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ABSTRACT

The Transparent Computer simulation was developed to address the educational system's need to provide the basic skills and knowledge that are required to understand computers and interact with them. Intended to be integrated in the computer literacy program in elementary and junior high schools, the Transparent Computer is an example of an interactive computerized model that focuses on "transparenting the black box" and unveiling the logical aspects of the structure and mode of operating the computer to the student. The goals and a detailed description of the Transparent Computer are provided, and an experimental program taught in several classes during the 1983-84 school year is described. The program was intended to examine the quality of interaction with the simulation among the different populations and find out whether this teaching unit fulfills its educational objectives. The unit was taught as an experimental program to two groups of deprived population, a group of 20 11- to 12-year-old pupils and a group of 14 16- to 17-year-old boys who had serious difficulties in functioning in formal educational frameworks. The model was found to be a most effective method of teaching computer knowledge and basic programming, and the model's basic characteristics--interactivity, simplicity, transparency, and concreteness--played a major role in the success the students experienced in operating the model and in writing and running programs, as well as in their achievements at the levels of knowledge, understanding, and application of the learned concepts. The text is supplemented with various figures, and a 16-item bibliography is provided. (EW)

THE COMPUTERS IN EDUCATION RESEARCH LAB

המעבדה לחקר יישומי מחשבים בחינוך



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Mioduser David, Nachmias Rafi, Chen David

Research Report No. 4
July 1984



TEL AVIV UNIVERSITY SCHOOL OF EDUCATION

בית הספר לחינוך אוניברסיטת תל אביב

UNIT FOR COMMUNICATION & COMPUTER RESEARCH IN EDUCATION

היחידה לחקר תקשוב בחינוך

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..."What is essential is invisible to the eye"...

(The Little prince, A. de Saint Exupery)

## Introduction

Ever since the first stone tool manufactured by man, the history of technology has been rich in "black boxes". A "black box" is an instrument, tool, machine or mechanism which is operated by an individual who acts as a user, lacking any thorough understanding of the structure or mode of operation of the instrument used. Today, people of all ages in practically all walks of life have daily contact with a special "black box" - the computer. This technology is characterized by its structure, which is composed of electronic circuits, the components of which are tiny; its performance, which appears to mimic the human brain, and the way of communicating the technology, which requires the use of a programming language or at the very least some acquaintance with a specific set of terms. These characteristics turn the technology into something foreign, threatening and incomprehensible, as far as most of the population is concerned. With the increasing invasion of the computer into daily life, the educational system is faced with the major task of providing the basic knowledge and skills that are required for an understanding of computers, and interacting with them.

There are two major approaches regarding the appropriate means of providing the population at large with such basic knowledge (Mayer, 1981): - The black box approach and the glass box approach.

The first one is most often used in training various populations in specific areas of interaction with computers, for example, using computers in banking; operating computer-based automation in industry; or the use of authoring languages for courseware development. The user should know the various parts of the system, how to program it to suit specific purposes, and what output may be obtained from such a system. The user, in this case, is unconcerned with the structure of the computer, or how it works.

The second approach is intended to supplement the basic knowledge of the user, as far as understanding the logical aspects of the structure and the operating mode of the system are concerned (the purpose here is not to reach comprehension at the level of electronic circuits or engineering aspects). With this approach in mind, the "transparent computer" computerized simulation has been developed by the "Computers in Education Research Lab" of the School of Education, Tel Aviv University, supported by the Ministry of Education. In the following, the rational for using a computerized model for teaching computer knokwledge is presented and the "Transparent computer" as a representative example, is described.

## 2. "Transparenting" the black box

The computer's role in daily life is growing rapidly. Nevertheless, the majority of the population does not yet feel the motivation, the ability, or even the necessity of "befriending" the computer and becoming an intelligent user. Moreover, the attitude of a considerable part of the population towards the computer and its performance is characterized by alienation, reservations and uncertainty. The major sources of the above attitude will be discussed from three aspects: the individual, the machine and society.

A) The perception of the computer by the individual: "Personification" and prejudice:

Any technology is an extension and amplification of man's natural abilities (McLuhan, 1964). In the past, machines and tools were intended mainly to increase the capacity of the muscle, adding force, velocity, precision, etc. The electronics and computer technology is the first to be used on a large scale in order to amplify one of man's unique qualities: his mental activity. The current knowledge, though not negligible, is far from supplying the answer to the mystery of the workings of the brain. It is therefore rather difficult to adjust to the interaction with a machine which seems to simulate some of these activities, with astonishing precision and speed. The "personification" of the computer - the tendency to ascribe to it human characteristics - is most commonly seen during the interaction with computers ("what does he want now?!" "He's wrong again" "He remembers everything!" "This one understands BASIC", etc. Peelle, 1983). Yet, the incomprehension and lack of knowledge create, for many people, a barrier of misconception and feelings of alienation, which lead to reservations and rejection of computers. Sayings such as "the hammer is going to take over", or "Lathes will determine our fate in the future", are amusing. A similar reference to the computer, however, arouses mixed feelings in many.

Decoding the black box is therefore recommended in this respect, in order to reveal the logical aspects of the system, to enable its perception as "a machine that obeys commands" and lead to the understanding that these commands are issued by people (who have also built the machine), as well as comprehension of the logical steps in the process starting with input and leading to output. Such exposure may be conducive to a proper perception of the computer as an extention of the brain's activity, an extention which is dependent upon our actions, and adds to the feeling of confidence which is necessary for the interaction with the computer.

B. The lack of "transparency" of the computer

In familiar instruments and machines, some parts reflect their functions or hint at their contribution to the operation of the system as a whole. The relative transparency of the system (at least as far as its major components are concerned) enables the development of some image or intuition concerning its structure and how it operates. This image may be rather inaccurate technologically; nevertheless, it inspires the user with the confidence required for operating the system. In computers, the major components (cards, integrated circuits, etc.) usually do not give any indication to the process which follows the typing of the command on the keyboard, up to the final output. The computer is perceived as an opaque box (and as a technology intended only for a limited highly skilled group).

For this reason, it is advisable to allow "peeping" into the box, emphasizing in this case the acquaintance with various physical components of the systems and their functions. Turning the collection of various wires and miniature components into a more transparent box may bring the public somewhat closer to the new discipline. The change in image may lead to removal of suspicions & doubts, and to increasing confidence with regard to operating the computer.

C. Lack of "computer culture" & "computer tradition"

What is the cultural framework in which individuals in our society may relate to modern technologies? The "car culture", for example, is decades old: Operating cars has become a basic skill, and there is a wide supportive system (road signs, traffic patrols, insurance companies, driving schools, professional journals, etc.).

On the other hand, "computer culture" is not shared by the entire population. Often the user is not equipped with a conceptual framework and correct images concerning the computer, and the cumulative "computer tradition" (in its widest sense) is as yet rather young and poor.

"Transparenting the black box" in order to finish such a conceptual framework, may serve as a compensation for the lack of "computer culture" which may be relied upon, and at the same time it may help in crystalizing such culture.

To summarize, the "glass box" approach is very promising in its potential service for demystification of the computer and the removal of prejudice concerning it. It may bring the wider population closer to a discipline limited at present to specialists, and contribute to the building of a broad cultural basis for assimilating the computer in daily life & its becoming a "natural" component of the artificial modern environment.

3. The use of Models in teaching Computer Literacy

The structure of the computer and the communication with it are at the center of a new discipline with which the naive student has to cope. A appropriate teaching strategy must be developed as a way in which the student will be introduced to the new material which has to be learned. In the literature, the process of learning is described as a process of assimilating new knowledge into an existing conceptual framework (Mayer, 1981). The crystalization of a conceptual framework is frequently mentioned as a factor which helps in acquiring new knowledge (Ausubel 1960; Witkin, Moore, Goodenough, Cox 1977; Kleer, Brown 1980; Duboulay 1981). The desired aim of an efficient teaching strategy is, therefore, the supply of such a conceptual framework.

The following discussion will thus focus on the use of models as a teaching strategy for introducing topics of computer sciences, to the beginner.

## Interactive models for teaching "computers": types and characteristics

A model is a representation of reality. The aims for which models are developed, are: knowledge and understanding of a system, or predicting the behavior of that system in given circumstances. Usually the model represents that portion of reality which is significant for reaching the ends for which it has been developed.

Concrete models and computerized models can be given as examples of two types of interactive models, in which the student's activity is central, and the process of learning takes place through activation of the model.

A typical example of a concrete model is the various types of "paper machines". These models are usually comprised of a working board representing the various units of the computer, auxilliary means for recording the commands & their execution, and a set of rules according to which the machine operates (Sanders 1976; Mayer 1981; Mioduser, Nachmias, Chen 1984).

More complex concrete models are the various types of "button boxes", which are based on eletronic components and circuits. A representation of the various working units and a set of switches and lights for operating the machine and monitoring its operation, appear on the working board of the machine (Human Science Project, BSCS, 1976; Open University, 1976; Elogo Machine, DuBoulay, 1979).

The other type of interactive models is computerized models; in these, the reaction time. the ability to select divergent tracks, according to the student's input, and graphics, sound and animation capabilities contribute to the dynamics of the interaction between the student and the model, as well as to the learning process as a whole.

Examples are "The Simulated Computer" (Steketee Educational Software, 1982) for simulating the operation of a small machine language computer, "Rocky's Boots" (The Learning Co., 1982) for building an animated Logic Machine and the SRA software for teaching programming concepts through an animated robot (S.R.A. 1981).

Several characteristics seems to be essential when developing models for teaching computer concepts:

a) <u>Interactivity:</u> this turns the activities of the student into a major factor in the learning process. The student operates the model receiving continuous feedback, & through this, progresses in aquiring the concepts and contents to be learned.

b) <u>Simplicity:</u> The model must be simple enough to enable the students to focus on the contents and not in decoding and operating the software. Simplicity refers to the structure of the model (a limited number of components, which are structured and relevant to the goal of the model), the limited number of command keys to be used and clear presentation of options for action.

c) Concreteness: This should serve to present the various components of the system-including the abstract ones - in the clearest manner.

d) Transparency: This is essential for a model which proposes to reveal the structure of the computer and its mode of operation. Through this characteristic the student finds out the principles and dynamics of the system with which he works.

## 4. The "Transparent Computer": Computerized Simulation of the Process of Information Flow within the Computer Units

The "transparent computer" is an example of an interactive computerized model that focuses around "transparenting the black box" and unveiling the logical aspects of the structure and mode of operating of the computer, to the student.

### 4.1 The Goals of "The Transparent Computer"

The general purpose of the simulation is to provide the student with a conceptual framework for learning and understanding concepts related to the logical structure of computers and their mode of operating. The model presents the process of information flow within the various units of the computer, from input of commands and data, through processing, to output of the desired result.

The educational objectives of the "transparent computer" are:

a) The student will know that the INPUT unit, the MEMORY unit, the CENTRAL PROCESSING unit and the OUTPUT unit are the major components of a system which carries out the information processing.

b) The student will understand that in order to perform, the computer requires commands, which are provided by a program written by man.

c) The student will understand that a program is a SERIES OF INSTRUCTIONS, RECORDED IN THE MEMORY, IN A LANGUAGE COMPATIBLE FOR THE MACHINE.

d) The student will understand the interaction among the various units of the computer and how information flows from one unit to another in the different stages of information processing.

e) The student will be able to write and run simulation programs.

In advanced stages-when the first objective have already been achieved - the "transparent computer" might serve as an instrument for acquiring basic concepts in computer programming (eg. variable, infinite loops).

The first goal is related to acquisition of basic knowledge required to understand the logical structure of an information processing system: knowing the various units and their roles in the processing process.

The second goal emphasizes the fact that the computer is "man-made": It cannot operate without human interference (operating, giving commands).

The third goal centers around the nature of the communication with the computer: Definition of the concept of program, its storage in the computer's memory, and fulfilling the basic condition which requires that the language to be used is "understood" and suitable for the machine.

The fourth goal reveals the dynamics of information processing, defining the interaction between the various units and illustration of the flow of commands and of information items from one unit to another at any stage of the processing.

The fifth goal concerns the operating skills and thinking skills involved in applying the knokwledge which was acquired through interaction with the "transparent computer". Here the student is asked to write programs of various complexity levels, and run them through the simulator.

4.2 Description of the "transparent computer"

The following is a general ᶜ ·ption of the simulation.

A) Graphic representation of ..ie simulator: As soon as the simulator is run, the screen shows a graphic representation of the components of the system, this includes (Figs. 1, 2):

1) Input unit: Through this unit commands are given and data fed into the computer. It shows the working window and a list of the commands which may be used.

2) Memory unit: Here commands and da.. are kept in 20 optional memory cells.

3) Processing unit: Reponsible for calling and performing the commands, one at a time and executing computation in its accumulator.

4) Output unit This frame will take the place of the "input" frame when the commands are performed. This is a representation of the screen, on which the outcome of the processing process appears. It is comprised of 2 windows: A graphic window for drawings, and a text window for numbers.

5) Working modes: 6 options appear in the bottom "ruler" which represent the various working modes of the simulator:(Fig. 1) Input mode for entering commands and data into the memory): Run mode; Stop mode; "Speed mode (deter..ining the velocity of performing each operation of the simulator,); Diskette mode (for interaction with the diskette-(There are 4 options: save, load, delete, and catalog of programs); Delete mode Deleting the program currently in memory).

Insert Figs. 1,2 about here

B) Operating the Simulator: In operating the simulator only a small number of keys are needed (The space bar the return key and the arrow keys), and typing the first letter of the command is all that is required for the complete command to appear on the screen.

C) Information flow between units: While operating the "transparent computer," the flow of information from one unit to another is illustrated by animation showing commands and numbers moving across the screen, among the units involved in the operation. Freezing the operation of the machine may be achieved at any moment, by pressing the ESC key (Fig. 3).

Insert Fig. 3 about here

D) Demonstration of the desired qualities of a model: The "Transparent Computer" is an Interactive tool which differs from usual C.A.I. In CAI lessons the program leads the student through pre-planned tracks according to the correctness of his answers, while in the "transparent computer" the student controls the tool at every stage of the learning and working process. There are no "correct" or "incorrect" answers but an output that is determined by the student's input. The level of complexity of the inputed programs and the quality of the output increase as a result of the student's gradual process of acquisition of concepts and skills.

The Simplicity of the model is expressed in the small number of keys required to operate it, the convenience of entering and changing commands, clarity of representation of the information on the screen, moving from one work modes to another by moving along the options "ruler", etc. The entire model is a concrete representation of the various components of the computer, as demonstrated in Figs. 1-4. The transparency of the model is clearly illustrated by the movement of words from one unit to another, at the various stages of the process; by the arrow indicating which command is being carried out at any given moment, and by the ability to freeze the process any time, to see what is going on or might happen later.

4.3. Levels of Complexity of Working with the Simulation

The student's work with "the transparent computer" is carried out in several levels

Level 1: Writing and running simple programs:

This level is appropriate for the first four teaching objectives. While interacting with the software and the attached student booklet, the student learns which units comprise the computer, how commands are written and how the information flows from one unit to another. The commands to be used at this level are action commands (Luehrman, 1983): Printing command - PRINT; graphic commands - DOT/LINE; sound command - TONE; computation commands - ADD, SUBTRACT. Fig. 4 shows an example of a 1st level program and its output.

Insert Fig. 4 about here

Level 2: The variable

In level 2 the student learns to use a variable parameter in the commands. In the simulation, a command which is written in the input mode without mentioning a parameter will use the value already stored in the accumulator as a variable. The visual properties of the simulation enable a very concrete representation of the use of a variable in the program, of the process of changing it's value, and it's effect on the result in the output.

Level 3: Loops

At this level the student learns to use the Jump command for creating loops. The combination of variable and infinite loops enables the production of a complex, rich output, relative to the simplicity and brevity of the program (Fig. 5). This stage requires a more thorough understanding of the meaning of commands and the logical aspects at the basis of the structure of the program.

Insert Fig. 6 about here

Level 4: Information flow between the accumulator and the memory

Here the commands Store and Load are introduced. These are intended to store the value which is in the accumulator, in a memory cell - STORE, or the opposite, loading a value which is kept in a memory cell, into the accumulator - LOAD.

This expresses a further complexity in defining variables. A memory cell is defined as a variable, and values are written into it or loaded fom it, as the need arises. The changing contents of those cells will serve as parameters for the commands of the program. As an example see Fig. 6.

Insert Fig. 7 about here

5. The "transparent" computer implementation at school

"The transparent computer" simulation is intended to be integrated in the program of teaching computer literacy in elementary and junior high schools. An experimental program was taught in several classes during the 1983-4 school year with the purpose of examining the quality of interacting different populations with the computerized simulation, and find out whether this teaching unit fulfills its educational objectives.

Four classes (97 pupils) participated in a controlled experimental paradigm which was carried out in one school which belongs to a high socio-economic residential area. The unit was taught parallely to two groups of deprived population: the first included twenty 11-12 year old pupils; the second was a group of fourteen 16-17 year old boys, with serious difficulties in functioning in formal educational frameworks. The following are preliminary impressions of the potential, the achievements and the problems involved in operating the "transparent computer" in the classroom. A detailed description of the experimental design and the results appears elsewhere (Mioduser, Nachmias & Chen, 1984).

5.1 <u>The achievements of the pupils at the various working levels:</u>

The results concerning the first working level are clear-cut: Based both on observations in the classroom and the test results, it was found that all pupils, of all age groups and populations, succeeded in operating th simulation and in writing and running programs.

Following the running of several exemplary programs which are included in tne working booklet (Mioduser, Nachmias, Blau & Chen, 1984), the pupils wrote their own programs, using the various classes of output: numeric, graphic and sound. The significant increase of the post-test scores among the experimental group students points to the contribution of the work with the "transparent computer", to the understanding of contents & concepts, and meeting the educational objectives.

The results at the second and third working level point out a considerable difference between the understanding and application levels with regard to the concepts of variable and infinite loop. Approximately half of the 4th grade pupils, and most of the 6th graders and the older boys understood the processes in the demonstration programs and could introduce changes into these programs or write up similar programs. However, when it came to the application level (in which they were asked to design programs which differ from those in the booklet), only very few of the 4th grade pupils, and a small number of the 6th grade pupils and the older boys group succeeded in writing original programs.

At the fourth working level, which centers around programs with STORE and LOAD commands, only a few of the best 6th grade pupils succeeded in understanding and applying the concepts in their programs.

5.2 The properties of the model and their contribution to the process of learning:

Interactivity, simplicity, concreteness and transparency were mentioned as the desired properties in developing a computerized instructional model. The transparent computer is basically an interactive model. All along the experiment, the pupils enthusiastically fed commands, ran programs, located errors and corrected them, etc., the simplicity of the simulation and its ease of use enabled the pupils to work freely in a very short time and to concentrate in the educational contents right from the beginning.

The contribution of the transparency to the pupils' understanding of concepts and process was significant. The transparency of the memory unit enabled the examination of the program, planning of changing or correcting commands, reference to specific cells and their contents in order to create loops, etc. the crawling of information items while the program was running and following the gradual building of the output gave the pupils an opportunity to locate commands which cause undesired results, and understand the contribution of each command to the final result.

5.3 The affective and motivational aspect: Enthusiasm and fascination characterized the entire work of most pupils, even those described as having short attention span, whose very status outside any educational framework indicates difficulties in either ability or willingness to concentrate on learning activities for prolonged per'ods of time. The three kinds of output, the "transparent" presentation of everything that happens during the processing, the immediate feedback (output) during work and the fact that everybody can work successfully in his own level - all these created strong motivation. Soon after the first lesson most pupils invested home-time in writing programs and insisted on running them at the beginning of the next lesson. An indication of the confidence in running the simulation was found in the pupils' attitude to the speed parameter. At about the middle of the first lesson, most pupils were already working at the highest speed, (no word animation on the screen). From that point and onwards, the speed was adjusted to the need: Following commands and processes - was carried out at the lowest speed, running programs - at the highest speed.

5.4 Problematic aspects: Two aspects were revealed as problematic: The first was the difficulty encountered by many pupils to create programs which differ from those included in the working booklet. The pupils found it difficult to discover new contexts or problems dissimilar to the examples supplied for applying the commands which were learned.

The second aspect is related to understanding and applying programming concepts of the higher working levels. After the completion of work at the various levels as planned, most pupils tended to go back to writing programs which were based on execution commands of the first level, adding only the "impressive" performance of variable and infinite loop levels (the latter were expressed as graphic output or a complex sound, which were produced by a small number of commands).

5.5 <u>Duration of teaching:</u> Based on the success of most pupils, the teaching time required for the core level seems to be 4-8 hours. Further elaboration of the various concepts and application of commands should require additional teaching.

6. Discussion and Conclusions

The transparent computer is an example of the use of a computerized interactive model for teaching computer knowledge and concepts in programming.

The use of the model was found as most effective as far as teaching "computer knowledge" is concerned. The results of the post-tests of the experimental groups reflect the contribution of the model to the knowledge, understanding and application of concepts related to computer knowledge, as described in the educational goals (Section 4.1).

The model's characteristics-interactivity, simplicity, transparency and concreteness-play a major role in the success the pupils had in operating the model and in writing and running programs, as well as in their achievements at the levels of knowledge, understanding and application of the learned concepts.

Certain characteristics of the model supplied a strong motivation to the pupils. The ability to work with different outputs (numeric, graphic, acoustic), the transparency and concreteness of the processes (animation of movement of words on the screen; the ability to follow the program step by step, etc.) - were received most enthusiastically by the pupils. The simplicity of operation was reflected in the confident work of the pupils, even after a very short experience. The obvious consequence is that realization of these properties should be aimed at when educational software is being developed.

The experiment did not provide sufficient information regarding the integration of the transparent computer in programming courses. Working with the simulation prior to programming studies, the transparent computer may provide a framework for understanding the machine which the pupils are about to learn to program, as well as understanding the ways of communicating with this machine. Working with it where pupils have previously learned to program a "black box", the simulation serves as to complement the understanding of the process beginning with entering a command and ending with an output. The issue of integrating the "transparent computer" in programming studies needs further examining.

As an alterative option, "The transparent Computer" may also be taught as an independent unit, in order to equip students who are not going to study programming-basic computer knowledge & programming concepts. Two curricular conclusions were derived from the present experiment: The first concerns enlarging the teaching plan: Following the core level activity, it would be advisable to focus the work on concepts in programming, add practice time and increase the range of examples and programming tasks. The second conclusion is related to the need to increase the "computer language" of the simulation. It is recommended to add a condition command, similar to the IF... THEN command in BASIC, in order to complete the basis of programming cocepts.

The "Transparent Computer" does not pretend to present with absolute precision the structure and functioning of any computer. The principles and characteristics of the simulation were designed taking into account didactic considerations and the low age of the target population side by side with professional considerations.

"Transparenting" the black box appears to be a promising direction in preparing the population at large for satisfactory functioning in a computer-based society. It may complement the basic knowledge and skills of the naive user by deepening his understanding of the process inside a working computer, and thus reassure him while interacting with the computer. In view of the promising experience with the transparent computer, we intend to continue research and development of similar educative products.

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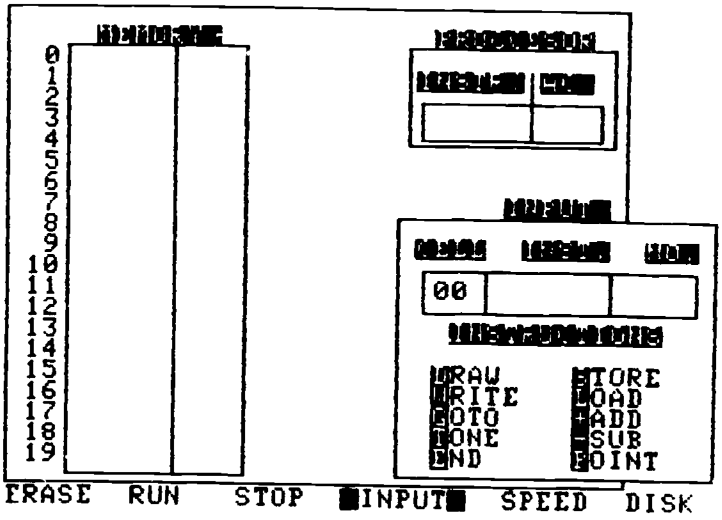


Fig. 1: Simulation's Input mode

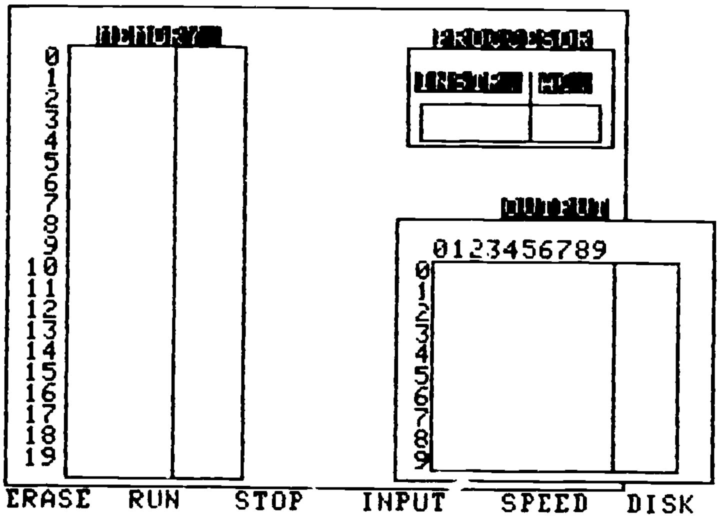


Fig. 2: Simulation's Output mode

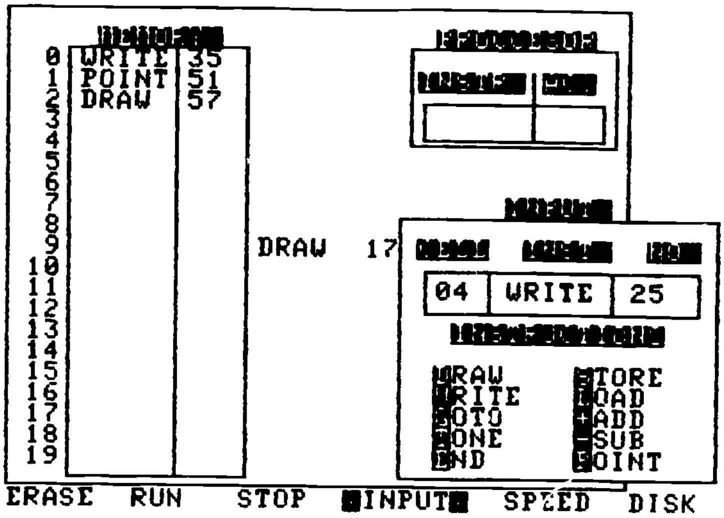


Fig. 3: Information flow betw^cn units

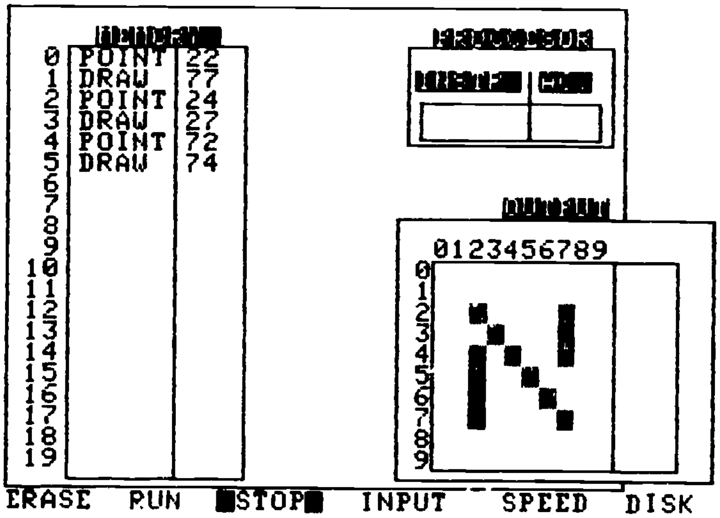


Fig. 4: Level 1 progıam example

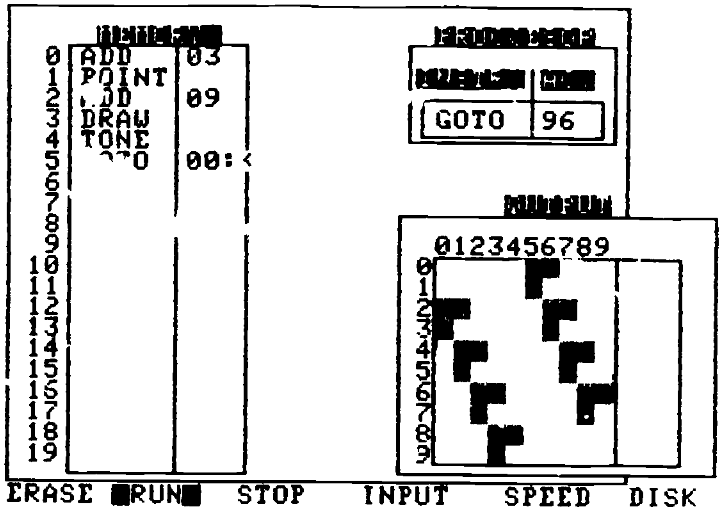


Fig. 5: Level 2-3 program example

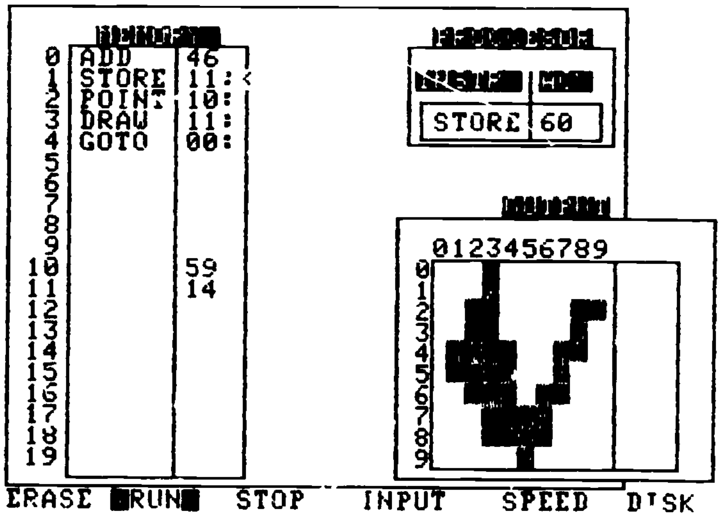


Fig. 6: Level 4 program example