for CAI work must represent motion by continuously redefining a graphic in a new part of the screen. Although this does work, the smoothness of the representation tends to be a function of the load on the central processor unless the terminal contains sufficient "intelligence" to effect the proper generation of movement. The ability to simultaneously mix true video with computer generated displays would be very useful for teaching some subject matter.

We have found that a magnification capability for the terminal is highly desirable, since it provides the opportunity to the course author to highlight important concepts, and to enlarge character sets for use with very young children who would have difficulty learning to discriminate among the various characters during initial phases of reading.

3) Audio Output.

Although our own facility has made extensive use of audio, the use has been limited to those specific courses which, by the nature of the subject matter, or the student, must have the audio facility. For example, audio must be present for instruction in the cardiology program and the beginning reading program currently under development. In the cases where audio is not an integral part of the subject matter, we have found authors using the audio only after they have made full use of the graphic and picture projection capabilities. Based upon our work with both very young children and adults, we would suggest that a faster audio response time is required for young children than for adults. Without the rapid response time, of say less than 1/2 second, a child will attempt alternative actions at the keyboard or with the light pen, with the result that the audio message becomes associated with the last action carried out, when in fact, the message may be in reply to the first action made by the child. In the case of adults they rapidly become accustomed to a two or three second delay in the message, or can be given a textual message indicating that the system is processing and active. Because of the wide range of subject matter which can make use of audio, the quality of the audio must be high. Audio response curves which are flat only over the 2,000 to 6,000 cycle range are unacceptable in most cases. Our first evidence of this problem arose during the attempt to reproduce subtle heart murmurs which are embedded in sounds of both high and low frequency. Further evidence for high quality has been noted in working with young children who are learning for the first time the correct pronounciation of phonemes in beginning reading. On the basis of these experiences we cannot accept some of the audio devices currently on the market. Compressed audio which has been digitalized or the use of disk systems seem to be the most promising. Although audio tape, which can be made addressable for both forward and backward searching, and which may have up to three audio message tracks available at any one point, are currently being produced but they seem to all suffer from unreliability to some extent. Clearly, the problem of reliability is crucial for a young child, for that child may not complain when the sound "mmmm" is presented when the sound "aaaa" was supposed to have been presented. Therefore, it is very important that audio devices be checked to assess the correctness of their search before a message is played to the student. The generation of digitally coded sound through such devices as the Votrax, might be acceptable for adult students, they are quite out of the question for young children whose speech patterns are still developing, and for such special applications as heart sounds.

Although digitally stored audio may present problems in terms of audio fidelity, it would have the one marked advantage of being more amenable to sychronization with central processor activities, and particularly that material being displayed to the child. In the development of our first reading course it is considered very important that synchronization be achieved between the display of a character, the symbol which indicates the child should speak the sound, and the teacher's recorded message to say the sound with her. In our facility this synchronization is obtained by the recording of special pulses on the audio tape being played to the student. These pulses signal the central processor to continue with the next instruction of the course code sequence.

4) Image Projection

Although considerable advancements have been made in the development of high resolution images using CRTs, the most severe test of whether the CRT image is acceptable for photographic-like reproduction is the x-ray used in medical CAI programs. Although many non-medical computer people make judgements as to the adequacy of such images, these images can only be judged by the radiologist. At the present time, it is still difficult to obtain a truly acceptable reproduction of a large chest plate on 35mm for presentation during a CAI lesson. At present CAI terminals appear to be oriented toward the use of 35mm film slides utilizing random access projectors. These devices have some advantages particularly when courses are in the initial stages of development and testing, and when courses are not very long. However, they will present more serious operational problems when long courses are operated. Clearly, the flexibility of being able to replace slides is very desirable during the development phases of a course. The processing procedures are readily available and are generally of high quality. However, if a student is operating within a course of, say 50 hours, and is allowed to move himself about in the course for purposes of review, and if the course contains four or five hundred photographs, then a considerable storage problem and movement of slide containers will result. It would seem desirable that the advantages of 35mm be retained, but that these frames be incorporated into continuous film such as is currently used in the movie industry. As with the audio, it is important that the logic within the terminal, or at the cpu, identify whether the correct film has been found. It is our understanding that this checking is not available with the current Plato terminals. Since film length will also increase access time, projection units must have some capacity for pre-positioning the film in anticipation of being exposed. It may be possible in the future to have sufficiently high resolution CRT and video disks which will allow an acceptable resolution to be attained. Outside of the special subject matter areas where subtle shading is important, and where color fidelity is also important, the standard color television display would probably be acceptable.

5) <u>Special Output Signals</u>

It has not been uncommon that the author would like to be able to control a special device, such as laboratory equipment beside the student terminal. For example, in a course involving electronic servicing, it would be desirable to have the facility for opening up a specific circuit prior to asking the student to make a measurement. The availability of the terminal to identify special digital signals and shunt them to an external device would be desirable. The fastest and cheapest way to achieve additional signals of the type noted, particularly when equipment is rented, is by attaching small photo cells to the corner of a CRT display surface. In this manner, placing a character, or dot of light, under the photo cells can be used to generate a wide range of digital output which can be used to control other devices. No internal connections are required to the terminal itself.

B. INPUT DEVICES

1) Keyboard

Contrary to the many predictions some instructors and teachers made about the hindrance of inability to type would have, we have found that this has not been a serious problem even with children. It is true that more time for the response is required with students who cannot type, but typing speed soon increases to an acceptable level. Although those who work around computers daily, can easily adjust to not having a true erase capability available for correction of input, this capability must be present for most CAI students. The introduction of extraneous characters in a string to indicate to the system that previously typed characters are to be deleted, causes havoc with the student's input whether it be numerical or alphanumeric. An erase feature should be a single function key operation and not a combination of two keys used in sequence or simultaneously.

Some CAI systems have available for the student, special function keys for such operations as "help," "go back one display," and to replay the audio message. These are desirable, although their use must also be anticipated in the design of the course by the author. For example, a "help" sequence must be planned as an integral part of the course. Such function keys have been developed for both Plato and the TICCIT CAI systems (Mitre Corp., 1974).

2) Pointing Response Input

The capability of allowing a student or author to make a pointing response to the surface of any display medium is highly desirable to increase the effectiveness of a simulation, to provide for a substitute for a complex textual input, and to provide those students who cannot, for one reason or another, use a keyboard. Students who are very young and cannot yet construct a typed response must make responses by pointing. In some cases, older students suffering from problems of motor coordination cannot make the fine eye-hand movements necessary for the use of a keyboard. In this situation where the pointing response is a substitute for a complex constructed input, one need only consider the identification of the location of a city on a map. Clearly, in this example, a pointing response is superior to a typed descriptive response. In the case of simulations, the use of the pointing response by a medical student to indicate the location on the chest where he would like to place a stethoscope adds to the realism of the simulation. The practicality of the pointing response for the course programmer can be illustrated by the construction of graphics, where the pointing response to the display surface can be used to construct special drawings or figures. Although the ability of accepting a pointing response can be easily justified on the basis of the examples cited, in some cases there can be an over reliance on this method of response input. Thus, a student tends to find a course more boring when the input is limited to only one device. In addition, it implies that the available choices for a response must appear before the student, and the ability of recognition is not necessarily to be equated with the ability to construct an unprompted response. This point is frequently raised in the context of multiple choice test questions.

At least four different approaches have been used to accept a pointing response: (a) the light pen which receives a light pulse from the display medium which is being continually rewritten, (b) the sonic pen emitting audible click, and the coordinate position determined by the differential time taken for the sound to reach sensors bordering the display surface, (c) beam interruption, and (d) sonic reflection. In terms of use for CAI these methods must be considered in relation to the student's needs, the demands of the subject matter, speed of input, and costs.

At the University of Alberta we have been using the first type of pointing response input, i.e., the light pen. As the CRT is being continually refreshed, the pen is able to quickly obtain a pulse of light from the display surface. Given the speed of the scanning beam of the CRT from a known origin, timing hardware can calculate the coordinates at which the light pulse was received by the light pen. Thus, this method of accepting a pointing response is dependent upon a display surface being continuously refreshed according to a known time base. The maximum speed of response being a function of the scan rate and the ability of the cpu to service the incoming signals. In terms of student use, the following factors have been identified:

a) Since the light pen must receive light from the display surface, areas not containing light cannot serve as target areas. This is an advantage when the pointed at location is removed to prevent a re-point, thus disallowing the student to select that choice again. However, if a large character is placed on the screen such as the letter "O" a young child may respond by pointing to the center of the character which contains no light. Thus, the child must be first taught to make a stroking action as if to "draw a line" through the character.

b) If the area pointed at is not removed after the first response is made, a fast cpu may cycle to subsequent inputs and accept a second, or even a third response from the student before the pen is withdrawn when a sequence of pointing responses are programmed. In all likelihood, the first message as a result of the first point which is the appropriate response by the system, is quickly replaced by the message for the second response. Meanwhile, the student interpretes the last message as the result of the first response made. Clearly, this can be confusing to the student.

c) Since the light pen is activated by incoming light, a light source other than that from the CRT must be gated out. In the case of our equipment, two light pulses from two even or two odd lines of the CRT must be present before a legimate response is recognized. Many times it is desirable to be able to have the student point to an image displayed on a surface other than the CRT, for example, a projected picture. In this case it is impossible to adapt the light pen for this purpose.

d) Since the light pencil has a small pointed opening which does help the student direct his point more exactly, any obstruction at the aperture will cause the pen to malfunction.

e) In order to avoid a problem of parallax, the pen must be pointed perpendicular to the display screen. Depending upon its sensivity, and the level of screen brightness, an angular point may pick up light from an incorrect light source. We have found that this problem occurs with both young and older students. In some cases a wider spacing of target characters or symbols reduce the problems.

In the case of the sonic pen we see the advantage that a pointing response can be obtained from a wide range of display surfaces. In fact this method can also be used as a digitizer for input of such things as graphics. Control over the speed of accepting input would be desirable. The beam breaking method is relatively cheap to construct, usually based on infra-red emitters and sensors placed around the area of interest. However, both emitters and sensors must be protected from ambient light, or at least their sensivity corrected for external light, and protected from misalignment by students. The resolution in this method is generally less than for the sonic or light pencil method, however, it does allow the student to simply use a finger to make the pointing response. This method is, therefore, a more natural mode of responding for the young child.

The method of sonic reflection (Hlady, Brahan, Gratton, Humphries, 1976) takes advantage of using any object for a pointing response, and provides a very high rate of data input. It is at its current level of production more costly than other methods such as the beam interruption method. It may prove, however, to be useful in situations where beam interruption is not easily adaptable, such as in the case of a keyboard-like response surface.

Three remaining considerations with regard to methods of accepting a pointing response should be made: (a) should input choice be given to a student by simultaneously providing a keyboard and pointing response, (b) if both methods of input are available but not at the same time, how should the student be told which method of input is active, and (c) in the case of a pointing response, how should the student be told that the response has been accepted by the system and is being processed. In the case of (a), the facility may be desirable only if the course author ensures that a meaningful response can be made by a target area of the display surface as well as the keyboard. With the possibility of information on a screen accumulating, one can envisage many debugging problems. In the case of (b), our system places the small letter "p" in the lower right corner of the screen. Although this character can be changed and relocated on the screen, some students forget to scan this area and unless the author indicates a pointing response is required, the student may attempt to use the keyboard. Since in our experience the keyboard is used more frequently than the light pen, it would seem desirable to use a high intensity point source type of LED to indicate a pointing response is required. In the case of (c), our system indicates a pointing response has been accepted by the removal of the letter "p" from the screen. However, if the next response is also a pointing response, it may reappear so rapidly as to be missed by the student. It would seem that the audible tone used on the Plato terminal is a good method of recognizing that a pointing response has been accepted. In addition, two even closely spaced audible pulses are more easily recognized than two closely spaced visual pulses.

3) <u>Audio Input</u>

The application of audio input for CAI has not been used extensively probably because of the recency of the methods and their associated technology. However, with the development of micro cpu chips, hardware can be designed to take over what in the past were software functions. At the moment, given the needs of every educational system to instruct young children in reading, it would appear that audio input will become a necessity for this area. If a child is to be taught and checked in the pronounciation of sounds, then some method of identifying sounds must be available. In addition, since most reading specialists would recognize that sound blending is important to basic reading skills, some method of checking for minute pauses between sounds also becomes important. This latter problem is, however, not as difficult as that of actually identifying sounds. Since this application would be made with very young children, the speed of the identification becomes very important.

4) <u>Special Input Signals</u>

In our experience we can identify two types of potential CAI authors. There are those authors who want many terminal capabilities far in excess of what technology can reasonably provide, and those who start with an under utilization of terminal capabilities, but who rapidly escalate their demands. In the first case, the potential author is probably not serious about using CAI, and is looking for excuses not to make an effort. In the case of the second type of author, his demands are an outgrowth of using the system with a sincere desire to do a better instructional job. There are instances where input from an external source is desirable. Here are some examples illustrating where input other than through terminal generated input may be useful:

a) It is desirable from the author's point of view to have the system recognize an inattentive student. This might be recognized by input from a physiological source such as eye target location or EEG patterns.

b) In some cases, particularly experimental situations, it might be desirable to identify the target of the eye and place information at that particular point. This might be useful, for example, in studying and perhaps correcting problems of reversal reading in young children (Petruk, Hunka, 1974).

c) When instruction involves the use of external equipment, for example, an audiometer, a simulation of a patient's receptivity to the sound generator to be adjusted by the student is required. It then would be desirable to have an input signal from an audiometer interpreted as a response from the student.

Although student-computer interactions have been discussed almost solely to this point, one must not underestimate the interaction which must go on between the computer and the course author and the course programmer. Without the subject matter expertise of the author, and his experience with students, CAI courses cannot be developed. With the use of such terminal facilities as graphics, a wide range of character sets, audio, and picture projection, some help must be given to the CAI author by the system to debug his course and to document the features which are characteristic of the course. For example, if a graphic is created using the terminal display surface, then some facility is required for identifying this graphic and making it available for documentation through hardcopy. The same problem exists with specialized character sets created by authors. There is no question, that on the basis of our experience, there will probably never be sufficient print chains to handle the characters created for CAI use. Our present solution to documentation of graphics involves the use of a larger computer and plotting a dot-by-dot, one to one reproduction of the graphic.

Documentation in the CAI area suffers from the same problems as documentation in other programming applications, however, since a large variety of facilities are available the problem is compounded. In addition, authors are not generally very competent in the ways of computing, and are usually unwilling to spend time documenting their courses. We have attempted solutions to this problem in two ways. Firstly, we have attempted to provide software based upon a list processor (Flathman, 1969) which would scan source code and produce a list structure representation of the instructional logic. This has not been used extensively because the output, although it provides a flow chart of the instructional logic, is devoid of the subject matter. Thus, it is hard for an author to follow. The number of branches which can exist in a CAI course can rapidly exceed the capacity of the printing device to list forward branches in parallel fashion. Using continuous plotting methods might be a solution. The advantage originally perceived in this approach was that the list structure abstracted from an operational course could be used as the basis for interrogating an author for new subject matter to fit the same instructional strategy. In addition, once the list structure was present, one could simulate students taking the course under different conditions of response probabilities.

Although each computer and terminal specialist tends to reflect that the terminal of current choice, and use, clearly fits the needs of CAI, an overview of the needs of CAI would suggest that one should not over generalize too quickly. It is quite possible that it is impractical, say from the cost point of view, to provide all the desirable terminal capabilities in one terminal. It might well be found, that the current advances in micro circuitry would suggest that terminals be developed with limited but specialized capabilities for use with particular types of students in specific subject matter areas. Costs can be made to come down if production is increased, however, the primary users who require CAI terminals have been subjected to severe budgetary limitations during the last six years, and their current resources are intimately assigned to human resources not easily convertible to capital resources. A solution to the problem can only be made by the infusion of public funds in the support of CAI.

REFERENCES

Flathman, D.P. List Processing Simulation of Computer Assisted Instruction, Ph.D. Dissertation, Department of Educational Psychology, University of Alberta, 1969.

Hlady, A.M., Brahan, J.W., Gratton, G., and Humphries, J. A Terminal Development Facility for Computer-Aided Learning, Proceedings, Second Canadian Symposium on Instructional Technology, Quebec City, Quebec, 1976.

Hunka, S., Romaniuk, E.W., and Maguire, T.O. Report on the Use of the Computer-Assisted Instruction Course STAT1, Division of Educational Research, University of Alberta, Report RIR-76-7, 1976.

Kearsley, G. Some "Facts" About CAI: 1976 in Depth, Division of Educational Research Services, University of Alberta, Report RIR-76-4, 1976.

McEwen, N., and Robinson, A. Computer-Assisted Instruction in Secondary School French, Division of Educational Research Services, University of Alberta, Report RIR-76-9, 1976.

Olivier, W.P., and Lomberg, E.S. CAI for Colleges of Applied Arts and Technology: Prerequisite Mathematics Skills, Ontario Institute for Studies in Education, Toronto, Ontario, 1973.

Pappert, S. Teaching Children to be Mathematicians vs. Teaching About Mathematics, LOGO memo #4, M.I.T. Artificial Intelligence Laboratory, July, 1974.

Petruk, M.W. Effectiveness of a CAI-Taught Electrical Theory Course for Training Electrical Apprentices, Final Project Report to Canada Manpower, October, 1975.

Petruk, M.W., and Hunka, S. The Development of a Laboratory for the Study of Learning in Responsive Instructional Systems, Final Report to Canada Council, Division of Educational Research Services, Univeristy of Alberta, 1974.

Rossall, R.E. Computer-Assisted Instruction in an Undergraduate M.D. Cardiology Program, Part I and Part II, Division of Educational Research Services, University of Alberta, Report CAI-2-74, 1974.

Stifle, J. The Plato Terminal: Description and Operation, CBERL, University of Illinois, Urbana, 1974.

Wang, A. (Ed.) Index to Computer Based Learning, Instructional Media Laboratory, University of Wisconsin, 1976.

Westrom, M.L. The Teacher-Authored Instruction Manager: A Computer Managed Instruction System, Ph.D. Dissertation, Department of Secondary Education, University of Alberta, 1973.

Zarsky, D.E. Design and Implementation of a Computer-Based Teacher-Authored Instruction Manager, M.Sc. Dissertation, Department of Computing Science, University of Alberta, 1973.

..........An Overview of the TICCIT Program, Mitre Corporation, McLean, Virginia, 1974.