A Graphic Teaching-Material Production System Using Personal Computers

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The authors have developed a graphic teaching-material production system for computer-based education, which makes it possible for classroom teachers to produce computer graphic teaching-material easily to meet their unique requirements.
The system has been implemented on personal computers, and a tablet digitizer is used as an input device. Two specially designed sheets to be set on the tablet digitizer are provided, and a menu of commands for picture drawing and text writing is printed symbolically and systematically on the sheets.
Course authors, who are assumed not to be good at computer operation and programming, can create animated displays easily merely using the commands.
In this paper, the authors describe the design, the function and the utilization of the system.

1. Introduction

Recently the surge of interest in computer graphics in education has expanded. Many recent papers (e.g., [7]) report on how computer graphics can be and are being used in computer-based education as teaching-material. In fact, graphic teaching-material is very effective and powerful in aiding students to understand and study material contents.

Several authoring systems and authoring languages (e.g., PILOT [1], Coursewriter [3], BOOK [6], TUTOR [8]) in computer-based education have been developed, which represent a high level interface to allow authors to create courseware easily [4]. However, it is still difficult for almost all teachers who are not good at computer programming, to produce unique materials and courses that include computer graphics, even when such high level interface authoring systems or author languages are used.

We have developed a graphic teaching-material production system, called LESSONWRITER, for computer-based education, which makes it possible for any author to produce computer graphic teaching-material easily [2][5]. This system has been implemented on NEC personal computers.

2. System Construction

2.1 Background

Authors (i.e., classroom teachers or experts on specific subjects) are not always good at computer operation and programming. In many actual cases of producing graphic teaching-material involving previously used authoring systems, the authors analyze teaching contents, make detailed plans, and then write manuscripts. Then, according to the manuscripts, computer programmers carry out computer graphics production. Under such situations, it is difficult to set up an equitable arrangement between authors and computer programmers. That is, it is difficult to correctly transmit the image which the authors have in their mind to the computer programmers. The teaching-material produced by the computer programmers often differs from what the authors wanted to present. Therefore, it is desirable that graphic teaching-material be produced by the authors themselves without any help from computer programmers. Authoring systems should be designed so that authors who are nonprogrammers are able to draw pictures on a computer screen as easily and simply as drawing pictures on a piece of paper with a ruler and compasses.

Typical methods for producing graphic teaching-material are computer programming, keyboard-based command input and electronic signal input tablet digitizer-based command input.

Computer programming is the most time-consuming and troublesome way, because locations of figures must be specified digitally. In addition, the authors must memorize many programming instructions. They are not always good at computer operation and programming.

Keyboard-based command input is easier than computer programming. However, cursor control with a keyboard is still far from drawing pictures on a piece of paper.

Electronic signal input tablet digitizer-based command input is the easiest method. Operating a stylus on a tablet digitizer is very close to writing on a piece of

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paper with a pen. Authors can trace a pattern on the tablet digitizer. For this reason, we adopted an electronic signal input tablet digitizer (a tablet digitizer, for short) as the main input device.

2.2 System Design

(1) Tablet Sheets for Picture Drawing and Text Writing

This system has two specially designed sheets which are set on the tablet digitizer. One of them is a picture drawing sheet, on which symbols for selected commands, such as line and circle, are printed in a menu format. Authors can draw pictures on the screen quickly with this sheet, because they only have to choose pertinent commands on the sheet. The other sheet is for text writing. Authors enter the desired text by picking out each character with a stylus from a character set printed on this sheet. This method for text writing is applicable to input several kinds of characters (e.g., Japanese phonetic characters, Chinese ideographs, special symbols, etc.). In addition, since KANJI typewriters, which also adopt the character-picking method, are widely used in Japanese schools, Japanese school teachers are experienced in writing text in this way.

A typical procedure for drawing a figure is shown in Fig. 1 to clarify the general idea of the method.

(2) Command Storing Method

At the stage of producing graphic teaching-material, the authors draw figures, paint, write text, and edit displayed pictures, interactively using pertinent commands. The series of commands are compiled into operation codes, which are stored sequentially into disk storage files along with their location data. This command storing method has two advantages. First, since the order of chosen commands is retained, produced figures and text can be presented on the screen in the same order of input at the presentation stage. This function is indispensable for presenting a process dynamically. Second, this method requires less memory space to store the graphic data than the image storing method.

(3) Teaching Material Structure

Each display produced by using this system is called "a page". A page can be made up of several "sections". The authors define the pages and the sections by choosing "page end" command and "section end" command, respectively. The whole set of pages is called "a lesson" which is a teaching-material unit.

At the presentation stage, the pages (and/or sections) can be presented on the screen in any order. Authors who are familiar with BASIC language can also write CAI course program, which controls the presentation order of the pages (and/or sections), in BASIC.

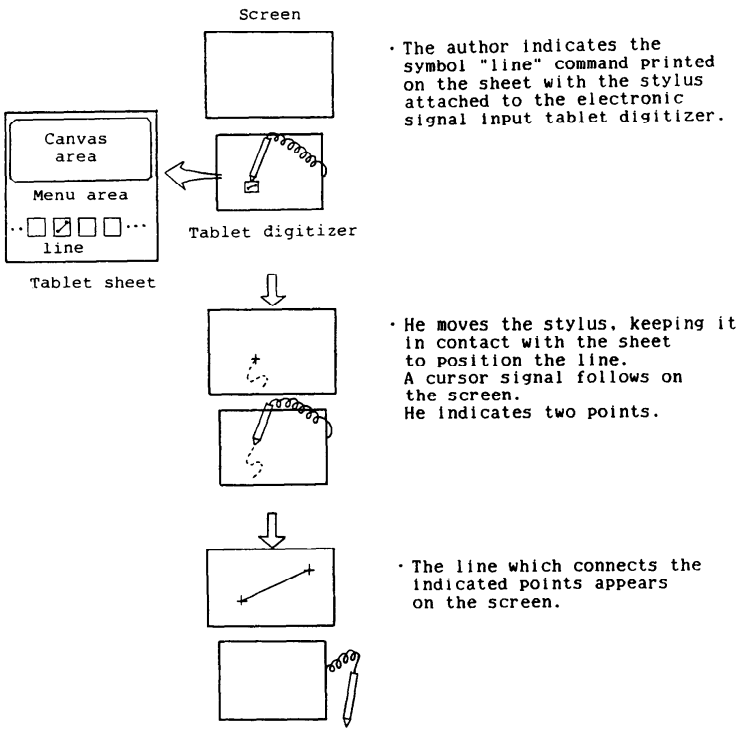


Fig. 1 Procedure for drawing a line

3. System Configuration

3.1 Hardware System

The hardware system, which is a stand-alone system, is made up of a personal computer and an electronic signal input tablet digitizer.

The system components are as follow.

- •Microprocessor unit with a keyboard: 256 k bytes RAM.
- •Floppy disk storage: 8 inch, two drives.
- •Color graphic display: 640 h × 400 v resolution.
- •Electronic signal input tablet digitizer.

3.2 Software System

The system is composed of two subsystems, that is, authoring subsystem and executing subsystem, as illustrated in Fig. 2.

The commands which are chosen for picture drawing and text writing are compiled into operation codes registered into the lesson file by the command builder. The command executor carries out the graphic and/or text commands. The author can write CAI course program in BASIC, as described in Section 2.2. The teaching course executor carries out the CAI course program.

The author can define his own commands by writing programs in BASIC as the occasion demands. These commands are registered into the user-defined command library and can be used in the same way as the preset commands.

4. Functions for Teaching Material Production

This system has functions involving generating graphics, writing text, providing presentation effects, editing and defining user-defined commands.

(1) Generating Graphics

To generate graphics on the screen, the sheet shown in Fig. 3 is used.

The selected graphics commands menu is printed on this sheet. The graphics commands are made up of the basic graphics command set and the animation commands. The basic graphics command set includes line, circle, arc, paint, etc. A list of the basic graphics commands is shown in Table 1.

Animation is often helpful for learners to understand the instructional concept in addition it sometimes motivates them. Creating animation usually requires a lot of elaborate effort. The animation commands in this system enable authors to easily generate simple animations, such as the movement of an object and the flow of a fluid.

For example, to realize the movement of an object, such as a running car and a walking boy, the authors only have to indicate the object and the points on the trace where it is going to pass through. Then, the object is copied and appears at each point. For animation such as when water is being poured into a beaker, the authors choose the pouring command and indicate the bottom of the beaker and the point up to which the water will reach.

(2) Writing Text

To write text on the screen, the sheet shown in Fig. 4 is used.

The commands for writing text and the character set are printed on the sheet. About 2500 characters, including KANJI, HIRAGANA, KATAKANA and other special symbols, are input with the sheet. Authors only have to indicate characters and symbols, one by one, on

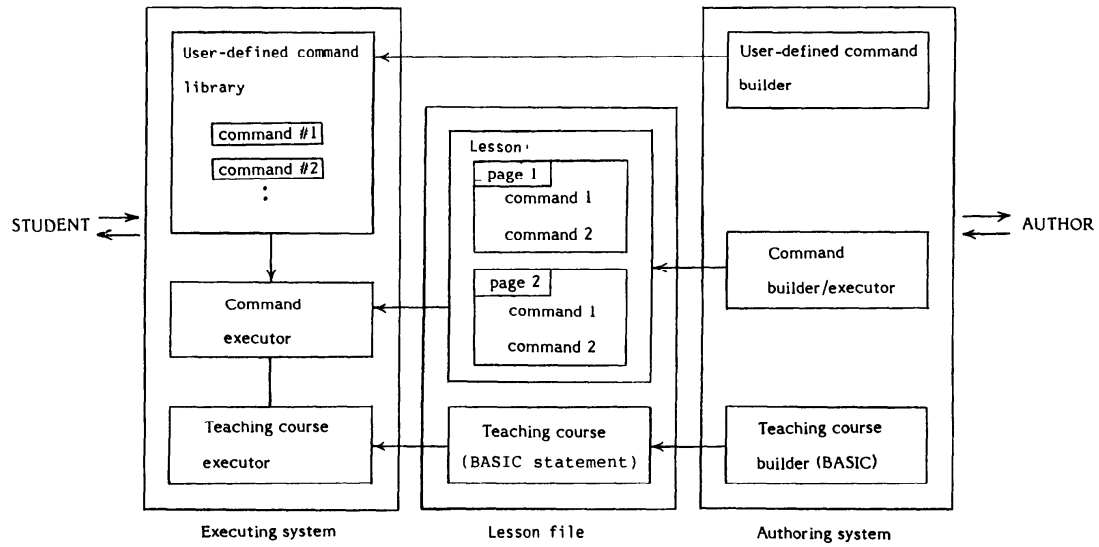


Fig. 2 Software system structure

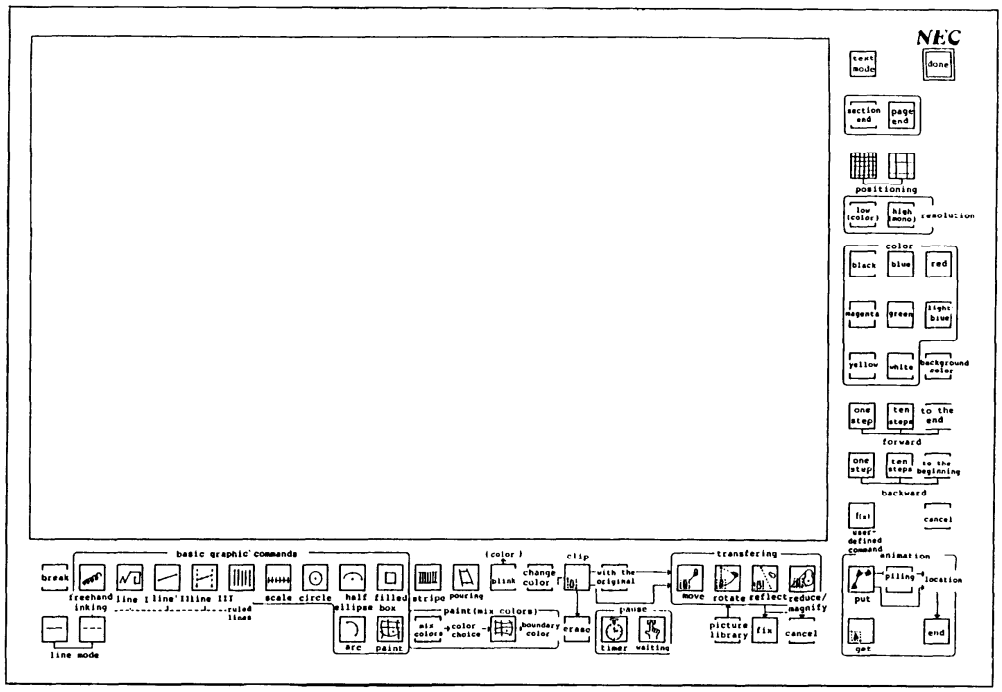


Fig. 3 Sheet for picture drawing

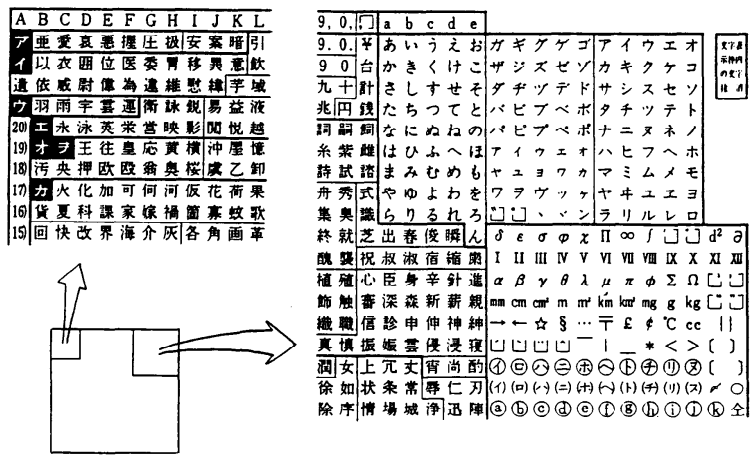


Fig. 4 Sheet for text writing

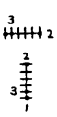
the sheet. Text with alphanumeric characters can be written directly using the keyboard.

Mathematical expressions, as shown in Fig. 5, can be written neatly by shifting characters up and down, and/or by using special character set of superscripts and subscripts.

(3) Presentation Effects

Authors should make efforts to smooth the man-machine communication between learners and computers. This system provides a lot of presentation effects to attain this goal. Functions, such as presenting-speed control, variable character interval and variable character size are provided so that learners can read displays naturally. Attracting the learners' attention is also important. Attention-getting command, such as colors, blinking and beep, are also available. In addition, timing control commands, that is pause command and key input waiting command, can be used when

Table 1 Basic graphics commands

Command	Symbol	Function
Freehand inking		Draw a trail showing the pen's movement.
Line I		Draw a line which connects points specified in sequence.
Line II		Draw a straight line which connects a pair of specified points.
Ruled lines		Draw ruled lines defined by three specified points. . The 1st point defines the startpoint. . The 2nd point defines the lower right corner. . The 3rd point defines the spacing.
Scale		Draw a horizontal/vertical scale defined by three specified points. . The 1st point defines the origin. . The 2nd point defines the right/upper limit. . The 3rd point defines the pitch.
Circle		Draw a circle defined by two specified points. . The 1st point defines the center. . The 2nd point defines the radius.
Half ellipse		Draw a half ellipse defined by three specified points. This command is used to draw the cut end of a column.
Arc		Draw an arc defined by three specified points.
Filled box		Paint a box defined by two specified points, any color. These points are regarded as the endpoint of the diagonal line of the square.
Paint		Paint the closed area, including the specified point, any color.

$$Y_{ij}=R_0+\sum_{i=1}^{n}(X_{ij}/X_{i\cdot})$$

$$\int(\mathrm{an}X^{n-1}+3bX^2)dX=aX^n+bX^3+c$$

Fig. 5 Writing mathematic expressions

authros allow learners to take time to understand a certain point being expounded.

(4) Editing

This system provides two kinds of editing methods. One is screen editing. The other is command-sequence editing.

a. Screen Editing

A set of figures presented in a specified area on the screen can be edited as a whole. Figures inside the rectangle specified by diagonal points are the target object to be edited. The target object can be moved, rotated, magnified/reduced and reflected by using the editing commands as shown in Table 2.

b. Command-sequence Editing

As described in Section 2.2, the commands chosen are stored in the order of input. To edit the sequence of commands, several functions are provided, such as "one step forward/backward", "ten steps forward/backward", "to the end/beginning", and "cancel a command".

c. Picture Library

The picture library is a file which contains a variety of basic pictures, such as a test tube, a thermometer, electric circuits and maps. Authors can choose the pictures which they want from the picture library. They can also register their own pictures into the picture library.

(5) User-defined Functions

Some geometric figures and functional curves require precision and elaboration. When drawing such figures on a screen by computer programming, it is difficult and time-consuming for novices to lay out a display and decide on the coordinates to accurately delineate these figures. Authors can define their own commands, such as drawing trigonometric, logarithmic and cycloidal curves by writing programs in BASIC. These commands are registered and can be used in the same way as

Table 2 Editing commands

Command	Symbol	Function
Clip		Indicate figures to be edited.
Move		Move the appointed figures according to the vector defined by two specified points.
Rotate		Rotate the appointed figures. . The 1st point defines the center of rotation. . The 2nd and the 3rd points define the angle of rotation.
Reflect		Reflect the appointed figures. . Two specified points define the axis of reflection.
Reduce/ Magnify		Reduce/Magnify the appointed figures. . The 1st point defines the center of reducing/magnifying. . The 2nd and the 3rd points define the rate of reducing/magnifying.
Save		Save the appointed figures in a temporary file.
Recall		Recall the saved figures from the file.
Erase		Erase the appointed figures.
Change color		Change the color of the appointed figures.

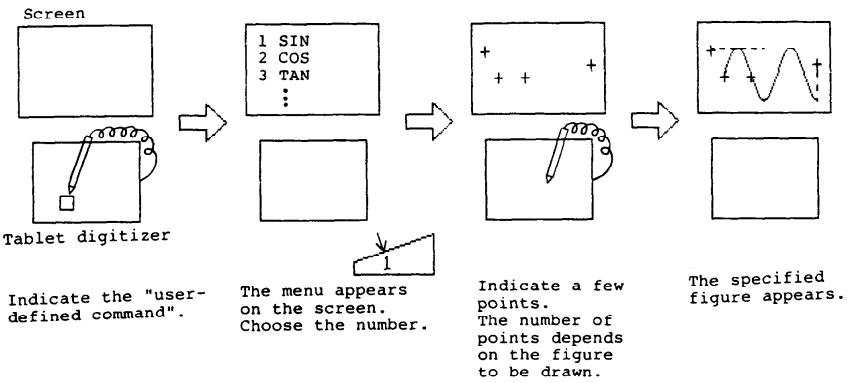


Fig. 6 Drawing a sine curve

the regular commands. These registered commands are held in common among authors. Operation using those commands is illustrated in Fig. 6.

5. System Operation and Utilization

This section describes how to operate and create an actual display, using the commands mentioned in the preceding section.

(1) An author (a school teacher) makes a rough sketch on a blank form in advance, whose size is the same as that of the canvas area on the specially designed sheet shown in Fig. 3. He should make a rough sketch, such as the one shown in Fig. 7, where only the principal edge points of the figures are clear. Fig. 10 shows the completed display. This display is created in the following sequence.

(2) In the beginning, the sheet for picture drawing is set on the tablet digitizer and the rough sketch is put on it.

(3) The "line I" command and the "half ellipse" command are used to draw the outline of the beaker containing the electrolyte and two carbon rods. Its outline is made up by indicating the edge points for the figure. The two carbon rods are drawn in the same way. Many parts of the circuit in the picture are drawn with the "line I" command. The arc in the ammeter can be drawn with the "arc" command. The arc is drawn by indicating three points on the arc. The "arc" command is useful to draw round parts

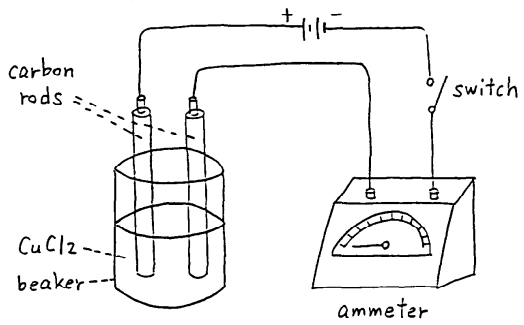


Fig. 7 Rough sketch

somewhere in a picture. The picture has been made showing the circuit switch open. The result of this step is shown in Fig. 8.

(4) Next comes the step used in writing some comments in the picture. The "text mode" command is indicated on the sheet. This action caused a change in the program within the computer. Then, this sheet is removed and the other sheet, the one for text writing, is put on the tablet digitizer. Words, such as "carbon rods", "$CuCl_2$", "beaker" and "ammeter", are written in the picture by positioning each word and indicating the pertinent characters. After that, the sheet is changed. The first sheet, originally used for picture drawing, is put into use again. The result of this step is shown in Fig. 9.

(5) In the next situation, the circuit will be shown with the switch closed. Indicating the "color-black" command, the switch arm and the meter hand are traced with the "line II" command to make them invisible. By indicating the "color-white" command, the switch is closed, and the meter hand, which is on the mid-point in the meter scale, are drawn. In consequence, a picture is made where the circuit is closed and the meter hand moves to the mid-point.

(6) In this simulated experiment, some bubbles are generated from the carbon rod connected with the plus terminal of the battery. A small circle is drawn with the "paint" command. After indicating the painted circle with the "animation-get" command, the author indicates the points where the circle appears, with the "put" command. Then, the painted circle moves quickly along the trace, giving the illusion that bubbles are rising. The result of this step is shown in Fig. 10.

(7) A display has been created which shows a scene where electrolysis reaction is in progress. The author can easily obtain a hardcopy of the displayed picture.

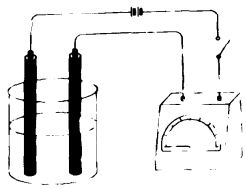


Fig. 8 Developing display

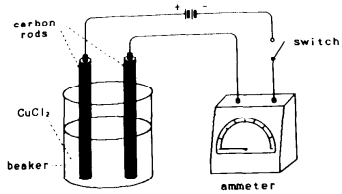


Fig. 9 Successive display

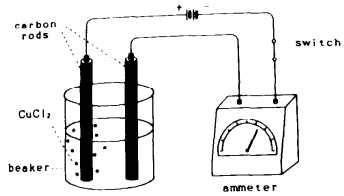


Fig. 10 Completed display

6. Conclusion

We have developed a graphic teaching-material production system, LESSONWRITER, for computer-based education, which helps school teachers to create computer-generated graphic teaching-material to meet their own requirements, using a personal computer. This system is designed so that school teachers can utilize it easily and simply. Even a teacher who has no knowledge of computer programming language can develop his own useful and successful computer graphics after only a few hours training.

This system can also be used as an easy-to-use document production system in business, so that requirements for a non-technical, non-programmer user can be satisfied.

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