OZNAKI and BEYOND

Harvey A. Cohen
La Trobe University, Bundoora,
Victoria Australia 3083

OVERVIEW

OZNAKI, Polish for SYMBOLS, is the name of a project involving the use of contemporary computer technology to further mathematical education In primary and junior high schools. In OZNAKI, microprocessor technology has been used to construct interactive models of mathematical systems. In these computer models, the student programs the activities of robots called NAKIS which haven In addition to a body state (vide the position, heading, and screen shape of the LOGO Turtle) a mind state having memory for both commands and the local environment. A rather novel scheme is used for passing numerical parameters to procedures without enforcing distinctions between formals and actuals. (i.e.: no " , : or the like indicator . The TINY languages In which the student programs these NAKIs are Intended for implementation on exceedingly low cost controllers; for the moment personal computers based on 8080 and 6300 microprocessors are used In school studies together with a minimum of specialised project hardware. Inherently the Project has a special interest In the microprocessor code production: update, and transport problem.

OZNAKI PROJECT: TEACHING AND EVALUATION

The Education Research and Development Committee of the Australian (Federal Government) office of Education has supported the teaching and evaluation aspects of the OZNAKI systems PLUSMINUS, OZGRA, WHAM and CROC. Approximately seventy children have been directly involved with OZNAKI in state primary and secondary schools near La Trobe University Campus. The aim of this paper is to provide an overview of the OZNAKI Project, to show how its objectives have been realized, and to discuss further and new directions for its development.

GOALS OF OZNAKI

The OZNAKI Project was initiated early in 1975 with the following avowed aims and objectives:

a) A commitment to the analysis of the structure of mathematical understanding. That is, a concern w1th the cognitive processes: (operations) involved in DOING mathematics, mathematics being rather broadly conceived.

b) To design computer controlled domains of robotic effects where the basic commands provide an embodiment of such OPERATIONS.

c) To extend the basic systems by means of a run-time macro facility so as to produce a family of clean robotic languages with a minimum of distracting computerese features. These languages to be similar in syntax to traditional algebra

d) To design teaching modules that blend discovery with creativity. Such modules to have definite cognitive goals and involve a directed set of tasks somewhat akin to science laboratory units. In these set tasks, students by guided observation are lead to appreciate the significance of the operations that are modelled and the symbolic representation provided by key commands. These modules should also Include mini-projects wherein children manipulate the symbolic operations (i.e.: key In programs of their own design) to produce mathematical artifacts.

e) To use psychometric tests to evaluate the effectiveness *if* particular modules In achieving its stated objectives.

f) To demonstrate the possibilities of truly inexpensive microcomputers for personal use In Australian schools.

g) Insofar as purely computer concepts are to be presented, to develop stratagems of presentation that are purposeful and effective.

h) To investigate the practicality of developing the relevant computer software in a way that facilitates transport between different microcomputers.

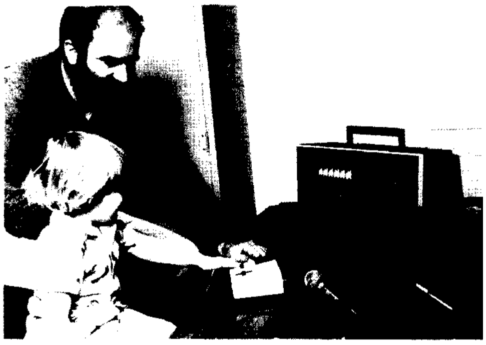
Harvey A. Cohen, *OZNAKI and BEYOND*, in D. Harris (Editor), Proceedings of National Education Computing Conference, NECC 1979 University of Iowa, Iowa, USA, June 1979, pp 170-178.

THE PLUSMINUS

The young child who plays with the PLUSMINUS is confronted by two large keys, marked + and -. and a TV screens on which a large 0 is displayed. If the large + key is struck there is a sharp metallic clack, a train appears on the screens and the number displayed becomes a 1. Each further time the + key Is struck one further train appears, and the new total of trains is displayed. If the - key is struck there is a loud clack, the train at the end of the row disappears and the number display is altered to show the new total. In place of trains, birds or dogs may be displayed.

In PLUSMINUS the number display together with the row of screen animals provide the same sort of embodiment of numbers as is given by the more traditional concrete materials. such as those of Zoltan Dienes. The PLUSMINUS associates a digit with a definite number of objects and with the number of tames the + key has been struck in counting up to the screen total (or counting down to make the TV animals disappear.) Unlike rods, the PLUSMINUS also provides a concrete representation for the symbols + and - ; the actual OPERATIONS of addition and subtraction are modelled. Traditional materials can show only the before and after pictures for an arithmetical operations and cannot model the operation itself.

A more detailed understanding of the significance of the PLUSMINUS can be derived from Gelman's studies of the development of early number concepts. To quote German: "The cognitive processes by which people determine some quantity such as the numerosity of a set of objects: are called ESTIMATORS. The cognitive processes by which people determine the consequences of transforming a quantity in various ways are called OPERATORS." As Gelman asserts, "operators are more central to a mature conception of number." It appears from various evidence: including the studies of Piaget and Inhelder at Geneva, that the child's "number scheme is a central quantity scheme which facilitates the development of other quantity concepts."



The photo shows a 30 months child using the PLUSMINUS . Note the large keyboard, as well as the microphone for speech input. . (It is possible for the PLUSMINUS and other OZNAKI systems to accept speech input. We have experimented with a commercial1y available speech spectrum analyser . After a training session in which a child ta1ks into a microphone attached to the microcomputer: particu1ar words, up to 32 in current programs of that speaker can be recognised. In the Speech PLUSMINUS the words "plus one" function exactly 1ike the + keystroke, and the words "minus one" like the - key . The words " six " "dogs" wil1 cause just 6 dogs to appear on the TV)

Z0NKY

Z0NKY is a robot that craw1s about the f1oor or tab1e-top . Co n s i s t e n t with the general NAKI philosophy that a robot should have both a mind and a body, ZONKY has an e1ectronic control1er on board that is to some ex ten t indifferent to the form o f Z0NKY 's body . Basica11y the con t ro!1er wi1l switch on two DC motors in various direction combinations, and will switch off each motor after a (programmab1e) number of revolutions.. (The contro11er counts the spikes on the line due to the sectoring of a commutator.) The origina1 ZONKY had as body a Sherman Tank, made by the Takimaya plastic top company of Japan. ZONKY II had a circular plan, and w1th the pen holder mounted precisely in its geometric centre had improved accuracy. However students definitely preferred the more toy-like original ZONKY, so that in the radio controlled ZONKY III once more a clackedy model tank was adapted. On any ZONKY are marked the FORWARD direction any the directions for RIGHT and LEFT turns (on the spot) which take place about a central point where a felt tapped pen is mounted. This pen, if inserted, marks out the robot's trail.

The basic movement commands for ZONKY are F for forward, B for backwards, R for right, and L for left. While performing these movements the automaton can also be ordered to honked, glow, G (switching on its lights). A string of commands - - like an English command - - must be terminated by an exclamation mark ! (There is a version of the command language for pre-schoolers where the ! is not required and only one command at a time can be performed.) To illustrated following the command 3GF 2HR ! the robot makes 3 steps forward with its lights flashing, then makes 2 turns right (clockwise) on the spot whilst honking its horn. In between each forward step or unit turn there is a one second delay. On the TV screen the commands punched in by the student are visible; also displayed are the actual control words that are directed at ZONKY. Thus for the students commands,

3HF 2GR

a further embodiment of number is supplied through the display on the screen of the ZONKY language words.

aaaaaaaaaa aaaaaaaaaa aaaaaaaaaa

gggggggggg gggggggggg

Note that corresponding to a unit motor command: there are precisely ten lower case control characters displayed. This facilitates the introduction of decimals.

WHAM

In WHAM the student controls the happenings on a TV screen with a typewriter style keyboard. Most of the screen is taken up with a square In which a strange creature called a NAKI lives. This creature obeys the same basic commands as the OZNAKI robot ZONKY, namely FORWARD, BACK, RIGHT, and LEFT. These commands are represented by the typewriter keys F' B, R, and L. However the NAKI only turns ninety degrease e.g. from being

V

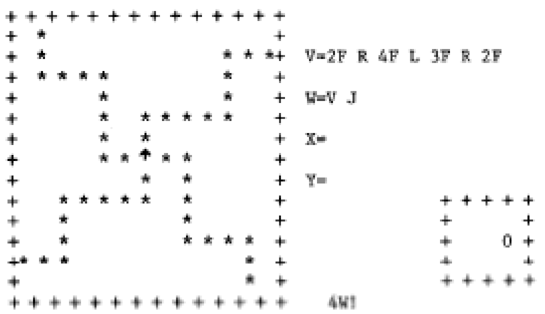
facing down (or South) on the TV screen. to the state

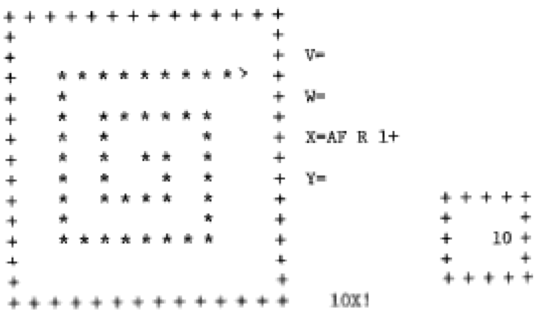
<

after the command R, now the NAKI as heading West. As the NAKI roams Its territory it leaves a trail of asterisks, so forming a design. So far we have described the body of the WHAM NAKIs and the movements of this body. The NAKI also has a mind visible on the screen but strangely detached from the body. In the NAKI'S mind is the last command. it obeyed, together with the total of what It has learned. Of course. on starting a session of WHAM the NAKI knows nothing. But each time the Z command is used to make it remember some 1ist of commands by name, that 1ist and its name are displayed in the mind. In the copy of the WHAM screen below the NAKI'S body has wandered around the area fenced off w1th + signs. To the right is the NAKI'S mind..

In WHAM the command P clears the NAKI enclosure (bounded by + signs) and returns the NAKI to its HOME at the centre of the enclosure. So there is great freedom for the child to experiment while gaining experience with the basic movement commands. To draw the logo design shown above, a child was asked to direct the NAKI from HOME to the top right hand corner square by a squiggly path, ending up heading east . (0vera1, along this path, the NAKI has turned through 90 degrees.) The chi1d was then asked to teach the NAKI how to draw such a path by punching in Z, then V (the name of what is to be remembered) and then the commands that the NAKI followed in sequence. Thus the child had to work backwards along the marked path on the screen to f i11 out the memory list . This 1ist is, of course, a symbolic representation of the path, SYMB0LS being what OZNAK is about . Having checked that this V command was the one intended, clearing the screen and trying again if it wasn't, the child was ready for a direct suggestion from his teacher. The command J returns the NAKI to HOME, without changing the direction in which the NAKI is facing. So by punching in ZW V J ! the NAKI learns how to draw an entire arm of the logo: followed by a J jump home . Having c1eared the screen with the P command the NAKI could then traced out the entire 1ogo on the command 4W ! Note how much issues of planning and problem decomposition enter into drawing such a logo.

But this is on1y part of the WHAM story. A1so demarcated on the screen is a little area containing a number. This number is in fact the display of an electronic calculator. Unlike the defined macros displayed on the TV, this number is not actually in the WHAM NAKI's mind: but in the mind of the WIZARD (of OZ . natura1ly) who is the over1ord of the system. (In a multi-NAKI environment this number, together with a few others can be used by ALL NAKIs.) The name of this number is A. One can enter numbers in the display and perform arithmetic just as in any reverse Polish calculator. Thus 2+ adds 2 to the number displayed in the accumulator, while 5- subtracts 5 from the number





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Display. Combining this calculator arithmetic with the NAKI movement commands yields a numeric geometry which includes not only squares and rectangles but also several forms of spiral. In the spiral shown with the TV screen for WHAM on the bottom of the page previous, the student had cleared the game area with the P command and reset the A accumulator with the command A-, elsewise using the command of E0, (E for enter). On an X command, the NAKI moves forward A steps, turns right, then A is increased by 1. The spiral depicted was drawn as shown on the command 10X!

The similar spiral in the line-graphics of LOGO is termed by Papert a squiral. It is worth comparing the clean traditional algebraic formulation used in WHAM to draw a squiral with the more computerese recipe of LOGO.

OZ/TINMAN

The language in which children program the walking automata ZONKY was originally called OZ. With the introduction of a front panel display of the NAKI mind (remembered command macros) together with primary and secondary accumulators A and B, this language was tuned up to become TINMAN. (Perhaps in a later version TINMAN's heart will also be displayed, and the robot will be truly complete.)

```
       *
      ***
     *****
    *******
   *********
   **********
  ************
  *************
 **************
***************
       *
       *
   **********
    ********
    ******
```

In TINMAN the messages from the WIZARD to ZONKY appear on the left hand half of the TV screen, and scroll upwards. Using the slash command / simple patterns of characters can be formed on the screen, messages can be printed by macros, and built-in commands such as the Forward command F can be duplicated since all type-out goes to ZONKY. The incorporation into macros involving/ of the simple number handling capabilities of OZ/TINMAN can give interesting patterns, such as the XMAS tree design above.

ZONKY is a Johny One-Note which can be programmed to sing. There are just two commands for this purpose, T to toot for unit time duration, P to pause - - do nothing for unit time duration. Built into the command language is the command J, a composite macro, whose contents students can see, though not modify.

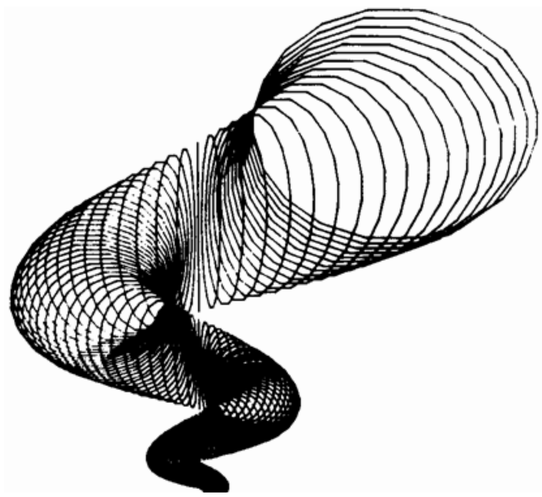
J= 3T 2P 3T 2p 5T 4P /J /I /N /G /L /E / /! /

The command J causes ZONKY to give a quite credible rendering of the opening bars of "Jingle Bells", followed by by the appearance of the actual words on the screen, as specified by the printing primitive "/"

OZGRA

OZGRA also called OZ-Graphics, is a line-graphics language closely related to LOGO. In fact OZGRA has some picture manipulation primitives not available in LOGO. Our implementation uses a Tektronix GT1024 graphics terminal for display. A detailed description of OZGRA is given in the article by H. A. Cohen and D. G. Green (1977).

OZGRA has been tailored to the processing capabilities of a microcomputer with limited memory. OZGRA requires a fine graphics screen which at the moment costs of the order of two thousand dollars. For this reason OZGRA has been excluded from our school trials.



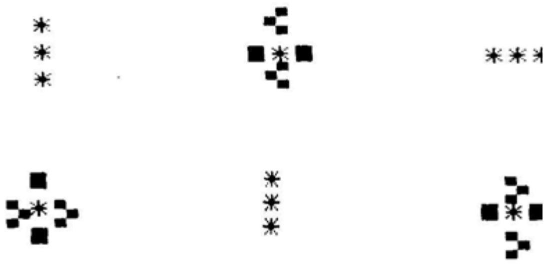
LIFE

The game (?) of Life was devised in 1969 by the Cambridge mathematician Conway in his studies of cellular automata. In school trials of OZNAKI, a new computer version of Life has been used, in which Conway's Life provides growth and life to drawings composed by the user.

In this microcomputer Life, the user first guides about the TV screen a NAKI which obeys the commands, N for North, S for South, E for East, and W for West. Each command moves the NAKI just one step about the screen composed of 16 rows of 64 cells. On the command L – for Life –the NAKI puts life into the cells currently occupied, the cell being marked with an asterisk. Similarly, on the command K, for Kill, a cell – if live becomes dead, so that the asterisk disappears.

Each cell on the screen has eight immediate neighbours. If a cell has two live neighbours, then in the next generation that cell will be live. For other than two or three live neighbours, any cell will be dead in the next generation. That is, these simple creatures can neither abide loneliness nor overcrowding.

In Wizard Box Life, the student can single step from one generation to the next, or set the process going so that each new generation is displayed for just one minute. In addition, on the command H, a Half-way state is indicated, whereby live cells that are doomed to die on the birth of the next generation are indicated by a trident graphic character, while dead cells destined for life in that generation are marked with a rectangular mark. An example if provided by the progress of a set of traffic blinkers:



In working with school children a number of simple patterns are supplied or suggested that give easily understandable results when the Life process gives birth to a new generation.

EVALUATION PROGRAM

How does one evaluate the educational robotics developed by the OZNAKI Project? Essentially there are two (intersecting) forms of evaluation. Typically educational systems (broadly conceived) are evaluated on a behaviorist basis: the student is conceived as some sort of black box, of unknown and unknowable inner structure, and the difference in behavior (equated to class marks and the like) is measured before and after exposure to the system.

In contrast, the OZNAKI Project is concerned with the difficult task of defining cognitive goals. To specify a cognitive objective, one must state a set of changes we want to bring about in the student's cognitive processes. Thus we are inherently concerned with the inner structure of knowledge - - where the inner is the contents of the behaviorist's black box.

It is in this general philosophic framework that studies of the OZNAKI Project were conducted in 1977. In the 1977 evaluation study we sought to examine enhancement of spatial abilities. We focused on **projection** – the ability to see with the mind's eye from elsewhere - - this having been demonstrated by Piaget as a major process in spatial thinking.

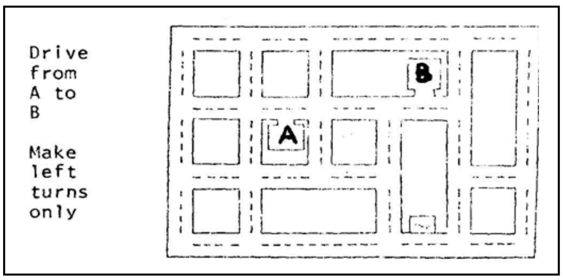
Dr David Green and this writer designed an introductory course in OZNAKI with a pronounced emphasis on projection. In this course of just eight lessons, the first lesson involved ZONKY, our real robot, then WHAM, and finally LIFE. This module provides an introduction to the algorithmic aspects of OZNAKI, including WHAM calculator maths, some geometry, and music.

The evaluation study carried out in Spring 1977 has the following phases:

(a) Pretesting p=of all students involved
(b) Selection of Experimental and Control Groups
(c) Teaching the Projection Module to the E Group.
(d) Post-testing of both E and G Groups.

The students participating in the study were aged 8 to 13. They included both primary and secondary students. Similar, but distinct, experiments were carried out at the high school and primary schools. Primary students were tested in Piagetian interviews, whereas the secondary students used multi-choice questionnaires.

A detailed account of the 1977 evaluation study of the PROJECTION Module is given elsewhere. In sum, the results derived from our study were dramatic. Following a course of just eight lessons in OZNAKI, students improved remarkably in spatial skills. In certain of the Piagetian interviews used in the evaluation, the student is asked to guide a model car about the streets of a model town, keeping the car on the correct side of the dual carriageways. In the "Left-Handed Route" problem the subject was asked to guide the toy car from car-park A to car-park B, as marked in the map below.



In the pretest only 4 members of the experimental and also 4 members of the control group of primary students could find a route satisfying the conditions given. On the post-test, of the experimental group, 21 (out of 27) students found a solution. whereas in the control group only 5 found correct solutions. Other Improvements were so large and generally consistent that despite the small sample sizes Involved (22 or 27 in each of the groups), statistical analysts confirms that highly significant changes were achieved in the children's projective skills.

That such good results can be achieved with such short exposure to OZNAKI highlights the importance of the Projection Module as a paradigm for the development of other courses of instruction involving computer embodiment of mathematics. In all phases, the hardware and software, and the lesson structure: the module was designed with definite cognitive goals in mind. Having definite objectives it was possible to measure effectiveness in reaching these objectives.

BEYOND OZNAKI

The OZNAKI Project is now in its fourth year of operation. The initial hardware and software goals have been reached with the systems described above. At this date there Is only a very modest amount of teaching experience In schools. The 1977 Evaluation Trial supplied a paradigm for evaluation, and more extensive work In the same spirit is scheduled for 1978. The emerging question is what lies beyond the core of OZNAKI as described above. A full answer ls not attempted heres rather some departures from the original framework are chronicled.

WIZ77

WIZ77 represents a first attempt to go beyond the confines of four user-defined macros. Just as in WHAM, on the right hand side of the screen are displayed the user's command line and user-defined macron. There is room on the screen for 14 such macros. on the top right are displayed the contents of two accumulators. A and B. The arithmetic operation + adds one to A while - causes one to be subtracted from A. Numbers are entered into B by a SWAP command that swaps the contents of A and B stores. Thus two numeric parameters are available to user macros without complicating the simple calculator arithmetic introduced first in WHAM. The really nice feature of two accumulators is that I was able to implement conditionals that compared A with B. For instance, the symbol "=" has value if A and B are equal: zero otherwise. By using this symbol before a bracket: the bracket contents are executed if A=B. Incidentally, the incorporation of brackets is very natural in macro languages. In WIZ77 a bracketed expression may be closed either by a right-hand bracket or by the "DO-IT" symbol. The original implementation runs a SHAH NAKI that can turn in units of 45 degrees. This NAKI can sense the contents of the cell immediately ahead and hence steer around obstacles.

WIZ77 is seen as a universal TINY robotics language. In future versions of WIZ77 the user wI11 be able to name a particular NAKI so that, for instance, having written a series of macros for drawing stars the student might simply invent the name STARMAN. Then on storing away STARMAN: using the mass storage facilities of the microcomputer, the student could in future sessions simply summon STARMAN to reappear.

COMPUTER ART

It is clear that in any OZNAKI-like system students are using mathematics: can what they do really be art? If the microcomputer graphics medium was used by children to produce stereotypes of trucks, houses stick figures, and the like the students might be kept busy, but this activity could hardly be called art. (In the same spirit concerned art teachers have condemned the use by children of ditto master outline drawings that children fill-in with coloured crayons.)

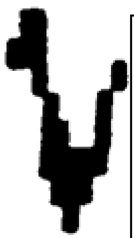
In order to expand the gambit of OZNAKI to Include art, it became essential to have an understanding of the evolution of the artistic capacities of children. Studies of the artistic development of children have for historical reasons focussed on representational art. Recently, Drora Booth of La Trobe University has completed a study of the development of painting skills In preschoolers attending a child minding centre fully involved in her experiment. The unique feature of this experiment was the protection of the children from the usual pressures to produce representational art. Al1 paintings (which were never called by the name "pictures") were kept at the center. To reduce the pressures on the children to produce representational art, the objective of the experiment was explained to their parents. The children had regular sessions for what was called painting (the medium being not commonly used at home.) Over a year, more than two thousand paintings were produced which were then analysed to show a clear-cut developmental pattern. Booth's work showed that children spontaneously discover ideas of pattern, and in progressing through stages more and more elaborate use of the mathematical (!) ideas of repetition of a basic motif on a rectangular lattice, with reflection and variants of glide symmetry.

Although pattern drawing has been almost totally neglected in traditional school education due to historical reasons (as discussed by Booth in her thesis 1978), her study demonstrated that it was a natural element in children's art, with perhaps not-so-surprising links with spatial ideas in mathematics. There are signal prospects for "Education through Art" (as espoused by Read) by linking a drawing system with a mathematical formalism. One must provide the child with a facility for repetition of motifs, combination, translation, reflection, and rotation operations. A graphics language for microcomputers with such capabilities is TV Sketch.

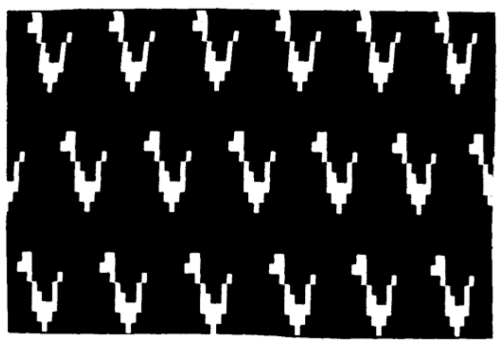
TV SKETCH

TV Sketch is a block oriented language, rather different to the line (or streak) drawing languages of more conventional computer graphics. TV Sketch was originally conceived as a vehicle for teachers to use to write their own extended version of PLUSMINUS. It does seem naturally related to children's spontaneous pattern making, and is being adapted for use by children.

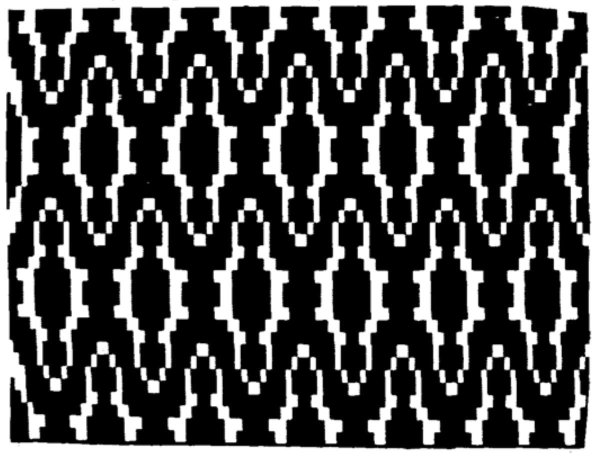
In TV sketch the motif is a primitive construct, owned by a NAKI, whose existence simplifies the repetition and combination of a motif over a lattice. Reflection and colour inversion are basic primitives of TV Sketch.



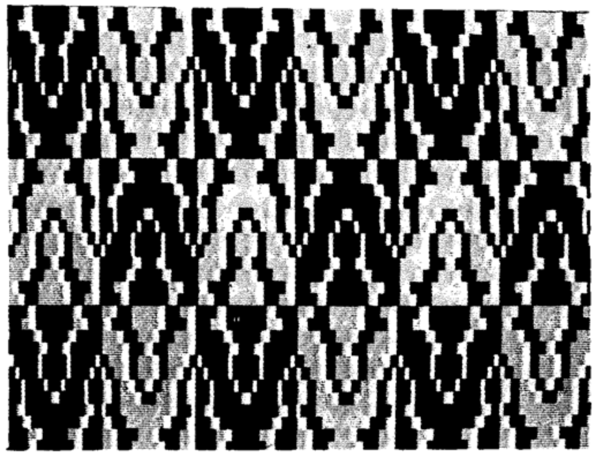
To explain the general idea, suppose the user creates the NAKI motif to the left of this text. (If you insist on a representational interpretation this might be a bird.) Suppose now the NAKI drags this motif around the screen and dumps the motif in a regular manner.



Reflecting this pattern twice yields



Reversing regularly about the pattern gives



SYMBOL GRAPHICS IN SPECIAL EDUCATION

The scope of OZNAKI has been the fostering of the intellectual development of normal children. Recently the author and Ms. Robyn Hannan have been applying the spirit of OZNAKI to the needs of special education.

As demonstrated above, OZNAKI has been concerned with the construction of domains in which keyboard commands that model some cognitive operation. Even though what is being modeled might be a relation, in OZNAKI it becomes a command (transitive verb!). The base level of symbol graphics is to use a keystroke to stand for a thing (noun) so that the symbol on the key is more precisely the command that the thing denoted appear, disappear, or move about.

The children we are now working with have considerable difficulty acquiring reading skills, so that it is not helpful to use alphabetical letters as key-symbols. We have chosen to use the pictorgraphic language of BLISSYMBOLS.

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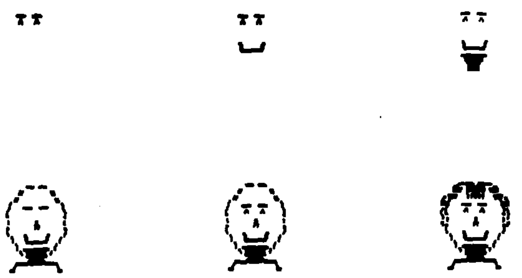
The first system developed is called HANGMAN (because of its resemblance to the well-known children's game.) Commuter power is supplied by an OZNAKI microcomputer (Wizard's Box). When the game commences' on the screen the child sees an outline face. On the twelve keys of a giant keyboard are the Blissymbols for eyes, mouthy hair: and nose. By pressing the appropriate large key, the corresponding picture element appears. lf the face feature is already displayed, pressing the corresponding key causes it to disappear. The child in the photo below is one of a group of Down's Syndrome children at the Moorabbin Day Training Centre Melbourne, Australia.

The film strip below shows (in colour reverse) the entire face and various partial faces the student can produce enroute.



The PLUSMIMUS is relevant in this environment for presenting the most basic ideas of numbers and number operations. The children we deal with lack the more basic spatial skills. As the TV screen is near vertical: UP/DOWN is easily modelled, while IN/OUT can be made key commands to move displayed objects In and out of given areas. HANGMAN was implemented in TV SKETCH. which will be appropriate for constructing these spatial micro-worlds.

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CHILDREN' S DRAWING

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ACKNOWLEDGEMENTS

The Teaching and evaluation studies described here were supported by the Education Research and Development Committee (E.R.D.C.) of the Australian Office of Education

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