

Programming in PostScript

*Techniques and applications in vision research,
plus a survey of PostScript hardware and software*

Denis G. Pelli

MOST PEOPLE WHO use PostScript-driven printers have never seen a PostScript program because their application software generates and sends the necessary PostScript commands automatically whenever they say "Print." For routine applications, this is as it should be. However, programming directly in PostScript opens up many new possibilities, particularly for creating images from mathematical descriptions.

For instance, I use PostScript to produce patterns to help my study of the visual system. In this article, I will use some of those patterns to illustrate PostScript's power. I'll also list some useful PostScript products and services.

PostScript programming is best for those occasions where you begin by knowing only a mathematical description of an image and want to find out what the image would look like. This approach is old hat to anyone who has done computer graphics on a video display. Unfortunately, it is difficult and expensive to obtain an accurate photograph of what's on the screen, primarily because of the non-linearity and variability of photography. PostScript lets you get faithful renditions directly on paper.

Another attraction of PostScript is that you can debug and refine your picture-generating programs using a relatively low-cost (around \$5000) laser printer such as the Apple LaserWriter, which will produce fair-quality drafts (300 dots per inch) immediately for a few cents per page. For the final output, you can send the same program by modem to a \$60,000 printer like the Linotype L300,

which will produce superb quality prints (2540 dpi) for \$10 per page. The same program runs on both printers because PostScript is machine independent. (This article includes examples produced by both printers.)

Overview

PostScript is a full-fledged structured language. Like FORTH, it is stack oriented and uses postfix notation. For example, to add 2 and 2 you say 2 2 add. Each PostScript printer has a built-in microprocessor and a PostScript interpreter that will run your program. The page is represented by a bit map, with 1 bit per pixel. (PostScript incorporates some limited support for color, but none of the available printers supports color.) When the page is printed (usually by the showpage command), the bit map is transferred to the page, making each pixel either black or white. However, to preserve machine independence, you are not allowed to read from or write to the bit map. Instead, your program includes "painting" operators that set and clear bits within defined areas of the bit map.

PostScript offers three kinds of painting operators, allowing three quite different approaches to describing your image: one-dimensional paths, two-dimensional sampled images, and text. Before explaining the three kinds of painting, I should say a few words about an operation that can be applied to all three: digital halftoning.

Each pixel in a PostScript image is either black or white. PostScript produces the illusion of intermediate gray

levels by digital halftoning—breaking the image up into cells, each containing many pixels, and setting some of the pixels to white and the rest to black. If the cells are too small for the eye to resolve, the viewer will see a uniform gray, and the illusion will be successful.

You can adjust the size of the cell by the screen operator, which lets you specify how many cells per inch. When you request a particular gray level, PostScript will set approximately that fraction of the pixels in each cell to white and the rest to black.

Obviously, there's a trade-off here. You'd like to have very small cells so that the eye can't resolve them and the picture will look continuous. But if the cells are small, they will contain few pixels and you will have only a few possible gray levels.

Your gray levels will be coarsely quantized (approximated by the nearest available discrete level). In images where the gray level varies smoothly, such as in a person's face, coarsely quantizing the gray level will produce noticeable contours at the transition between gray levels.

Note that digital halftoning is quite new and the terminology has not yet settled. In particular, the word "dot" refers

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Denis G. Pelli is a visual psychophysicist studying the information rate of the human visual system. He is an associate professor at the Institute for Sensory Research, Syracuse University, Syracuse, NY 13244-5290.

to two quite different things. If the resolution of a printer is specified as "300 dpi," it means 300 pixels per inch. If a halftone image is "18.75 dpi," it means 18.75 halftone cells per inch. If the image is produced by digital halftoning, you can assume that each cell has many pixels. For example, nearly all the black-and-white continuous-tone images in BYTE have 120 cells per inch. Most of those images were produced by traditional halftoning, which does not involve pixels at all.

The faces below (see figure 2) were produced by digital halftoning with 120 cells per inch and 2540 pixels per inch, so each square cell contains $(2540/120)^2 = 448$ pixels. In principle, this would allow for 449 different gray levels (from 0 to 448 pixels set to white in each cell), but an undocumented limitation of PostScript is that the requested gray level is quantized to 8 bits, allowing, at the most, 256 different gray levels.

Paths

One of the fundamental design goals of PostScript is to be independent of the details—especially the dot resolution—of the particular printer used. To achieve and enforce this, PostScript does not let you ask any questions about the state

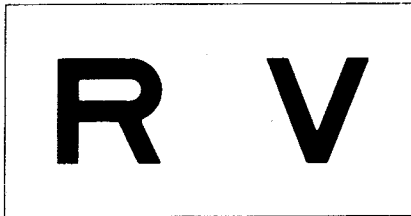


Figure 1: Two letters of the Sloan font for vision testing produced by listing 1 on a Linotype L300 at 2540 dots per inch.

(black or white) of the pixels that make up the page's image. Instead, you create an image by defining an area or "path" and then filling it.

A path is a series of lines and curves, like a line drawing. However, the path itself is not a drawing. To make an image, you must use a painting operator. The two painting operators that can be applied to paths are stroke and fill. Stroking a path produces an image on the page consisting of a line of specified thickness. (You can also specify the gray level, the kind of dashes for a dashed line, the type of line termination, and the shape of corners.) Filling a path causes areas that are inside the path to be painted with a specified gray level, without affecting areas that are outside. The meanings of "inside" and "outside" are obvious for a simple closed curve. For more complex paths, PostScript offers a choice of two different rules for determining which areas are inside and out.

Figure 1 was produced by stroking paths. The R and V are two of the ten characters (C D H K N O R S V Z) in the Sloan font, named after its designer, Louise Sloan. The Sloan font is recommended for vision testing (reference 1).

Obviously, if you are designing vision tests, it is helpful to be able to use the officially sanctioned font. Listing 1 shows the programs that I wrote to produce R and V. I wrote similar programs for the other eight characters in the Sloan alphabet. With some extra statements, you could make this a proper PostScript font, usable in any place where you would like to display text.

The first two statements in listing 1 are comments. Everything from a % to the end of the line is ignored. It is traditional for the first line of a PostScript program to begin with %! to help your computer identify it as a PostScript file. The third

line begins /preSloan, which pushes the name preSloan onto the stack. Then comes a procedure enclosed in braces that extends over several lines. PostScript treats spaces and carriage returns merely as separators. The procedure is compiled and pushed onto the stack as one item. After the closing brace of the procedure is the word def. That causes PostScript to pop the top two items from the stack and use these to define the word preSloan to refer to the given procedure. It does that by putting the word preSloan in a dictionary, with the procedure as the meaning. From now on, the word preSloan will invoke that procedure.

The following lines similarly define the procedures postSloan, R, and V. The line 50 700 moveto first pushes 50 onto the stack, then pushes 700 onto the stack. Then the operator moveto pops the top two items from the stack and moves the current location to that x-y coordinate. (The default coordinate system puts the origin at the lower left corner of the page and measures distance in "points," 72 to the inch, so the location [50,700] corresponds to [0.69 inches, 9.72 inches], which is 0.69 inches from the left margin and $11 - 9.72 = 1.28$ inches down from the top of the 8½- by 11-inch page.)

The 40 40 scale command amplifies the scale so that one unit corresponds to 40 points. R invokes the R procedure, which draws an R one unit wide and one unit high (where one unit is now 40 points). The R is made up of lines and arcs. It is all "clipped" by a unit square, set up in preSloan, so that only what falls inside the square appears in the final image. It is the same for V. Finally, showpage transfers the image to paper and ejects the page from the printer. You can send this program to any PostScript printer to obtain an image like figure 1.

Figure 2 was also produced by paths.

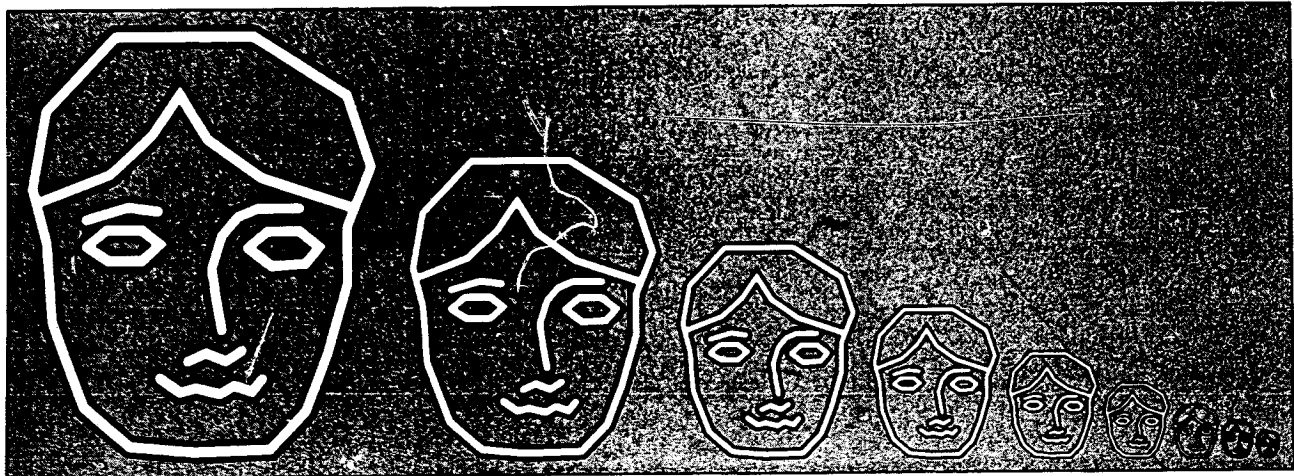


Figure 2: Faces for testing infant acuity produced by listing 2 on a Linotype L300 at 2540 dots per inch.

The face in the figure is designed for acuity testing of infants. When you can see anything at all, you can see that it's a face. The black and white lines making up the face disappear when they are too thin for the eye to resolve. The biggest face will disappear when you are about 24 feet away, depending on your visual acuity. The smaller faces will disappear at proportionally shorter distances. The smallest face will disappear at about 18 inches. The trick to making it disappear is to draw it with a ribbon consisting of equal parts of white and black, so that when the white and black are blended together by the eye, the resulting average is identical to the gray background (references 2 and 3).

Listing 2 gives the PostScript program used to produce figure 2. After a few comments the face procedure is defined; it consists solely of moveto and lineto commands that trace a path. The draw procedure is defined next. Then the whole page is painted gray.

The program is optimized for the Linotype L300 running at 2540 dpi. For best results at 300 dpi, such as on a LaserWriter, you should remove the % from the beginnings of two lines labeled "at 300 per inch" and place the % symbol at the beginning of the two lines marked "at 2540 dots per inch." The % causes the rest of the line to be treated as a comment—in other words, ignored. After you remove the % from each line, those lines will give you the best choice of screen density for a LaserWriter.

Note that this does not contradict the claim that PostScript is device independent. When you go from higher resolution to lower resolution, you have to make some trade-offs in coarseness of screen and precision of gray level. You can often get acceptable results by letting the PostScript printer make the trade-off itself, but if you understand the underlying issues, you can usually get better results by specifying exactly what you want. The two gray levels were found by trial and error to produce 50 percent reflectance on the two printers at these screen densities.

The main program is next. It consists of a loop 9{ . . . }repeat, which means that the procedure enclosed in braces should be repeated nine times. Inside the braces you will find the commands face, which lays down the path of the face, and draw, which paints the path, and the operators translate and scale, which shift and shrink the coordinate system to get ready for the next face.

To produce a black-and-white ribbon, the draw procedure must stroke the same path twice. This requires a trick, since

continued

Listing 1: *The PostScript program to produce R and V in the Sloan font.*

```
%!
% Produce Figure 1
/preSloan {gsave currentpoint translate 0.2 0.2 scale
  newpath 0 0 moveto 0 5 lineto 5 5 lineto 5 0 lineto
  closepath clip newpath 1 setlinewidth 2 setlinecap 0
  setlinejoin} def
/postSloan {stroke grestore 2 0 rmoveto} def
/R {preSloan 0.5 0.5 moveto 0 4 rlineto 3.5 3.5 1 90 270
  arcn -3 0 rlineto 4.44370 0 moveto -0.97547 2
  rlineto postSloan} def
/V {preSloan 0 6.34629 moveto 2.5 -6.25 rlineto 2.5 6.25
  rlineto postSloan} def
50 700 moveto
40 40 scale
R
V
showpage
```

Listing 2: *The PostScript program to produce the faces in figure 2.*

```
%!
% Produce Figure 2

% path of face
/face {39 210 moveto 108 210 lineto 155 181 lineto 167
  146 lineto 155 117 lineto 155 89 lineto 145 55
  lineto 134 27 lineto 116 8 lineto 78 7 lineto 46
  10 lineto 23 30 lineto 7 71 lineto 4 110 lineto -
  3 136 lineto 4 174 lineto 39 210 lineto 1 130
  moveto 36 143 lineto 57 162 lineto 71 182 lineto
  85 160 lineto 112 141 lineto 158 126 lineto 24
  121 moveto 45 127 lineto 60 125 lineto 24 108
  moveto 34 116 lineto 52 116 lineto 61 109 lineto
  52 101 lineto 35 101 lineto 24 108 lineto 105
  107 moveto 115 115 lineto 131 115 lineto 141 107
  lineto 134 99 lineto 117 98 lineto 105 107 lineto
  131 126 moveto 110 126 lineto 100 122 lineto 92
  113 lineto 87 97 lineto 89 83 lineto 92 67 lineto
  61 44 moveto 71 37 lineto 79 39 lineto 91 36
  lineto 98 40 lineto 107 37 lineto 112 43 lineto
  75 52 moveto 84 56 lineto 94 52 lineto 102 57
  lineto} def

% Draw high-pass ribbon
/draw { gsave 0 setgray stroke grestore gsave
  currentlinewidth 2 div setlinewidth 1 setgray stroke
  grestore newpath} def

% Set up screen, etc.
%120 currentscreen 3 -1 roll pop setscreen % at 2540 dpi
%0.69 setgray clippath fill 0 setgray % at 2540 dpi
30 currentscreen 3 -1 roll pop setscreen % at 300 dpi
0.58 setgray clippath fill 0 setgray % at 300 dpi
1 setlinecap
10 setlinewidth
30 560 translate

% Ever smaller faces across page
9{
  face
  draw
  190 0 translate
  .707 .707 scale
} repeat

showpage
```

PostScript-Related Products

Publications

- Colophon PostScript* newsletter (free). Adobe Systems Inc., 1870 Embarcadero Rd., Palo Alto, CA 94303, (415) 852-0271.
- Computer Shopper*, \$21 per year. The "Ask the Guru" column by Don Lancaster has occasional tidbits on PostScript. Computer Shopper, P.O. Box 1419, Titusville, FL 32781.
- Graphic Perspective PostScript* newsletter, \$40 per year. Ashley House, 176 Wickstead Ave., Toronto, Ontario, Canada M4G 2B6.
- PostScript Language Tutorial and Cookbook*, \$16.95, and *PostScript Language Reference Manual*, \$22.95, by Adobe (Reading, MA: Addison-Wesley, 1985).
- PostScript Supplement for the Linotype Series 100*, Version 38.0, 1985, revised May 15, 1986. Adobe Systems Inc.
- The PostScript Language Journal*, \$15 per year. Pipeline Associates Inc., 39 East Twelfth St., New York, NY 10003.

Software

- Applewriter/Laserwriter Utilities Package (ProDOS software), \$49.50. Synergetics, 746 First St., Box 809, Thatcher, AZ 85552, (602) 428-4073.
- AppleTalk PC Card, \$399. Apple Computer Inc., 20525 Mariani Ave., Cupertino, CA 95014, (408) 996-1010.
- Colophon 2 Images disk includes program and sampled image data to produce figure 3. \$12 including postage & handling. Adobe Systems Inc.
- Cricket Draw program, \$295. Cricket Software, 3508 Market St., Suite 206, Philadelphia, PA 19104, (215) 387-7955.
- SendPS 1.0 downloader program. Included on the Colophon 2 Images disk. Adobe invites free distribution of SendPS but forbids selling it without permission.
- Ehandler.ps 2.1 error break page handler program (free). Adobe Systems Inc.
- JustText program, \$195. Knowledge Engineering, G.P.O. Box 2139, New York, NY 10116, (212) 473-0095.
- MockWrite 4.3.2 desk accessory program, \$35, shareware. CE Software, 801 73rd St., Des Moines, IA 50312, (515) 224-1995.
- Onyx projection plate media. 3M Company, 6850 South Harlem Ave., Bedford Park, IL 60501.
- PC MacBridge Appletalk network interface board and LaserWriter utilities and network software for IBM PCs, \$350. Tangent Technologies Ltd., 5720 Peachtree Parkway, Suite 100, Norcross GA 30092, (404) 662-0366.
- Post-a-Matic 3.3z program, Canadian \$50, shareware. Peter Bennett, Graphic Presentation Charts, 23 Exford Dr., Scarborough, Ontario, Canada M1P 1L5, (416) 751-2727 home. CompuServe 76314.1670.
- PostHaste downloader program, \$50. Micro Dynamic Ltd., 8555 Sixteenth St., Suite 802, Dept. 2, Silver Spring, MD 20910, (800) 634-7638.
- TOPS. AppleTalk network fileserver for Macintoshes, \$149 per computer; for IBM PCs, \$389 per computer on an AppleTalk network. Centram Systems West, 2560 9th St., Berkeley, CA 94710, (415) 549-5900.

PostScript-compatible printers (more than 300 dpi)

- Agfa-Gevaert P400PS (400 dpi)
- CompuGraphic CG400PS (400 dpi)
- Linotype Linotronic L300 with PostScript RIP (up to 2540 dpi)
- Linotype Linotronic L100 with PostScript RIP (up to 1270 dpi)

PostScript-compatible printers (300 dpi)

- Apollo Domain/Laser 26
- Apple LaserWriter and LaserWriter Plus
- Dataproducs LZR-2665
- DEC PrintServer 40
- Diconix Dijit 1/PS
- Facit Opus 2E and 3 (with optional PostScript cartridge)
- Hanzon Data LP-5000
- ITT Qume Scrip TEN
- Laser Connection PS Jet (upgrade for existing printers, including HP LaserJet)
- NBI Model 908
- NEC SilentWriter LC-890
- QMS PS 800 and PS 2400
- Sun Microsystems LaserWriter
- Texas Instruments OMNILASER 2108 and OMNILASER 2115

stroking a path eliminates the path. The first command in draw is gsave, which saves the graphics state, including the path. Then the line width is set, the gray level is set to 0 (i.e., black), and the path is stroked. This produces a black line drawing of a face on the gray background. Next, the grestore command restores the graphics state, including the path but not affecting the image, which is not part of the graphics state. Now, after reducing the line width by half and setting the gray level to 1 (i.e., white) draw strokes the path again. This produces a white line running down the center of every black line. After the nine iterations of the main loop, the image is done. All that remains to put it on paper is to give the showpage command.

A reasonable question to ask at this point is: How did I obtain the sequence of lineto and moveto commands to produce the face? I could have drawn the face in pencil on graph paper and read off the coordinates. In fact, I obtained this sequence by using MacDraw to draw the face freehand. I then captured the PostScript output of MacDraw and cleaned that up using Post-A-Matic (a program that translates Macintosh's abbreviated PostScript to standard PostScript commands) and a bit of editing. A new program called Cricket Draw makes this much easier. (Further information on items mentioned appears in the text box at left.)

To test an infant's vision, I would print up many gray cards, each with a single face on either the left or the right. The testing technique is called "Forced Choice Preferential Looking." A person who can't see the test card looks at the infant's eyes and tries to guess on which side the face is by which way the infant is looking. By testing many times, you can determine how reliably the person observing the infant's eyes can guess where the face is. If the infant's eyes tell you where the face is, you can reasonably conclude that the infant can see the face (reference 4).

Sampled Images

The second way to produce an image in PostScript is to use the image operator and provide it with the gray level of the desired image at each point on a regular grid. The most obvious application of this would be to reproduce a photograph that has been sampled previously. Figure 3a is an example. Each sample from the photograph is imaged by a cell containing many pixels. The fraction of the pixels in the cell that are white determines the gray level. Figure 3a was produced by a Linotype L300 at 2540 pixels

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per inch. Figure 3b was produced by sending exactly the same program to an Apple LaserWriter Plus, which prints at 300 pixels per inch.

However, there is a more interesting application of the PostScript image command. You can use mathematics to synthesize an image that never existed before. Figure 4a is an example. By just looking at this pattern, you can perform a systems analysis of your visual system.

Any patch of the pattern is a sinusoidal grating, varying from white to black and back again. However, from left to right across the image, the fineness of the grating increases until it disappears. Similarly, from bottom to top the contrast of the grating decreases until it disappears. The lower the contrast of the grating, the higher the contrast sensitivity required to see it. If you follow any one bar in the image from the bottom up until it disappears, the height at which it disappears is the contrast sensitivity of your visual system for a grating of that fineness.

The fineness of a grating is usually specified as a spatial frequency—in cycles per inch, for example, where a cycle is a pair of light and dark stripes. However, the sensitivity of your eye depends not on the number of cycles per

inch but on the number of cycles per degree of visual angle subtended at the eye (try looking at the pattern from various distances), so for vision work it is preferable to specify spatial frequency in cycles per degree.

The outline of visibility of all the bars describes the sensitivity of your visual system over a wide range of spatial frequencies. Notice that the vertical bars when taken together form a hump, peaking in the middle and falling off toward the left and right. The falloff to the right is determined largely by the optical quality of your eye. The falloff to the left is determined by neural limitations of your eye. This outline of visibility explains many characteristics of vision, including many visual illusions.

Figure 4a was produced by the program in listing 3. After a few commands to set up the coordinate systems of the sampled image and the page, the equation for the image is supplied to the image operator. The equation is essentially

$$g = 0.5 (1 + 10^{-y} \sin 10^x),$$

where g is the desired gray level (i.e., re-

continued

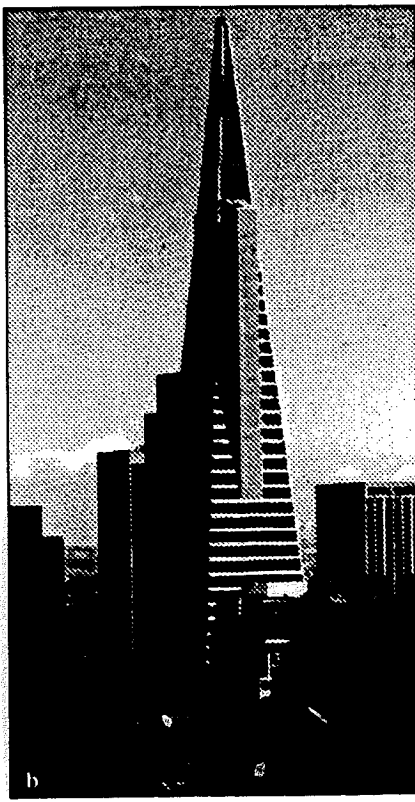


Figure 3: Digitized image of the San Francisco skyline. Program and image file courtesy of Adobe Systems Inc. (Included on the COLOPHON 2 IMAGES disk; see the text box.) 3a: Produced on a Linotype L300 at 2540 dots per inch. 3b: Produced on a LaserWriter Plus at 300 dpi.

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flectance), and x and y specify the position on the page. As x increases, the argument of the sine function, namely 10^x , increases more and more rapidly and the value of $\sin 10^x$ oscillates between -1 and $+1$ more and more rapidly. The program figures out the resolution of the printer and chooses the maximum spatial frequency (and thus the maximum value of x) accordingly. This is because proper representation of a sinusoid requires at least two samples per cycle. If the grating is so fine that fewer than two samples occur in each cycle (a pair of light and dark stripes), there will be a moiré effect, resulting in very broad stripes where there should be fine stripes.

The PostScript printers are not smart enough to take into account the content of your image in their efforts to print the image faithfully at whatever the printer's resolution happens to be. Thus, programmers must watch out for moiré effects. Figure 4a was produced by running listing 3 on a Linotype L300, at 2540 dpi and 127 cells per inch. Figure 4b was produced by running the same program on an Apple LaserWriter Plus at 300 dpi and 18.75 cells per inch. Note that figures 4a and 4b represent different

images because the program explicitly changed the image to best take advantage of each printer's resolution and avoid moiré effects.

This kind of image, a sinusoidal grating swept in frequency and contrast, was first produced by Fergus Campbell and John Robson at Cambridge University in the early sixties (reference 5). John Robson explained to me how they did it. They used two sawtooth oscillators to sweep the beam of an x - y oscilloscope in a vertical raster pattern, so that one vertical line took about 20 milliseconds and a whole frame took about a minute. The sinusoidal grating was produced by a sinusoidal oscillator connected (via a relay and capacitor) to the oscilloscope's intensity-control input.

Campbell and Robson produced the vertical fading in contrast by using a high-speed relay to quickly charge a capacitor to the oscillator voltage at the bottom of each vertical line and letting the capacitor discharge through a resistor as the beam swept upward. The horizontal variation in frequency (fineness of the grating) was produced by manually adjusting the frequency of a sinusoidal os-

continued

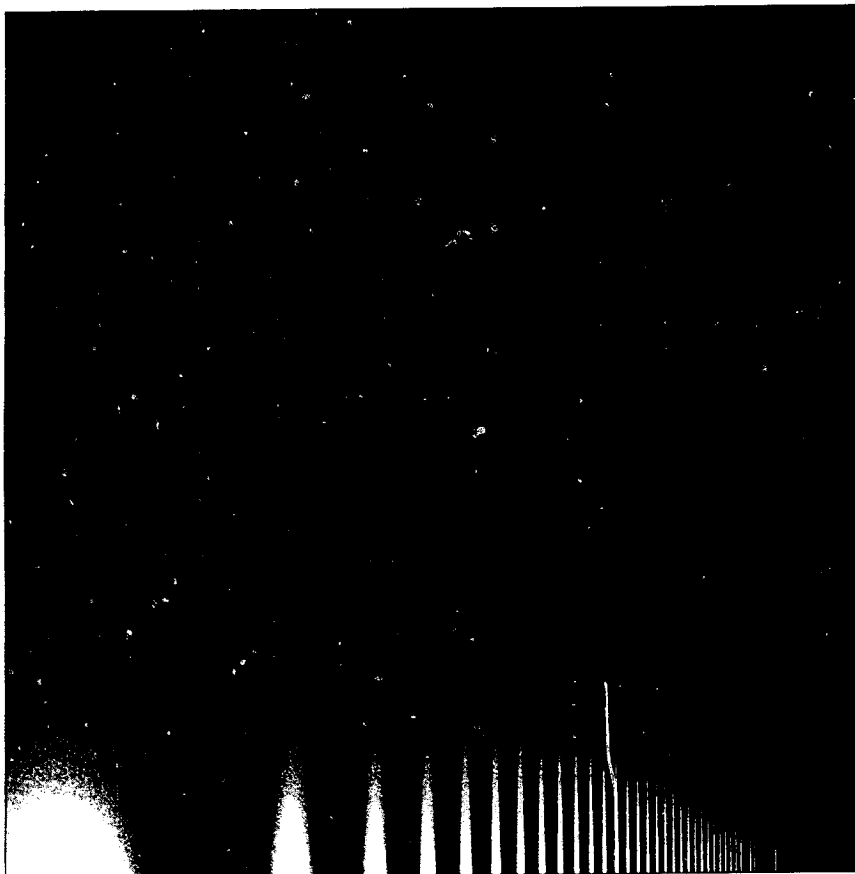


Figure 4a: Sinusoidal grating swept in frequency and contrast. Produced by listing 3 on a Linotype L300 at 2540 dots per inch and 127 cells per inch.

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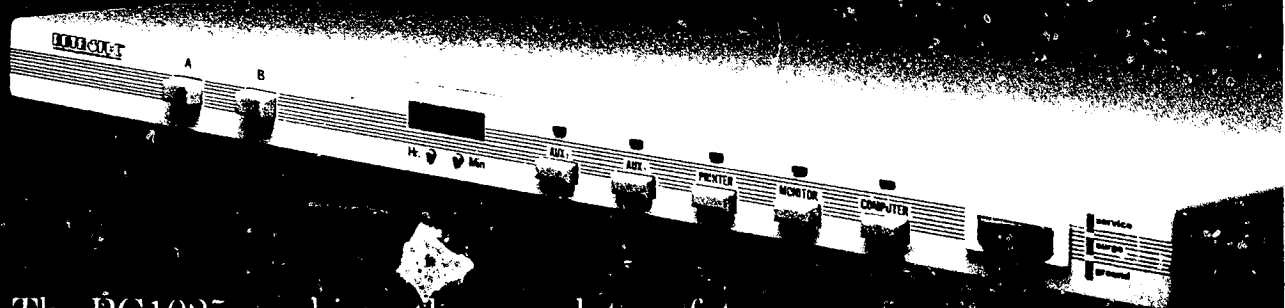
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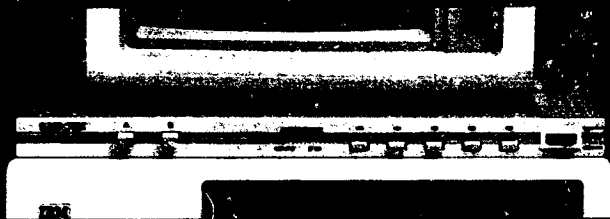
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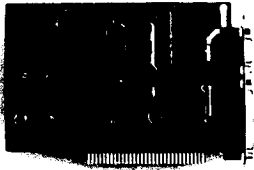
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POSTSCRIPT

Listing 3: The PostScript program to produce the sinusoidal grating test in figure 4a.

```
%!
% Produce Figure 4
/inch {72 mul} def
/width 4.54 inch def
50 400 translate
% make square image of desired width
width width scale
/dpi
  72 0 matrix defaultmatrix dtransform dup mul exch dup
  mul add sqrt
  def
/screen dpi 16 div def
screen 127 gt {/screen 127 def} if
screen currentscreen 3 -1 roll pop setscreen
% number of cells across image
/n width screen mul 72 div 2 sqrt mul 0.99 add cvi def
/nx n 2 mul def
/ny n 2 idiv def
/fbase 0.5 n mul 1.0 nx div exp def
/fa 360 nx div fbase ln div def
/c 1 def
/cbase 0.003 1.0 ny div exp def
/S nx string def

nx ny 8 [nx 0 0 ny 0 0]
{/c c cbase mul def /f fa def
  0 1 nx 1 sub {S exch f sin c mul 1.0 add 126.5 mul cvi
    put /f f fbase mul def} for
  S}
  Image

showpage
```

cillator as the beam swept across the screen.

Campbell read out the desired frequencies from a table, and Robson adjusted the dial. They recorded the image on film by taking a long-exposure photograph.

Working with Text

The third way to produce an image in PostScript is to use text.

PostScript makes it very easy to create characters of arbitrary size and rotation. In fact, the font machinery for producing text is built from the commands for producing paths. Each character is created by its own program. Typically, a program to produce a character creates a path and then fills or strokes it. However, because writing text is such an important use of PostScript, several things were done to make it easy and fast.

First, fonts are stored in special dictionaries inside the printer, with a little program for each character, and special commands are provided for specifying what font you want to use and at what size. Commands are also provided to produce a whole line of text from an

ASCII string, which is just a list of the desired characters. There are even facilities for kerning, or adjusting, the spacing between particular letter pairs, such as "TA," which looks best if the "A" is tucked slightly under the hat of the "T."

Second, it takes a lot of computation to run the programs corresponding to each character in a page of text. To alleviate this burden, whenever PostScript computes a character to paint it onto the page, it also saves a copy of the character's bit map in a special area of memory called the "font cache." If the character is needed again, PostScript retrieves it from the cache instead of computing it again. Naturally, the cached copy can be used only for the same character from the same font at the same size and rotation.

Figure 5 (produced by listing 4) is a simple example of the use of text. This is a test chart to measure visual acuity, much like one you might see in an optometrist's office. The letters are all at high contrast and get smaller and smaller until they disappear. The smallest letter that you can read is a measure of the resolution limit of your eye.

continued

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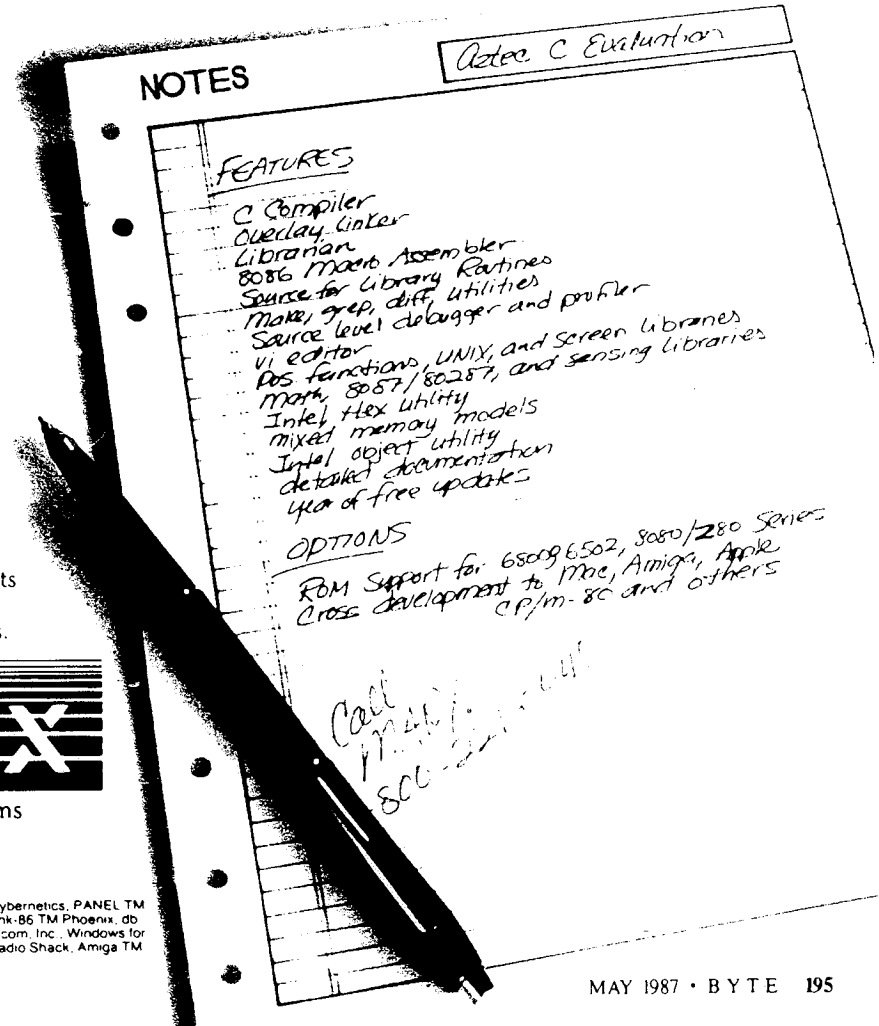
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Figure 6 (produced by listing 5) is a new kind of test chart. The letters are all the same size, but they vary in contrast, fading out until they disappear. The lowest contrast that you can read is a measure of the contrast sensitivity of your eye. The combination of acuity and contrast sensitivity results in a more complete assessment of the visual function of your eye than would acuity alone.

Incidentally, you may note a similarity between figure 4a and figures 5 and 6. In fact, the *finest* letter that you can read provides a useful estimate of the finest grating that you can resolve (the right edge of the hump in figure 4a), and the lowest contrast letter that you can read provides a useful estimate of your contrast sensitivity for gratings—the height of the hump in figure 4a (reference 6).

Figures 5 and 6 were produced by moving to a new location on the page for each character, setting the gray level, setting the font size, and printing the character by the show command. The programs are given in listings 4 and 5.

Note that figures 5 and 6 were produced with the Sloan font, which you won't have. The programs in listings 4 and 5 explicitly check to see if Sloan is

available; if not, they substitute Helvetica.

Tools for Programming in PostScript

First you'll need the *PostScript Language Reference Manual* and the *PostScript Language Tutorial and Cookbook*, both written by Adobe Systems, the company that invented PostScript and put it in the public domain. These clear, well-organized books are models for how manuals should be written, with a clear separation of the tutorial and reference functions. The tutorial has lots of real examples, and the reference manual is organized alphabetically.

You'll also need a computer with a plain text editor (to write your program) and connection to a PostScript printer. Your computer won't be doing much, just sending your program to the printer and receiving any messages from the printer. It's the printer that interprets and runs your program.

The simplest way to connect any computer to a PostScript printer is by a serial line, using any simple communication program. However, most users do not

continued

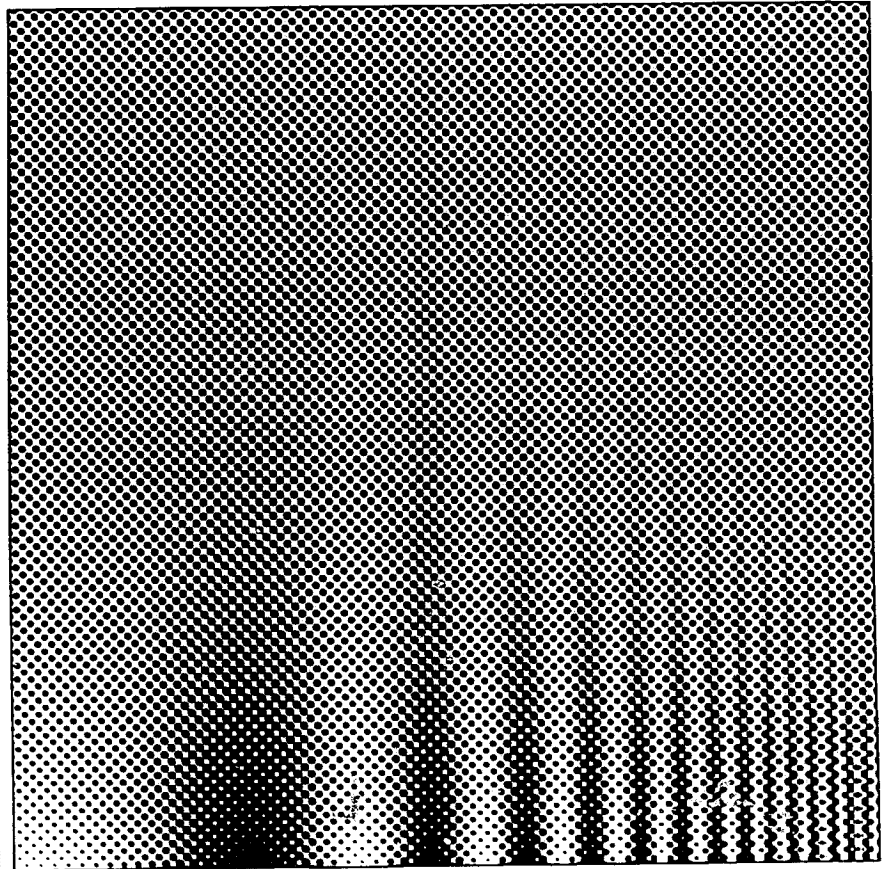


Figure 4b: Sinusoidal grating printed at 18.75 cells per inch on a LaserWriter Plus.

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own a PostScript printer. Typically, they share one over a network. This arrangement requires that you use a downloader program to send your PostScript program (a text file) via the network to the printer. A good downloader should also be able to receive, display, and save any messages sent back from the PostScript printer.

Receiving messages from the printer is very important; otherwise, you'll only know when your program crashes by the fact that no paper comes out of the printer. I debugged my first few PostScript programs that way, running to the other room, waiting to see if I got any output—usually I didn't—and walking back to edit my program a bit and trying again. It's reminiscent of using the toggles on a PDP-11/20 to program in machine code—obviously something best left to "real programmers," as no sane person would enjoy such a tedious procedure.

If you can't receive messages from the printer, a less convenient solution is to use Adobe's free "error break page handler," a PostScript program you send to the printer once. From then on (until you reset the printer), when any program crashes you'll get a printed page showing the error message, the offending command, and a peek at what's on the stack. However, this still requires running back and forth between your computer and the printer.

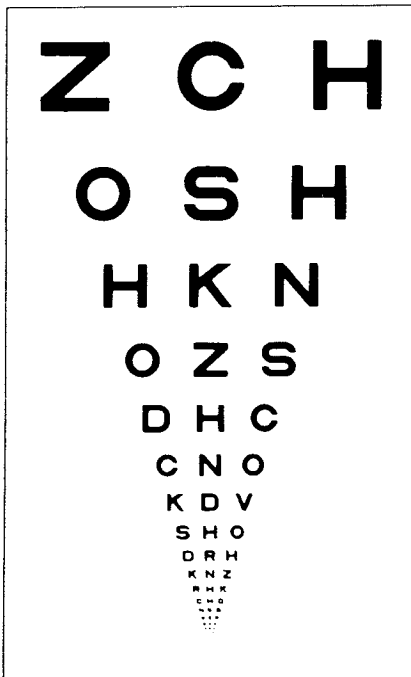


Figure 5: Conventional acuity chart produced by listing 4 on a Linotype L300 at 2540 dots per inch.

Several good downloader programs are now available for the Macintosh. The best one is free. SendPS from Adobe Systems will send your program over AppleTalk to the Apple LaserWriter. It will also receive any messages sent back over AppleTalk from the printer, show them to you as they arrive, and automatically store them in a file for your later perusal. You can also ask for a report on the status of the printer at any time, and you can initiate a remote reset of the printer. SendPS doesn't include a text editor, so you'll need one. (I recommend the shareware desk accessory MockWrite.) PostHaste and JustText have all the features of SendPS (except showing messages as they arrive), plus built-in multiwindow editing, and JustText comes with extra programs that convert MacPaint, ThunderScan, and MacVision files into PostScript.

Cricket Draw, from Cricket Software, lets you edit and download a PostScript program but does not receive messages from the printer. Its main attraction for the PostScript programmer is that it lets you make a MacDraw-like drawing (or read in a MacDraw file) and convert it into pure PostScript. It has a handy PostScript help function that lets you look up a brief explanation of any PostScript operator—moveto, for example.

One feature I'd like to see in future PostScript downloaders is an %%include: filename statement that would indicate to the downloader that another file (e.g., containing your favorite subroutines) should be included when the program is downloaded. This is a standard feature of most modern languages, but PostScript lacks it and thus deprives the programmer of many of the main advantages of modular programming. You have to put everything in one file, making nontrivial PostScript source files unreasonably long and making it difficult to keep all your copies of a given subroutine up to date.

At present, much less software is available for PostScript downloading for non-Macintosh computers. Synergetics sells some utilities for programming in PostScript on an Apple IIGS, IIc, or IIe. Several companies offer hardware and software (see table 1) to connect an IBM PC-compatible to an AppleTalk network; some of these products let you receive messages from the printer. Now that IBM has endorsed PostScript for use in its future desktop publishing products, things are bound to improve for IBM PC users.

Many computer companies, such as Digital Equipment Corporation and Sun Microsystems, are bringing out new PostScript printers and providing them

with interfaces to connect to computers from those manufacturers. (A list of PostScript printers appears in the text box on page 188.) Most of the existing and forthcoming printers have 300-dpi resolution, like the Apple LaserWriter.

Linotype makes two high-resolution *continued*

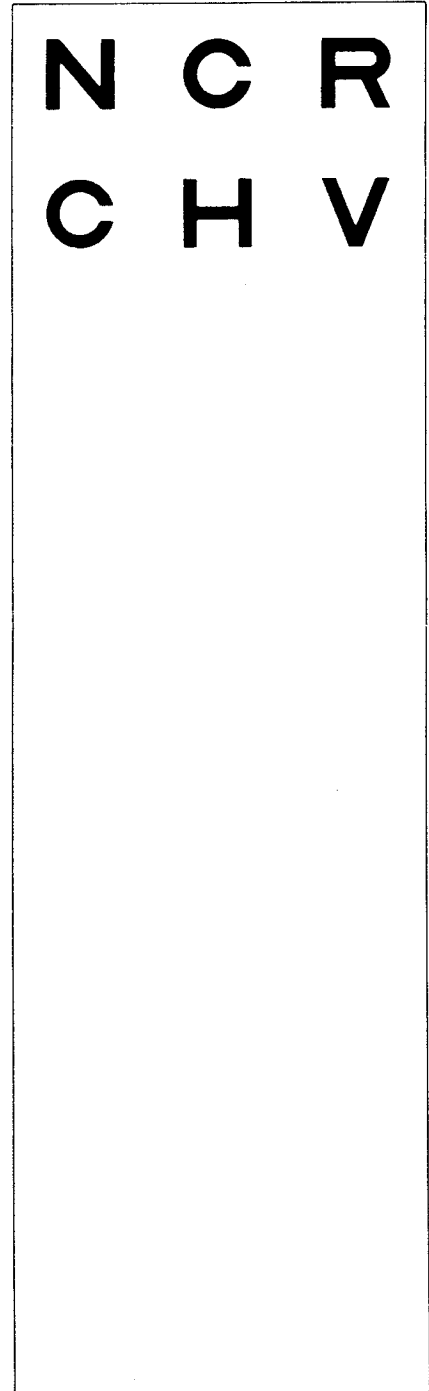


Figure 6: Pelli-Robson Letter Sensitivity Chart produced by listing 5 on a Linotype L300 at 2540 dots per inch. Copyright 1987 by Denis G. Pelli.

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*hard disk recommended

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Listing 4: The PostScript program to produce the conventional acuity test chart in figure 5.

```
%!
% Produce Figure 5
50 750 moveto
/width 250 def
/size width 6 div def
/cuberoot2 2 1 3 div exp def
width 2 div size -1.5 mul rmoveto

/showrow
{gsave
FontDirectory /Sloan known
{/Sloan findfont size scalefont setfont}
{/Helvetica findfont size 1.8 mul scalefont setfont}
ifelse
dup stringwidth pop -2 div 0 rmoveto
show
grestore
/size size cuberoot2 div def
0 size -2 mul rmoveto
} def

(Z C H) showrow (O S H) showrow
(H K N) showrow (O Z S) showrow
(D H C) showrow (C N O) showrow
(K D V) showrow (S H O) showrow
(D R H) showrow (K N Z) showrow
(R H K) showrow (C H O) showrow
(N K S) showrow (C Z R) showrow
(S O K) showrow (D N C) showrow
(C H D) showrow (R O H) showrow
(S N D) showrow (O C H) showrow
(Z H K) showrow (C V H) showrow
(V N Z) showrow (S C K) showrow
(N D C) showrow (C N D) showrow
(O V N) showrow (Z H V) showrow
(H S K) showrow (D N O) showrow
(N S K) showrow (D C Z) showrow
(V H K) showrow (S K V) showrow
(V R K) showrow (V R S) showrow
(K Z N) showrow

showpage
```

PostScript-compatible printers, the L100 (\$35,000) with a maximum resolution of 1270 dpi, and the L300 (\$60,000) with a maximum resolution of 2540 dpi. Linotype calls them its Series 100 printers. Oddly enough, the resolution of these computerized printers must be set manually, to 615, 1270, or (on the L300) 2540 dpi.

The 300-dpi LaserWriter is fine for drafts, and the 2540-dpi L300 will produce excellent final prints on either Kodak RC (resin-coated) paper or film. (3M has just announced a polyester plate called onyx that can be exposed on the Linotype L100 or L300 and used as a plate on small duplicator presses to print up to 25,000 copies.)

My experience is that the L100 is useless for halftoning because any gray areas that you print will have dark streaks every inch or so down the page. Appar-

ently, this is a result of the many stops and starts during printing and of the L100's poor paper handling when compared with the L300. (The dark streaks seem to be due to enlarged dots. It's only a problem for halftones and bit maps. Solid black and white areas, even fine text, are not noticeably affected.) Prices for using the L100 and L300 are similar, about \$10 per page, so use the L300.

Table 1 lists the print shops I know of that will run PostScript jobs on Linotype L300 printers. All will accept job submissions by modem or on a Macintosh disk. They typically charge \$10 per page (plus postage) and try for, but do not promise, one-day turnaround. I always ask to have my printout sent by express mail. (I've only used MacTypeNet, and I'm happy with its service, though it doesn't always achieve one-day turnaround.)

Some Linotype print shops will charge extra or refuse to run jobs that take many hours. For example, figure 4a took seven hours on an L300, and I was told, "Never again!" However, the Adobe books give no information about timing. Some of my jobs take only slightly longer to run on the Linotype than on the LaserWriter; others take much longer.

I find that I can get an upper bound on Linotype run time by measuring how long the job takes on the LaserWriter and multiplying by the factor by which the number of pixels will be increased. For instance, if the job takes 1 minute at 300 dpi on the LaserWriter, it might take up to $(2540/300)^2 = 72$ times as long (i.e., 72 minutes) at 2540 dpi on the L300. This is because the LaserWriter (and the LaserWriter Plus) and the Linotype L100 and L300 all use the Motorola 68000 microprocessor.

However, I've just learned that Linotype plans to upgrade the ROMs in all the Linotype L100 and L300 printers to PostScript version 42.5 soon. Apparently, this upgrade speeds up printing a lot, ranging from a factor of 1.5 times faster for printing noncached fonts to a factor of nearly 20 for bit-mapped images.

An odd deficiency of PostScript, given that it is a device-independent page-description language, is that it lacks any general device-independent way to describe the size of the page. To obtain nonstandard page sizes on the Linotype printers (up to 11.7 inches by 25.7 inches at 1270 dpi, less at 2540 dpi), you need to use a special operator, `setpageparams`, which is documented in a supplementary manual for the Linotype printers (see the text box on page 188).

PostScript Displays

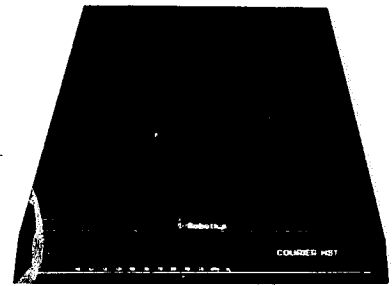
Sun Microsystems recently announced a machine-independent standard for windows, called NeWS (Network/extensible Window System), which is based on building a PostScript interpreter into each window. What is to be displayed in a window is transmitted to the window as a PostScript program. NeWS is good for networking because you can easily load into the window a PostScript program that will interpret other window protocols, such as MIT's X windowing protocol, thus making NeWS highly compatible. NeWS will be a boon to PostScript programmers because it will let them try out their programs quickly on any display supporting NeWS, without waiting for a printer.

Debugging

The error messages from PostScript are quite specific and helpful, particularly

continued

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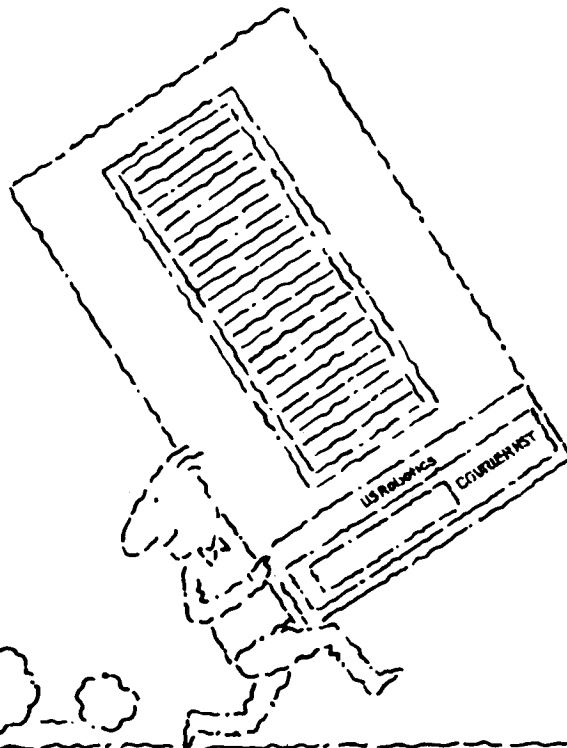
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Listing 5: *The PostScript program to produce the Pelli-Robson Letter Sensitivity test chart in figure 6.*

```

%!
% Produce Figure 6
50 750 moveto
/width 250 def
/size width 6 div def
width 2 div size -1.5 mul rmoveto
FontDirectory /Sloan known
  {/Sloan findfont size scalefont setfont}
  {/Helvetica findfont size 1.8 mul scalefont setfont}
  ifelse
/dpi
  72 0 matrix defaultmatrix dtransform dup mul exch dup
  mul add sqrt
  def
/screen dpi 16 div def
screen 127 gt {/screen 127 def} if
screen currentscreen 3 -1 roll pop setscreen
/c 1 def

/setcontrast {1 sub neg setgray} def

/showrow
  {gsave
  dup stringwidth pop -2 div 0 rmoveto
  c setcontrast
  show
  grestore
  /c c 2 div def
  0 size -2 mul rmoveto
  } def

(N C R) showrow (C H V) showrow
(Z R H) showrow (S H N) showrow
(V D K) showrow (N K Z) showrow
(S Z O) showrow (R D N) showrow
(R Z S) showrow (Z R N) showrow

showpage

```

Table 1: *Print shops that output PostScript jobs on Linotype L300 printers.*

Company	Location	Telephone
Ampersand Typographers	Toronto, Canada	(416) 422-1444
Cobb Typesetting	Cincinnati, OH	(513) 241-1146
Design North Inc.	Racine, WI	(414) 762-1320
Desktop Publishing Inc.	San Rafael, CA	(415) 258-0767
MacTypeNet	Livonia, MI	(313) 477-2733
National Colorite Corp.	New Berlin, WI	(414) 784-8980
ProTypography	Chicago, IL	(312) 266-8973
Typesetting Services Corp.	Providence, RI	(401) 421-2264

because all the PostScript operators do extensive type and range checking of their arguments and give out a specific error message if they don't like them.

PostScript has several "print" commands that are helpful in debugging. They do not put ink on paper—instead, they send a message back to the host. (To put ink on paper, you say showpage.) One especially useful print command is ==, which will print whatever is on the

top of the stack. What's great about that is that anything can be put on the stack, even a compiled procedure, and == will uncompile it and print it out for you. It took me a while to realize just how useful printing is, since the Adobe books don't say much about debugging.

Incidentally, there are bugs in the PostScript interpreters (version 38.0) resident in the PostScript printers. For example, I discovered that stroking very

large arcs can get a PostScript printer so confused that all subsequent jobs fail with a limit-check frame device error until you reset the printer. Adobe has acknowledged the bug and promises to fix it in a future release of the PostScript interpreter. The PostScript operator version returns a string with the version number of the interpreter.

Wrapping Up

You might find four periodicals interesting. Don Lancaster's "Ask the Guru" column in *Computer Shopper* has clever ideas for nonobvious uses of PostScript and the LaserWriter. *Colophon* and *Graphic Perspective*, glossy newsletters illustrated with fancy PostScript illustrations, often include program listings. Finally, the *PostScript Language Journal* will publish its first issue about the time you are reading this.

PostScript isn't really meant for programming, but it is very handy as a programming language to create images from mathematical descriptions. It offers various ways of describing your image, a high degree of machine independence, the possibility of debugging on moderately priced, widely available printers, and final printing at 2540 dpi for \$10 a page. PostScript makes it easy to produce images on paper that would be difficult or impossible to produce otherwise. ■

REFERENCES

1. NAS-NRC Committee on Vision (1980) Recommended Standard Procedures for the Clinical Measurement and Specification of Visual Acuity. *Advances in Ophthalmology*, volume 41, pages 103-148.
2. Howland, B., A. Ginsburg, and F. W. Campbell. "High-Pass Spatial Frequency Letters As Clinical Optotypes." *Vision Research*, 1978, volume 18, pages 1063-1066.
3. Dobson, V., and D. Y. Teller. "Visual Acuity in Human Infants: A Review and Comparison of Behavioral and Electrophysiological Studies." *Vision Research*, 1978, volume 18, pages 1469-1484.
4. Harris, S. J., R. M. Hansen, and A. B. Fulton. "Assessment of Acuity in Human Infants Using Face and Grating Stimuli." *Investigative Ophthalmology & Visual Science*, 1984, volume 25, pages 782-786.
5. Ratliff, F. *Mach Bands: Quantitative Studies on Neural Networks in the Retina*. San Francisco: Holden-Day Inc., 1965, page 156.
6. Pelli, D.G., G.S. Ruben, and G.E. Legge. "Predicting the Contrast Sensitivity of Low-Vision Observers." *Journal of the Optical Society of America*, volume A3, page P56.