PAINT

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Introduction

Paint is a menu-driven computer program for handpainting two-dimensional images in full color. It is a highly interactive software package with which a human artist may employ the power of a digital computer to compose paintings which are entirely of his own creation. The "canvas" is actually a large piece of digital computer memory which is displayed for the artist on a conventional color television monitor. His "brush" is an electronic stylus resembling an ordinary pen. Its shape can be any two-dimensional shape he desires, so long as it fits into the canvas memory space. He may choose any color he desires from a "palette" of 256 colors. If this is an inadequate selection, he may mix his own set of colors from a vast set of possibilities. The main purpose of this paper is to describe in detail how an artist accomplishes these acts and what his choices are.

A secondary purpose is a careful description of a successful human engineering design. Paint is designed to have a "natural feel" and to be readily usable by computer-naïve people. There are detailed descriptions of the techniques which make this possible. In fact, this paper is designed to be read as a textbook for Paint users. A more computer-science oriented description of the equipment used by Paint can be found in [2].[1]

Paint includes routines for defining and selecting brushes, automatic filling and clearing large areas, saving and restoring pictures, magnifying the canvas temporarily for detail work, and recording histories of picture composition. These functions will be described fully. Subsidiary routines available to the artist include such graphic aids as straight-line, ellipse, circle, and spline generators,

[1] The reprints of this memo slightly rearranged the wording of this paragraph, but with no substantive difference.

mirroring, rotation, etc. These programs will not be described here nor will be the large overseeing program Bigpaint of which Paint is a principal component. Bigpaint (see Fig. 2[2]) permits the artist to work on a canvas so large that it cannot all be displayed simultaneously. It will be described more appropriately in a separate memo[3].

There have been several versions of Paint at NYIT (New York Institute of Technology). Each version exists or existed for a specific configuration of equipment. Appendix A gives the various configurations that have been tried, with appraisals of each.

One version of Paint represents increased sophistication rather than mere equipment reconfiguration. This is called Paint3. It is superior to Paint described here in its use of 24 bits for representation of each point in the canvas memory rather than 8 bits. Appendix B explains the extension of Paint to Paint3.

Appendix C gives a brief history of painting programs, emphasizing those which most directly influenced Paint.

The Artist's View

An artist at a typical paint station (Fig. 1) faces a color display, a menu display, and a tablet with its stylus[4]. The color display is an RGB (red-green-blue) full-color standard television monitor. The menu display is a monochrome line-drawing monitor (sometimes called a vector display or a calligraphic display). The tablet is a flat rectangular device which continually sends to the computer the current location of the tip of the stylus. The stylus resembles a pencil or ball-point pen with a thin flexible wire connecting its top end to the computer. In fact, it is frequently called a pen. When the tip of the stylus is pressed (typically but not necessarily against the tablet surface), a switch is closed. The stylus is said to be in pressure. The artist can feel this because the stylus moves through a short distance, its throw, as the switch closes. The state of this switch is continually fed to the computer. So pen location and pen status is always available to Paint.

The artist would also find several devices of secondary importance to Paint: a keyboard for interaction with the system (e.g., to command the computer to start the Paint program) and a small monochrome monitor used for error display and other miscellaneous messages.

The artist starts Paint by typing "paint<return>" at the keyboard. He then takes up the stylus and begins tracking it on the menu display. Tracking is the process of sliding the stylus lightly over the tablet (in proximity but not in pressure) while watching a cursor on the display. The cursor is a small symbol which indicates position. The favored cursor at NYIT is an upside down V. Other computer programs ensure that every time the stylus moves so does the cursor on the menu display—in the same direction, at the same speed, and through a distance in direct proportion to that moved by the artist on the tablet. To him this appears

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[2] Figure numbers were slightly rearranged in the reprints. The original numbering is used here.

[3] Never written. This sentence is slightly modified in the reprints.

[4] Underinling was used in the original for new terms, italics in the reprints.

to happen instantaneously. It feels to him as if the cursor is in direct physical, mechanically rigid contact with the stylus. To complete the illusion, when he lifts the stylus off the tablet, the cursor disappears[5].

Frequently I have found that tracking sounds, to the uninitiated, as unnatural since "you can't see your hands". If the cursoring routines are written as described above, tracking begins to feel "natural" within 2-5 minutes after first exposure. Children, morons[6], and professional artists have all adapted to it quickly. A benefit derived by separating the eye focus from the finger focus is that one's hands are never "in the way" while painting.

Paint is designed so that the artist never has to lay down the stylus (e.g., to type at the keyboard) once the program is entered. This not only maintains the "flow" of the interaction but is convenient for darkened rooms in which Paint is frequently used and where hand placement on an ill-illumined keyboard is difficult.

The first thing Paint does when entered is to display[7] its menu on the menu display. A typical menu is shown in Fig. 3 with the cursor in an arbitrary position. It is a list of buttons of which only the labels are visible. The artist "pushes a button" by moving the cursor over the label he wants and pressing down momentarily on the stylus. The sequence of events initiated by pushing the "full paint" button will be described in detail below. Full paint is the regular painting mode—nothing fancy. The many variations on basic painting will be described briefly afterwards.

Immediately upon a push of the "full Paint" button, a palette appears on the color monitor which serves to display the artist's canvas. The palette is a display of the 256 currently available colors (see Fig. 4). (Paint3 has more than 16 million currently available colors, an improvement with many consequences. See Appendix B.) Although there are only 256 colors available at any one time, there are more than 68 billion colors from which these may be selected. There are more colors in this colorspace than a human can distinguish. Hence it is a perceptual continuum of colors for practical purposes. How the artist makes his selection from this colorspace will be described later.

The [appearance of the] palette is a cue to the artist that he can select a color to paint with. He may choose a color from the palette or from anywhere on the color display. As soon as he has made his selection, the palette disappears. He makes the selection with the following procedure: He begins tracking in the color display by sliding the stylus from one half of the tablet to the other half. On the displays this appears as a movement of the cursor from the menu display to the

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[5] This laborious description was necessary at the time, before personal computers, when nobody understood how natural it is to track a movement "down here" on the desktop while looking "up there" at a monitor. With the advent of PCs, I no longer had to explain this.

[6] In fact, a group of mentally disadvantaged children, officially morons (IQ 50-69), quickly learned to use the program. The word "moron" is no longer politically correct, its informal meaning having come to dominate its original meaning. It was dropped in the reprints.

[7] Better worded in the reprints as "When entered, Paint first displays".

color display. (Other arrangements are required for some of the configurations discussed in Appendix A.) He positions the cursor over the desired color and presses down momentarily to complete color selection. (A small triangle pointing upward is the color display cursor used at NYIT. Its apex is the sensitive point.)[8]

The palette's disappearance is a cue to the artist that he may proceed to paint. However, should he desire a new color, he may call up the palette again, with a simple flick of the wrist, by sliding (no pressure) the cursor off-screen momentarily below the color display. (We henceforth assume the reader identifies a cursor movement on the displays with the simultaneous and "similar" stylus movement on the tablet.)

Painting is accomplished[9] by moving the cursor to desired position then pressing down while moving the stylus. Painting begins with pressure and ends with release of pressure on the stylus. This constitutes one stroke. At the end of a stroke the artist is again tracking in the color display. He may begin a new stroke, select a new color (by sliding off-screen below), or return to the menu display (by sliding off-screen toward the menu display). However, while painting a stroke (with stylus in pressure), he may move the stylus off-screen in any direction without interrupting the stroke.[10]

What the artist sees while painting a stroke is a succession of copies of a brush he has previously selected with the "pick brush" menu button (see below). For example, a brush might be a disk about one-half inch in diameter. It can, in fact, be any picture which can be painted with Paint, but the very large brushes cause painting to be so slow that they are not used. The copies of the brush are written into the color display so rapidly as to appear to flow onto the screen. The brush is always written into the display in the color previously chosen. Fig. 5 shows some typical strokes and the brushes used to make them.

This completes our brief description of basic painting behavior in Paint. To select a different brush or to exercise any of a number of other options, the artist returns to the menu by sliding off-screen toward the menu display. Should the palette be visible when he so desires to return to the menu, it is erased. Thus the palette is never left in the color display to mar the composition. We will now list the options available and the menu buttons used to elicit them. [Then we will describe the ten available variations on simple painting.][11]

make brush

> As indicated above, the artist may define a brush of arbitrary shape. He does this by painting the desired brush shape then pressing this button. The menu is erased and a keyboard drawn in its place. The computer then instructs him to name the brush. (All instructions are displayed in the menu display.) He "types" on the keyboard by moving the menu display cursor over the de-

[8] Omitted in the reprints.

[9] "The artist "paints" with his chosen color" in the reprints.

[10] This paragraph is rearranged slightly in the reprints, but with no substantive difference.

[11] Added in the reprints.

sired key and pressing down momentarily (Fig. 6). The "done" key indicates the end of the name and causes the next instruction to be issued. This is a request for a window around the desired brush.

A window is a rectangular subset of the color display plus an origin, a point which may be thought of as where the stylus is to be attached to the brush. The artist designates the window by sliding to the color display and selecting a lower-left corner, an upper-right corner, and an origin much as he chooses a color when painting. He slides the cursor to the desired location and presses down momentarily. As cues, the cursor changes shape. First, it is L-shaped to indicate lower-left corner selection. This is the L-shaped cursor rotated 180 degrees around the intersection of the two arms of the L. And this is replaced by the standard arrowhead or triangle cursor described previously for origin designation.

The final step in brush creation is the specification of a transparent color. This is a color in the chosen window which is not to be displayed as part of the brush. The reappearance of Paint menu is the cue that "make brush" has been completed.

pick brush

Whenever a brush is created (see "make brush" above), its name is added to a list. When the artist presses the "pick brush" button, the Paint menu is erased and this list displayed in the menu display instead (Fig. 7). He selects the brush he desires by name in the usual way (by sliding the cursor over the name and pressing down momentarily). The next time he paints, the selected brush will be used. Redisplay of the Paint menu signals completion of this operation.

color maker

The artist may mix his own palette of 256 colors with the set of routines invoked by this button. He can change the color of each paint pot in the palette by varying its red, green, and blue primary components directly or indirectly by varying its hue, saturation, and value. The algorithms used are described in [1].

There are routines provided for setting the colors of several paint pots simultaneously (Fig. 8). For example, the first 20 paint pots might be set to a linearly spaced set of colors varying smoothly from red to blue (Fig 9.). Or the first 10 colors could be reversed in order.

Once the palette is set up as desired, it is usual to save it for future use. "Color maker" provides a means for saving the set of colors assigned to the paint pots of the palette. The artist supplies a name (as in "make brush" above), and the current set of colors is saved in the auxiliary memory of the computer (as a disk file). These saved sets of colors are called colormaps. A return from "color maker" to Paint is signified by redisplay of the Paint menu.

get colormap

The most frequently used way of selecting a new set of palette colors is by selecting a colormap previously defined and saved (see "color maker" above). This button provides the colormap selection facility. It is similar to "pick brush" above. A list of available colormaps is displayed, and the artist selects one. Completion of this operation is signified by a sudden change of colors in the color display (as the new colormap replaces the old) and a redisplay of the Paint menu.

full clear

To initialize the color display or to erase its contents, the artist selects this menu item. It causes a palette to appear in the color display. This is the cue that the artist is to select a color as in "full paint". The color display is completely cleared to this color. After each clear the palette reappears so that the artist can clear again to a different color if he so desires. He signals Paint that he is finished with clearing by sliding back to the menu, which causes the palette to disappear from the color display.

clear window

This button is similar to "full clear" above except it requires a window to be specified in the color display (see "make brush" above). This window only is cleared to the specific color.

save picture

At any time the artist may wish to permanently save his painting, either as a finished piece or as a safeguard. "Save picture" causes all or a window of the current color display to be saved as a disk file. The operation is very similar to "make brush" above, which is not surprising since a brush is just a (usually) little picture. This operation is slightly more powerful, however. It allows the artist to save the current colormap with the current picture in one step. It also allows him to specify any number of transparent colors, whereas "make brush" allows only one. The Paint menu is redisplayed to signify completion of picture saving.

get picture

Any picture saved with "save picture" (or with "make brush") can be recalled into the color display with this button. A list of pictures is displayed in the menu display and selection proceeds as in "pick brush". When the picture name has been selected, Paint asks the artist where he wants the picture to be restored. This query is displayed in the menu display as are all text messages. The artist indicates the location of the picture origin by sliding to the color display and pressing down momentarily at the desired location. Or he may opt for the default origin location by simply sliding back to the menu display without pressing down. The default origin is that of the picture as it was originally saved. Thus to restore a picture that originally filled the color display to this same position, the artist simply flicks his wrist toward the color display from the menu display. He is also given the option of changing

the current colormap to that saved with the picture (if one was saved with it) or leaving it unchanged. The Paint menu is redisplayed at the end of the operation.

cursor

This option selects the cursor displayed in the color display while tracking there in preparation for painting a stroke. The currently selected brush may be used as a cursor, or the standard arrowhead may be used. Whichever is the artist's choice remains in effect until this button is pushed again. Redisplay of the Paint menu indicates completion of this choice.

magnify

To do detail work, the artist may magnify the color display by a factor of 1, 2, 4, or 8 (Fig. 10). (A factor of 1 is equivalent to turning magnification off.) After he makes his selection, the Paint menu reappears. No magnification occurs until one of the "paint" buttons (e.g., "full paint") is pushed. The following modification of the basic painting behavior occurs: After the artist makes his color selection and the palette disappears, he is cued to select a portion of the color display to be magnified. The cue is a box-shaped cursor, the size of the box depending on the magnification factor. The contents of the box is the portion of the color display which will be magnified to fill the entire screen when the artist presses down. Thus he tracks the box-shaped cursor until it covers the portion he wished to have magnified. Then he presses down momentarily to make the selection. The magnification occurs immediately. It is important to understand that this is only a temporary magnification. The picture stored in the computer memory is not altered at all by the magnification. He can proceed to paint on the magnified picture. The magnification occurs in such a way that his cursor does not change position during the magnification, and a motion of the stylus on the tablet corresponds to the same distance on the color display after magnification as before.

To demagnify he either slides off-screen below (which is also the signal for palette display) or off-screen toward the menu display (which is the signal for return to menu selection). This implies that he must remagnify (with the box-shaped cursor) after each color selection. The disadvantage is that the palette is not fully visible, so constant magnification is used when the colors of possible interest all lie within the magnified area. (Recall that a color may be selected from anywhere in the display, not just from the palette.)

The magnification step is added to the basic painting behavior until "magnify" is pushed a second time and magnification turned off. The step is added to the behaviors required for all the "paints" and all the "fills" (see below).

sketch

This button invokes a set of routines which the artist may use to draw antirastered, or antijaggied, curves or straight lines. A line drawn into a digital

computer memory such as used by Paint will have an unpleasant “stairstep” appearance (see Fig. 11). It is said to have the “jaggies”. “Sketch” uses a computer graphics technique which removes these unwanted jaggies when viewed at a typical viewing distance. Fig. 11 shows what the technique does to a jagged line in closeup. “Sketch” also allows the artist to select the width of the “smooth” line he wishes to draw with. He draws with the chosen line width by sliding to the color display and stroking just as he would for painting. An antirastered stroke of the chosen width appears instead of a painting strip. He may not change the color of the line (see, however, the discussion of Paint3 in Appendix B). He returns to menu selection in Paint by simply sliding to menu display from the color display and pressing the “return” button of the sketch menu (Fig. 12). Reappearance of the Paint menu signals an end to sketching.

fill

To change the color of an irregularly shaped area in the color display, the artist presses this button. The behavior expected of him is much like that for painting. A palette appears to cue color selection. Then, if magnification is on, the box-shaped cursor cues selection of the area to be magnified. But instead of painting a stroke, he selects a point in the area he wishes to fill with the new color. This point is called the seedpoint. The area is filled quickly using the algorithm explained in [2]. The artist may then fill another area with the same color or choose another color (as in “full paint” by sliding off-screen below to cause palette display). Return to menu selection in Paint is the same as for “full paint”.

tint fill

This version of filling is more sophisticated that that used in “fill” in that it knows about antirastered lines (see “sketch” above). It is used just as the version described in “fill” is used. The main difference the artist will notice is that in color selection, a restricted palette of only 16 colors is displayed. This is because 16 shades of each color are used to do the antirastering depicted in Fig. 11, and 16x16 = 256, the total number of colors available at any one time. The restricted palette is called the tint palette. The other difference he will notice is a slower speed of filling. The more complex algorithm used by “tint fill” is described in [2].

palette

The “palette” menu (Fig. 13) replaces the Paint menu when this button is pressed. It allows the artist to select several options concerning the palette displayed for color selection (e.g., in “full paint”, “fill”, or “full clear”). Return to Paint menu selection is signaled by display of the Paint menu.

The “move palette” button is used to change the location of the palette when it is displayed for color selection. Pressing this button causes the palette to appear in the color display. The artist moves it by sliding to the color display and selecting a point in the usual way. The palette is moved so that

its vertical position is the same as that of the point selected. It is centered horizontally at this position.

There are three types of palettes in Paint. The most commonly used one is the "full palette" of 256 paint pots used in "full paint". Another is the "tint palette" of 16 colors used in "tint fill". The third is the "value palette" of 16 shades that each of the 16 colors in the tint palette may assume in antirastering (see "sketch above). The artist can force the display of any one of these palettes during color selection by pressing the corresponding button in this menu. The usual request, however, is "standard palette" which causes the display of the palette most appropriate to the situation (full palette for full paint, tint palette for tint fill, etc.).

Sometimes it is convenient to know exactly which colors have been selected in a painting. Keeping track of the last color used in a palette of 256 paint pots can be quite tedious. By pressing "dot switch on", the artist causes a small dot to be displayed on each paint pot corresponding to a color he picks during color selection, regardless of which routine he is performing. To turn off this option he must press "palette" again and then press "dot switch off" in its menu. "Clear dots" removes all dots from a palette during color selection but does not turn off (or on) the dot option.

history

A history is a list of actions performed in Paint between two times selected by the artist. By pressing the "history" button, he can start the recording of such a history or stop it. These options are available to him on the "history" menu (Fig. 14). When he starts the recording of a history, he is asked to supply a name for it. This name is added to a list of history names. From this moment until he returns to the history menu and presses the "cease recording history" button, the computer records each button he pushes, each brush he selects, each color he selects, each stroke he paints, etc. Thus a history is a way of saving a painting permanently as well as the sequence of events which composed it.

The artist can reconstruct a painting at a later time by pressing the "history" button in the Paint menu, then by pressing the "playback history" button in the history menu. He will be presented with a list of histories that have been recorded from which he may select one in the usual way (see "pick brush"). It will then replay the exact sequence of events as they were recorded.

remove

There are several types of items permanently stored by Paint in the computer disk memory as disk files. These are pictures, brushes, colormaps, and histories. They are stored at the artist's request and may be removed by him by pressing this button. He requests which type of file he wishes to remove by pressing a button in the "remove" menu (Fig. 15). A list of the files stored is displayed on the menu display from which he may select one in the usual way (see "pick brush"). He is then asked to confirm the deletion before the

file is actually deleted from the computer memory. The confirmation is made or not made by pressing yet another button on a two-item “confirmation” menu (Fig. 16). The “return” button of the remove menu causes redisplay of the Paint menu.

This concludes our brief overview of the options available to the artist in Paint to assist him while painting. To complete the survey of Paint options, we now list the variations on simple painting which are available to him. All the options listed above are, of course, available for these variations also.

cycle paint

Cycle paint is a simple variation on full paint where the color of the brush is not constant but cycles through the paint pots in the palette. As each copy of the brush is laid down, the next color in the palette is used. The effect is a cycle of colors along the stroke instead of constant color. No palette is displayed for cycle paint.

tint paint

In pictures composed with special 16-tint colormaps mentioned above in “tint fill”, tint painting can be used just like full painting but only the tint of the paint selected is used to change only the tint of pixels under the brush. (A pixel, for picture element, is one point in the digital canvas used by Paint.). Pictures created with “sketch”, for example, can be tint painted without destroying the antijagged curves created by sketching. The standard palette for tint paint is the tint palette.

value paint

Value painting is the complement of tint painting. Only the value, or blackness, of the selected color is used to change only the value of the pixels under the brush. The effect is to leave the tints unchanged but vary their darkness to that of the color selected. The standard palette for value paint is the value palette.

picture paint

No palette is displayed for this type of painting because the brush is restored exactly as it was saved (see “make brush”). The effect is to “rubberstamp” the picture which is the brush along the path of the artist’s stroke.

z picture paint

This is like picture paint above but a color in the brush is painted into the canvas space only if its position in the palette is greater than that of the color under it in the canvas space. (The positions of paint pots in a palette are assumed to be numbered; hence there is a number associated with each color.) If the brush is a picture of a smooth-shaded sphere, for example, then z picture paint has the effect of intersecting the spheres with one another as they are laid down in the canvas space along the stroke.

tincture paint

This is a combination of tint and picture painting. The tint is selected from the tint palette which is the standard palette displayed for this option. Then the tint of all pixels in the brush are changed to the selected tint, and the resulting picture is picture painted into the canvas.

z paint

The full palette is displayed normally for this option. The color chosen is painted into the canvas space at only those pixels under the brush which contain colors with lower numbers (see "z picture paint" above). The effect is to paint over some colors and under others.

filter paint

At every pixel in the canvas under the brush, a weighted average of the 3x3 neighborhood of pixels originally there is taken and written into the central pixel. This average is formed from the numbers associated with the colors, their respective positions in the palette. The effect is dependent on the colormap currently in use. For colormaps composed of smooth ramps of color, the effect is to smooth rough edges. No palette is necessary for filter paint.

smear paint

Smearing is similar to filtering above but the local average is written into a pixel in the direction of motion of the artist's hand. The effect is to smear the canvas contents in the direction of motion. No palette is necessary.

slide paint

Slide paint is just like smear paint above without averaging. The portion of the canvas under the brush is simply shifted in the direction of motion. Again no palette is necessary.

REFERENCES

1. Alvy Ray Smith, *Color Gamut Transform Pairs*, in **Proceedings of the Fifth Annual Conference on Computer Graphics and Interactive Techniques** (Siggraph 78), August 21-25, 1978 (to appear)[12].
2. Alvy Ray Smith, *Fill and Tint Fill*, Technical Memo No. 6, Computer Graphics Lab, NYIT, Old Westbury, NY 11568, July 1978.[13]

APPENDIX A – EQUIPMENT CONFIGURATIONS

Following is a list of various equipment configurations which have been used at NYIT for painting stations, together with a brief analysis of each one.

I. line-drawing device: Evans and Sutherland (E&S) Picture System I
tablet: Summagraphics 22"x22"

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[12] It did, in **Computer Graphics**, Vol 12, No 3, Aug 1978, 12-19 (SIGGRAPH 78 Conference Proceedings).

[13] Later published as *Tint Fill*, **Computer Graphics**, Vol 13, No 2, Aug 1979, 276-283 (SIGGRAPH 79 Conference Proceedings).

frame buffer: one E&S, 512x512x8 bits
computer: one Digital Equipment Corporation (DEC) PDP 11/45
remarks: one stand-alone station
advantages: very sophisticated line-drawing device, stand alone
disadvantages: only one station, Picture System monitor very noisy, only 8 bits, Picture System very expensive

II. line-drawing device: Tektronix 4014
tablet: Summagraphics 16"x30"
frame buffer: six E&S, 512x512x8 bits (or, equivalently, two 512x512x24-bit RGB buffers)
computer: DEC PDP 11/45 and 11/70 (one each)
remarks: five time-shared stations
advantages: double-width tablet feels "natural" and easy to explain, RGB frame buffers, several stations, cheap line-drawing device
disadvantages: time-sharing and interactive tablet manipulation do not mix well, Textronix 4014 flashes for screen clear

III. line-drawing device: 3 Rivers Graphics Wonder
tablet: Talos 16"x16"
frame buffer: six E&S, 512X512x8 bits (=2 E&S RGB), and 12 Genisco, 512x512x8 bits (=4 Genisco RGB)
computer: DEC PDP 11/34 (5 of them)
remarks: five stand-alone stations
advantages: high-resolution tablet, no time sharing, cheap sophisticated quiet line-drawing device, cheaper computer, RGB frame buffers
disadvantages: slower computer

Equipment configuration I is no longer used, and II is being phased out.

APPENDIX B – PAINT3, THE RGB VERSION OF PAINT

Only 256 colors are available at any one time in Paint although they can be selected from a vast number (4096^3) of possibilities and the selection can be changed very rapidly (by changing only the colormap). This limitation is due to there being only 8 bits per pixel. Paint3 assumes 24 bits per pixel—8 for red, 8 for green, and 8 for blue. The colormap mechanism is not used, or equivalently, it is assumed fixed at a ramp—i.e., a direct mapping of pixel values into gun voltages (with perhaps a curve in the mapping to compensate for nonlinearities). Thus, 256^3 colors are always available in Paint3. This large number of colors permits many types of painting not possible in Paint. Some of these are briefly described below:

tint paint:

This is a true tint paint as opposed to that described for Paint, which required the use of special colormaps. The tint of the color chosen to paint with is extracted using a color transformation [1]. Then this tint is substituted for that of every pixel under the brush, also using the color transforms.

hue, value, luminance, … paints

As for tint paint above but the color attribute substituted at each pixel under the brush is hue, value, luminance, etc., respectively, instead of tint.

wet paint

The (8-bit) values of the brush are used as "wetness" weights. The higher the weight w in the brush the more dominant is color A, the color selected to paint with, over the color B at a pixel under the brush. The computation is the familiar "lerp" function (linear interpolation): w*A+(1-w)*B. If the brush is shaped as a random distribution over a circular radius, clustering toward the center with higher weights there, then wet painting simulates airbrushing.14

intensity painting

As in wet paint, the 3-dimensional shape of the brush is used, where the values in the brush represent points in the third dimension. The computation at each pixel under the brush is as follows: The values of the brush are assumed to weight the colors under the brush. For a weight w from 0 to, say, 200 (the knee k), the weighting is direct. The new color at a pixel is the old color times w/255—i.e., it is weighted toward black. For a weight w from the knee to 255, the weighting is toward white instead: a*W+(l-a)*C, the lerp of the old color C and white W, where a=(w-k)/(255-k). The effect is to map the painting onto the surface represented by the brush shape, or to pass the brush under the surface of the painting, deforming it to the shape of the brush.

The structure of Paint3 is essentially that of Paint. The routines called by the menu buttons have either been rewritten for 24 bits when that makes sense (e.g., for fill and sketch) or replaced with items which were not possible in 8 bits (e.g., wet paint).

Although the frame buffer colormap is not altered in Paint3, there is still a "get colormap" button. This is used to select a set of 256 "convenient" colors to be displayed as the palette. For example, in tint paint 256 pure hues spanning the spectrum are convenient.

There is one additional "get picture" button ("get 1 picture") which fetches 8-bit paintings, created with Paint, and displays them in 24 bits. The "get 3 picture" button restores 24-bit paintings created with Paint3.

APPENDIX C—BRIEF HISTORY OF PAINT PROGRAMS

The following history is restricted to color paint programs. There are several black-and-white or gray "paint" programs not included in this short survey.

The earliest paint program with which I am acquainted is that of Joan Miller [C1], implemented at Bell Labs in 1969-70 on a 3-bit frame buffer. The user could draw lines and them alter the colors by turning potentiometers. More or less simultaneously, the "tricolor cartograph" [C2] came into existence with eight fixed colors, including black and white.

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14 Wet painting in general has come to be called "airbrushing", not just the special case described.

The first 8-bit frame buffer paint program that I know of, and certainly the first I personally used, is that written by Dick Shoup (associated by Bob Flegal and Patrick Baudelaire) at Xerox Palo Alto Research Center in 1972-73. This program is a direct predecessor of the NYIT Paint program and influenced in greatly. It is implemented on a frame buffer designed and built by Dick Shoup. Another direct influence on the current Paint is the paint program written by Garland Stern at the University of Utah for the same (Evans & Sutherland) 8-bit frame buffer first used at NYIT. He wrote his program in 1974-75 and brought it with him to NYIT when he joined the computer graphics lab in 1975. Yet another University of Utah paint program was used at NYIT briefly was that written by Jim Blinn, also written in the 1974-75 period. Duane Palyka wrote another paint program during this time, but I have not used it. The NYIT Paint was written in 1975-76 and has been in constant use ever since. It has undergone quite a few modifications, however, mostly to accommodate equipment reconfigurations (see Appendix A). A similar program was implemented at the Massachusetts Institute of Technology shortly thereafter. See [C3,C4] for descriptions of the equipment used there. More recently, Marc Levoy programmed an 8-bit paint at Cornell University and is currently at work on an RGB paint (awaiting only the acquisition of 16 additional bits per pixel in the Cornell frame buffer). A 24-bit, or RGB, version of paint at NYIT was certainly the first of this variety. It was implemented in 1977.

The Paint program was sold to CBS and Ampex in 1977 and implemented on an equipment configuration specified by NYIT (configuration II of Appendix A) under my supervision. Junaid Sheikh and Larry Evans of Ampex made slight modifications to the program. For example, a history editing facility was added. Then it was used by Leroy Niemann on the Super Bowl in January 1978 and subsequently written up in several publications: The New York Times, New Times, Videography, and Playboy.

REFERENCES

C1. Joan E. Miller, personal communication, Bell Labs, Murray Hill, N.J., Jul 1978.

C2. W. J. Kubitz and W. J. Poppelbaum, The Tricolor Cartograph: A Display System with Automatic Coloring Capabilities, in Information Display, Nov / Dec, 1969, 76-79.

C3. Jeffery Entwisle, An Image Processing Approach to Computer Graphics, in Comput. & Graphics, Vol. 2, 111-117, Pergamon Press, 1977.

C4. Nicholas Negroponte, Raster Scan Approaches to Computer Graphics, in Comput. & Graphics, Vol. 2, 179-193, Pergamon Press, 1977.

FIGURES

Figs. 1 and 17 were sketched (with ordinary pencil) by Ephraim Cohen. All of the menus were generated directly off a Tektronix 4014 using a Tektronix hard-copy unit. Figs. 4, 5, and 11 were generated by contouring the contents of the canvas space into a Tektronix 4014 using a program by Garland Stern. Then the hard-copy unit was again used to get the line drawings shown here.

1. A typical paint station.
2. Bigpaint menu.
3. Paint menu.
4. 256-color palette in a typical position.
5. Several brushes and strokes created with them.
6. The virtual keyboard.
7. A typical list of brushes.
8. Color maker menu.
9. Sliders for setting color.
10. Magnify menu.
11. Rastered line vs. antirastered line.
12. Sketch menu.
13. Palette menu.
14. History menu.
15. Remove menu.
16. Confirmation menu.
17. Author at work.

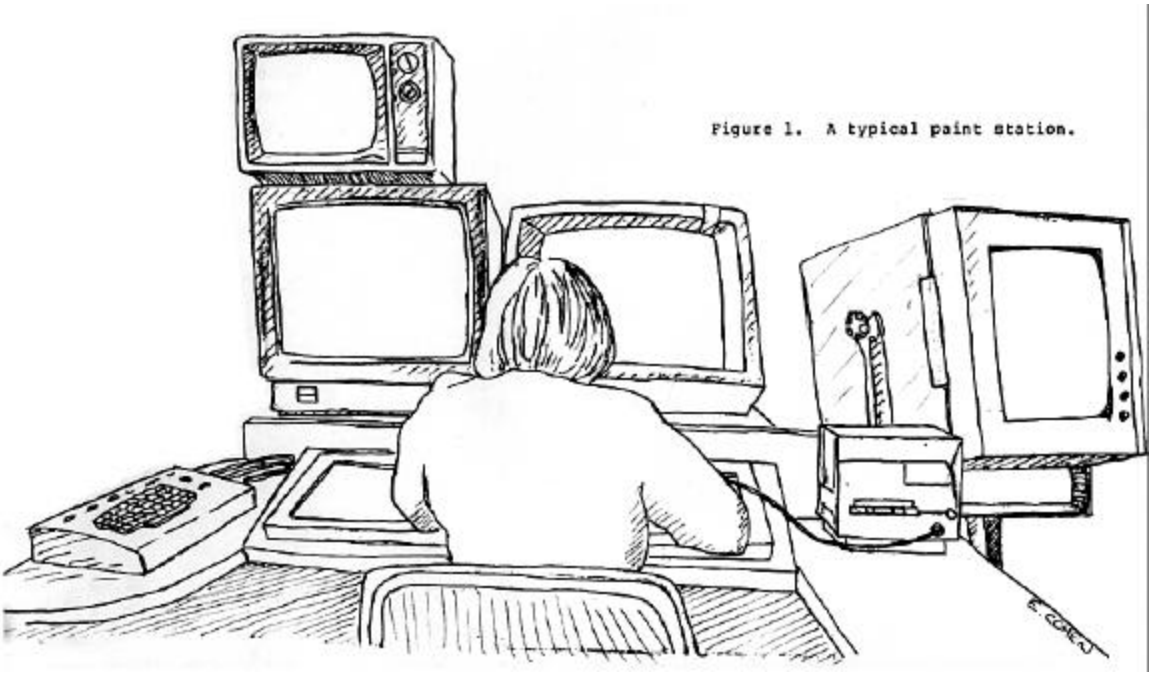

Figure 1. A typical paint station.

paint

create canvas
open canvas
delete canvas

select window
select grid window
display window
select & display
select & display grid

update window
update colormap
update transparency

display all
display all xparent

current window switch
state of the world

write all rough
write some rough

rotate
append
dissect

tablet mapping
transparency switch

exit

Figure 2. Bigpaint menu.

full paint
cycle paint
tint paint
value paint
picture paint
filter paint

sketch

pick brush
make brush

fill
tint fill

full clear
clear window

save picture
get picture

color maker
get colormap

palette
magnify
cursor
history

remove

run any program

redraw menu
exit

Figure 3. Paint menu.

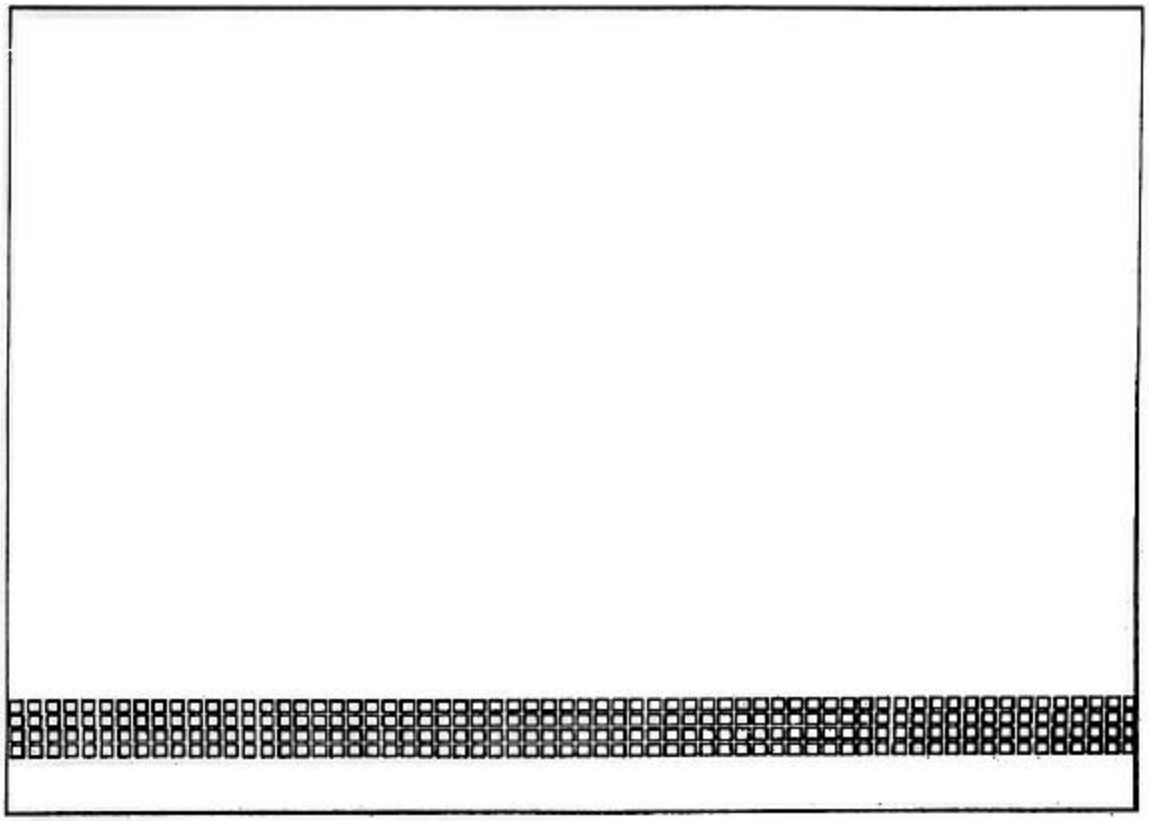

Figure 4. 256-color palette in a typical position.

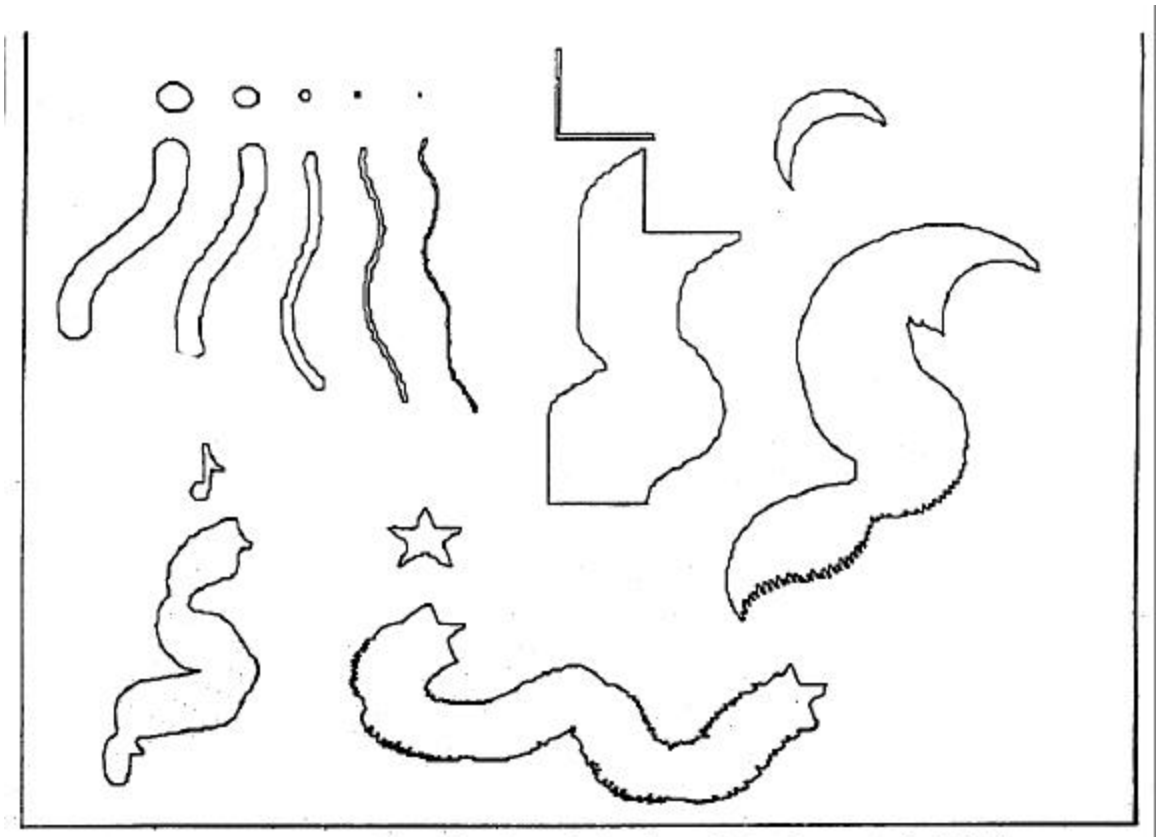

Figure 5. Several brushes and strokes created with them.

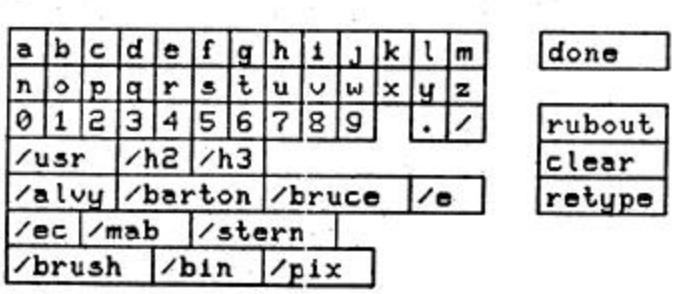

Figure 6. Virtual keyboard.

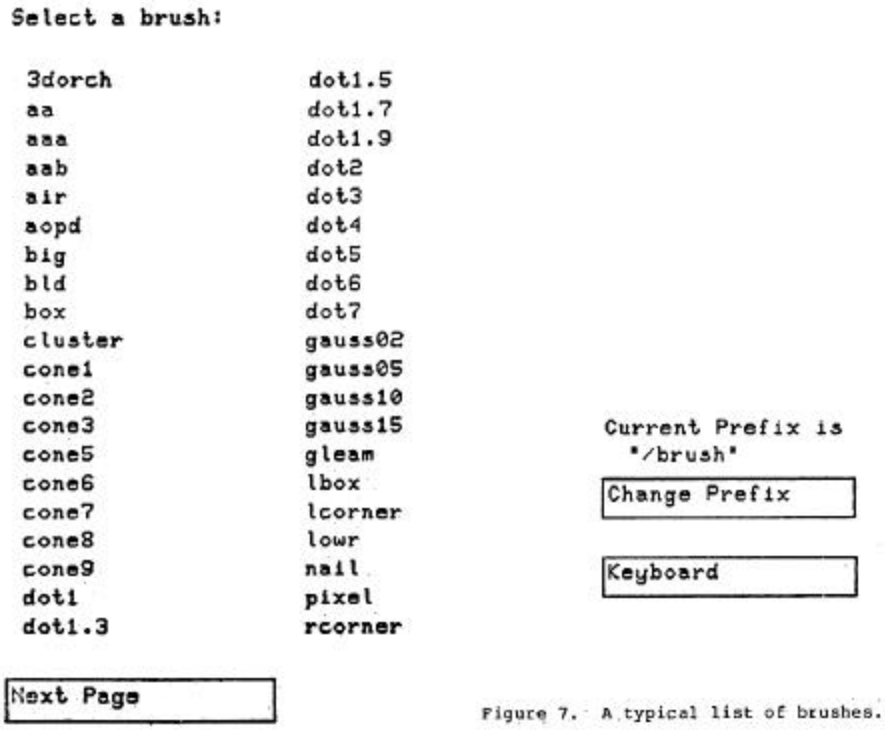

Figure 7. A typical list of brushes.

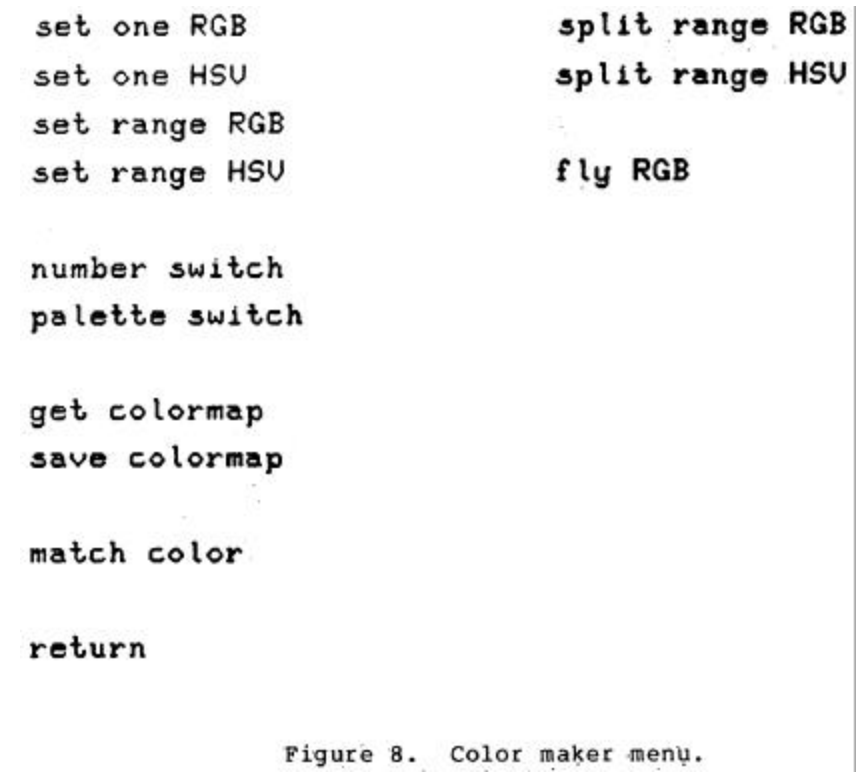

Figure 8. Color maker menu.

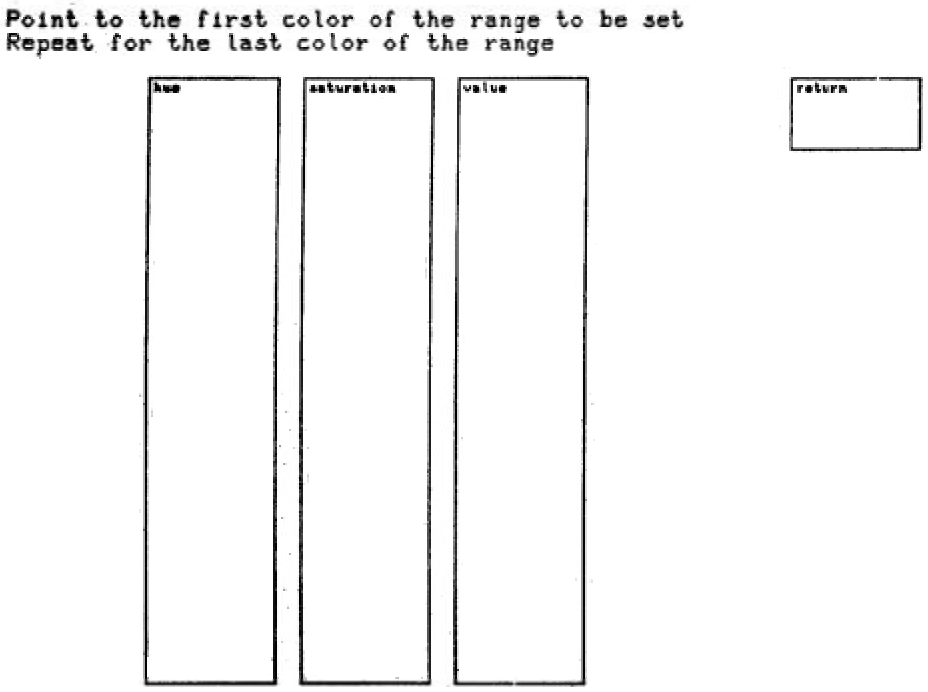

Figure 9. Sliders for setting color.

magnify off
magnify x2
magnify x4
magnify x8

constant magnify on
constant magnify off

Figure 10. Magnify menu.

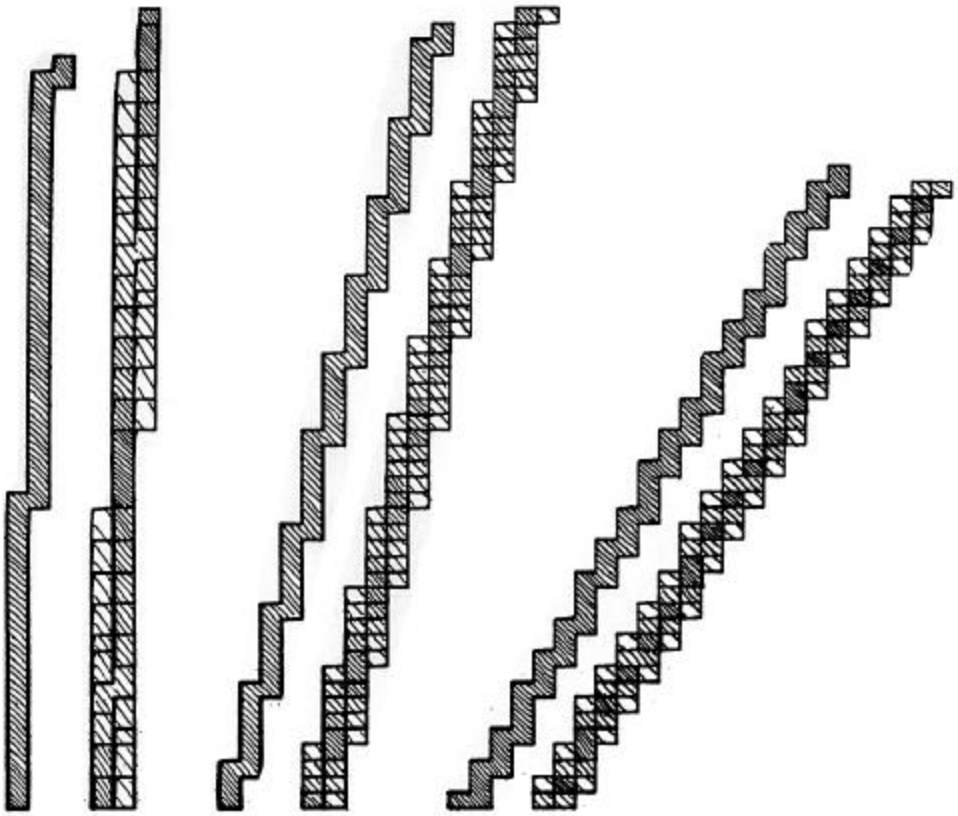

Figure 11. Rastered lines vs. antirastered lines.

smooth draw
smooth lines

change width

return

Figure 12. Sketch menu.

full palette
tint palette
value palette
standard palette
move palette

dot switch on
dot switch off
clear dots

Figure 13. Palette menu.

begin history
cease history
playback history
return

Figure 14. History menu.

Figure 15. Remove menu.

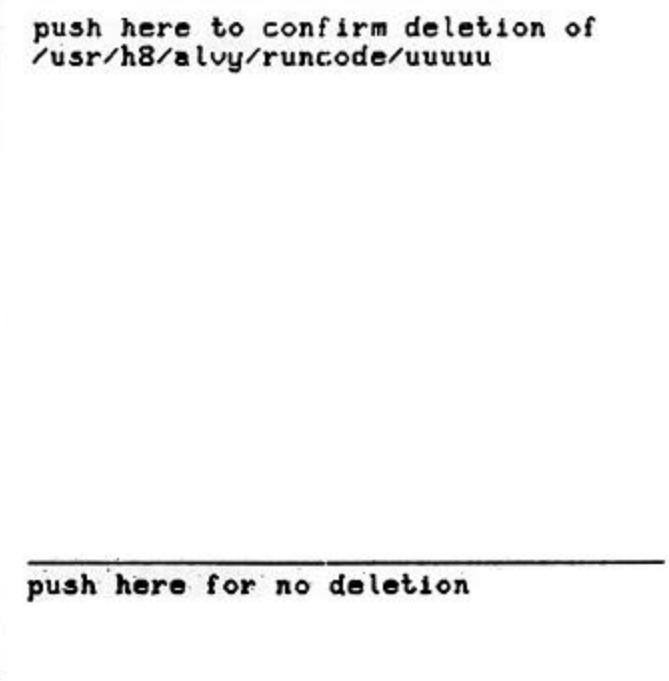

Figure 16. Confirmation menu.

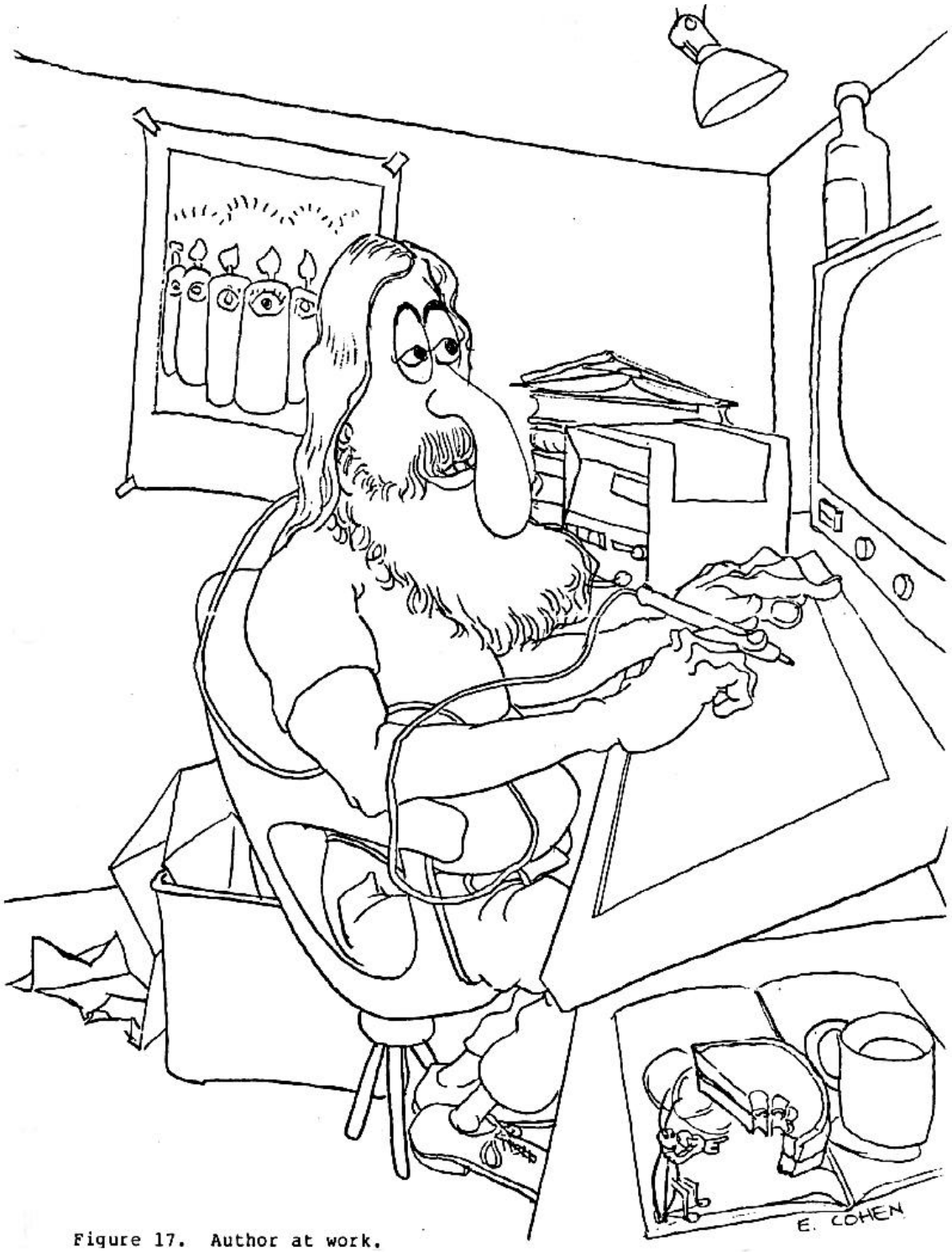

Figure 17. Author at work.