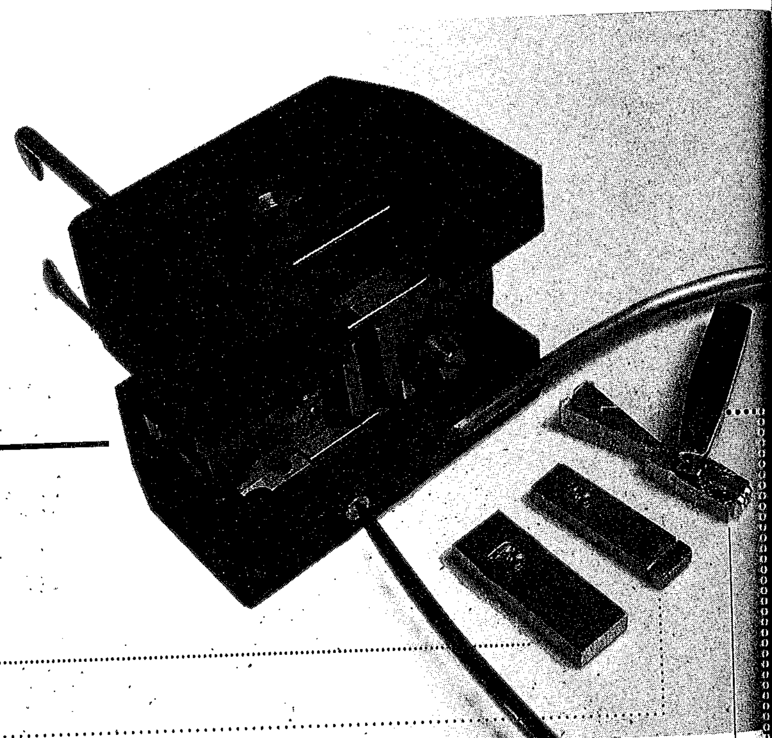


French-style type hand-casing mould.
From left to right:

mould assembled

copper matrix struck from punch

matrix justified

cast type (with tang)

steel punch

The Digital Typefoundry

Matthew Carter

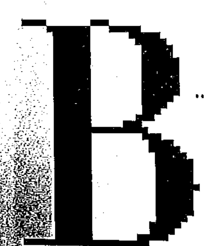
Guest Editor's Note

This article is based on a talk given at Stanford University in 1983 at a seminar for the Association Typographique Internationale (ATypI). It describes the first all-digital type foundry, Bitstream, established in 1981. Outlines, rasterizing, bitmaps, optical sizes, weight gradations, low resolutions, optical alignment, pixel editing, grayscaling and other processes and problems associated with digital fonts today are discussed in this early, unpublished 1985 essay by one of the founders of Bitstream. We thank the Cary collection for providing scans of the manuscript and images.

Charles Bigelow

Keywords

font design, typography, letterform, software design, splines, bitmaps



Upper case Didot "B", the font used for titles in this journal, set at 12' in a 300 dpi bitmap file in Photoshop, enlarged here 1000% as an example that the issues discused in this article are still applicable.

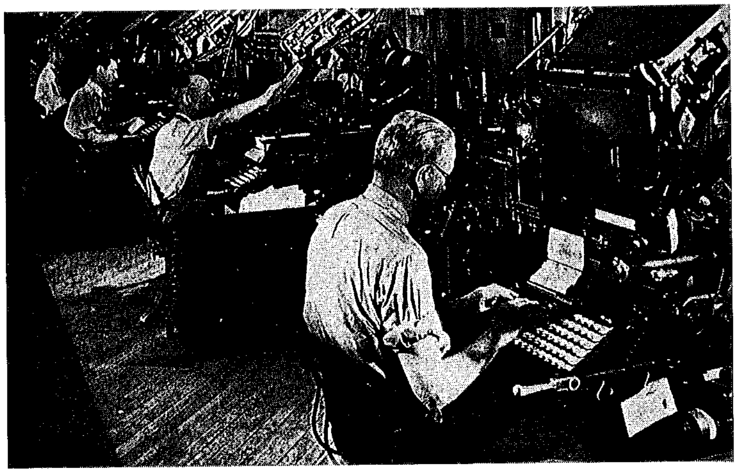


Figure 1

We are nearing the end of the natural life of the typesetting machine as we know it at present [1986]. Its death knell has been sounded by the recent improvement in computers which have become smaller, faster, and more capacious as the cost of their memories has dropped. Typographic computing used to be a matter of manipulating rectangular areas within a larger area - the page - like laying tiles on a floor. Now the same area can be filled with fine sand and every grain controlled independently.

Conventional typesetting systems are really only glorified word processors. The typeset image - the result of the process - is only visible at the end because the type font - the image source - exists only in the output device at its final output resolution.

As soon as the controlling computer is itself fast enough and powerful enough to handle type not just as anonymous characters with separate instructions as to style, size and position but as fully formed images of letterforms, then the font migrates forward from the output device into the heart of the system, the computer. And then type can be seen: played out on a screen or on a non- impact printer before it goes to final output on plotter or platemaker. If you can see it, you can design it. The implication of access to the image in such a system is obvious to the page designer.

Raster image processors (RIPs for short), these controlling computers, have the interesting characteristic that because they deal with images at final resolution they are indifferent to what those images are. They can be type, 2 point, 2 inches, 2 feet; they can as well be line art , half-tones, color separations - in fact any two-dimensional digitally expressed graphic. The RIP sends a stream of digital information to the plotter. It is the separation of the RIP from the plotter that is the key to the integration of text and graphics that is changing our ideas of how words and pictures reach paper, or screen tube.

Imaging systems that handle digital type in final resolution come in many forms: imagesetters for the graphic arts, control screens, printers for office automation and demand publishing, videotex decoders, slide generators, computer-aided design and artificial intelligence workstations, and personal computers.

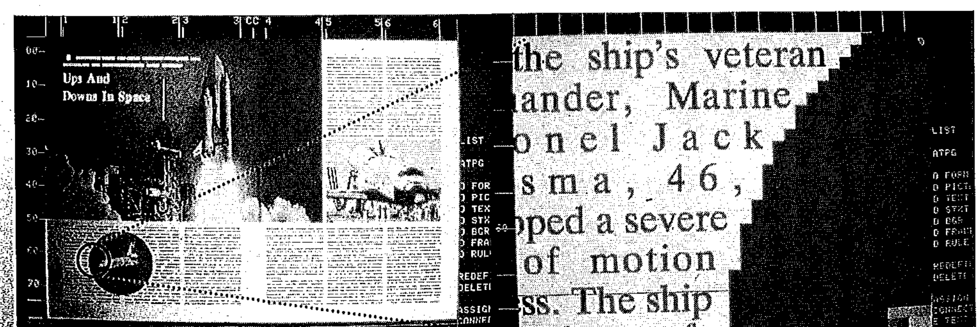
As far as anyone knows, the typefounder' s mold was invented by Gutenberg. Its product was cast type. For over 400 years, page make- up consisted of assembly character by character.

The industrialized mold was a late 19th-century invention. Its product was a line of type from a slug-caster. Page make-up now meant assembly line by line (see *Figure 1*).

A phototypesetter produces galleys. For the last 25, years page make-up has meant assembly galley by galley.

Finally, a laser plotter, a machine which places very fine dots very accurately on film, is used to produce a complete page. a broadsheet newspaper page for example, which can be set in under two minutes; text type, display type, line-art, half-tone and scanned-in type are set at a single pass. There is no longer a distinction between type and illustration, between cast type and woodcut, between slug and engraving, and between galley and half-tone negative: these are now integrated in the RIP, in the bitstream fed to the plotter and on the output film.

The output from a RIP can be directed to the control screen of a Scitex Vista terminal where a double-page magazine spread can be formatted. The first element to be put in place on the page is a large full-color illustration chosen from a selection displayed on a secondary screen. The area of the illustration is defined by the cursor. When it is in position, it can be sized and cropped. When the other illustrations are in place, the text stream (from an Atex) is flowed into the available column space, even run around the illustrations if desired. At a large scale, the headline is readable while the text is a simulation. By zooming in on a particular area, the smaller sizes of type become readable. A close up shows the text face run around the illustration.

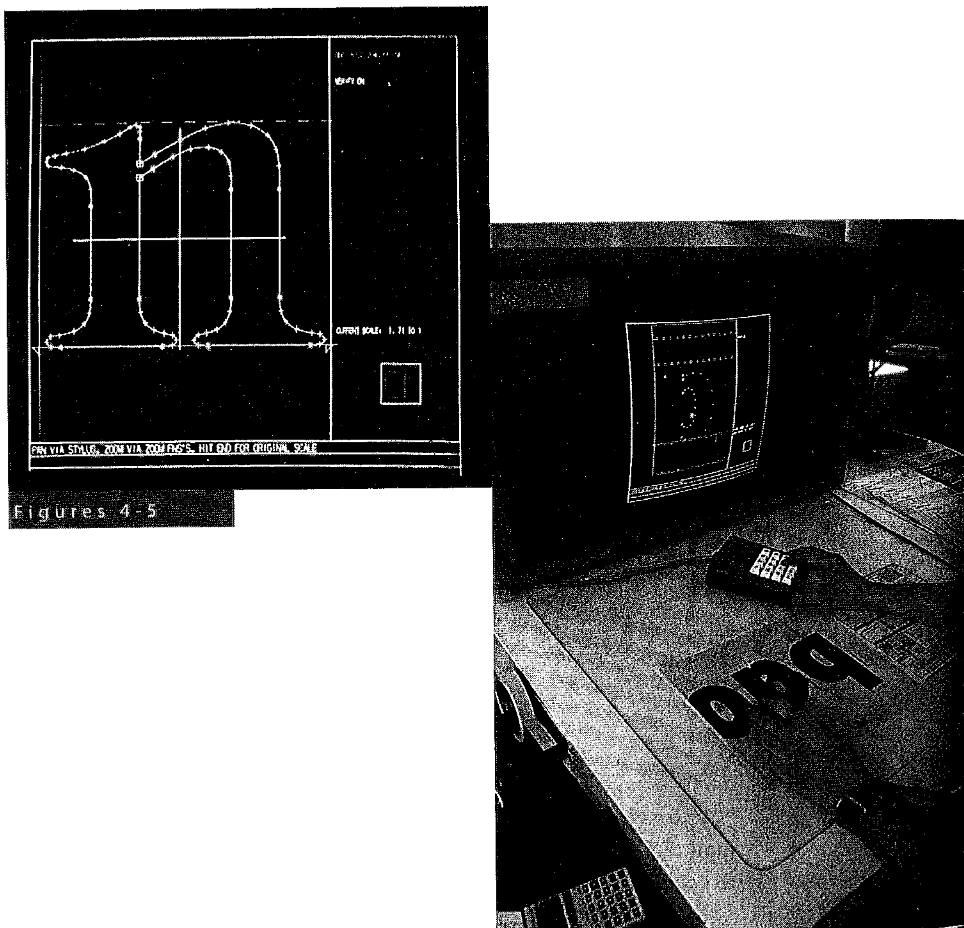


Figurse 2-3

A couple of short lines in Figure 2 and the detail in Figure 3 show that the justification program has letterspaced the type – something an editor or designer might revise at this stage.

Bitstream is a "digital typefoundry"; the phrase is Chuck Bigelow's and is useful to describe a company that makes digital type but not hardware (in the same way that typefoundries sold cast type but not typesetters) as distinct from equipment manufacturers who also make type. Bitstream has six Camex LIP workstations (interactive type design terminals with their own microprocessors). The underlying functional software was written at Camex with much subsequent enhancement by Bitstream's own programmers.

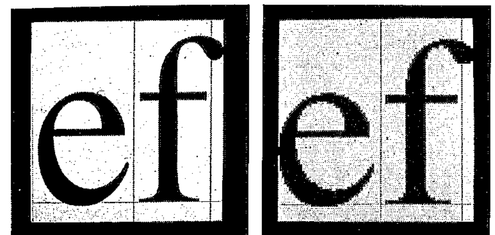
We don't scan characters; we input them through a digitizing tablet with a resolution of 4320 x 4320 lines to the em. This method allows the designers to do any necessary editing of letter shapes at the input stage, while seeing the results on the monitor. We mark significant points around the outline of the character and connect them with straight line segments and circle arcs which are easy to manipulate mathematically and to store. There are many useful software tools and routines available to the designers.



Figures 4-5

It used to take a good three hours to design a letter with pencil on paper, with most of the time spent on execution rather than thought. A well programmed computer workstation, such as the Camex LIP, can drastically reduce the time taken to capture the letterform – to an average of 25 minutes per character at Bitstream.

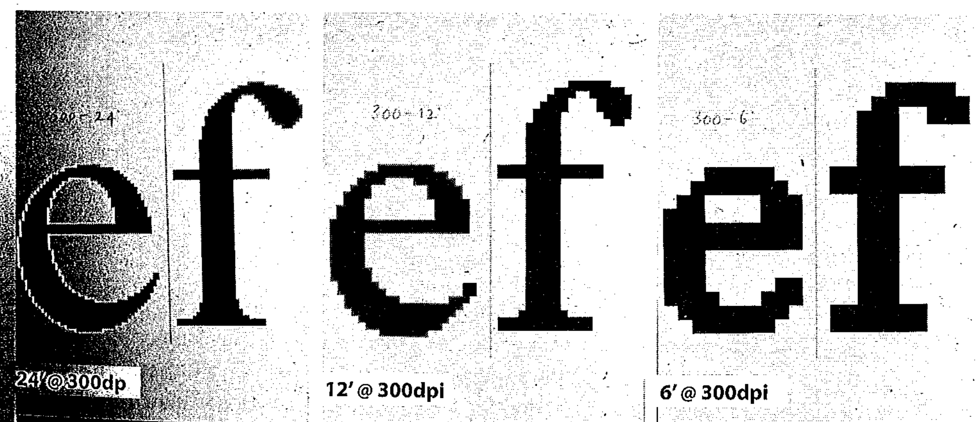
Bitstream's product is type expressed digitally as a definitive outline. Within an imagesetter, the outline will be converted by a RIP into raster form. At high resolution, say above 1000 lines per inch (lpi), the raster patterns at 96 point would be virtually analog in definition (see *Figure 6*); while at 12 point, the outline is starting to appear a little ragged (see *Figure 7*). Since 12 point is fairly small, the eye is unaware of the "jaggies" when they are softened by the roundness of the writing spot and the effects of printing. However, a RIP can equally well feed a low resolution output device such as an electronic non-impact printer designed for the office market.



Figures 6-7

6 left, 96'
7 right, 12'

At a typical resolution of 300 lines per inch, 24 point, 12 point, and 6 point are low-res bitmaps which have more to do with bricklaying than type design. At this scale the addition or subtraction of a single pixel can have a dramatic effect on the letterform, and corresponding care is needed in their design.

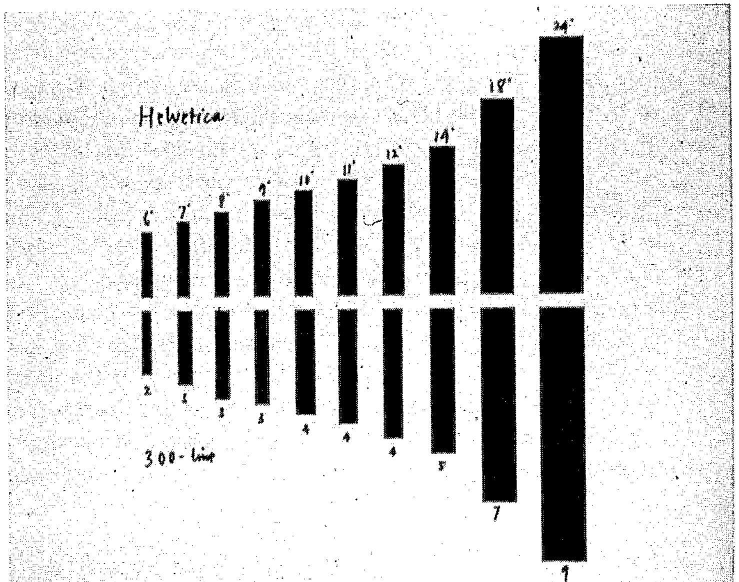


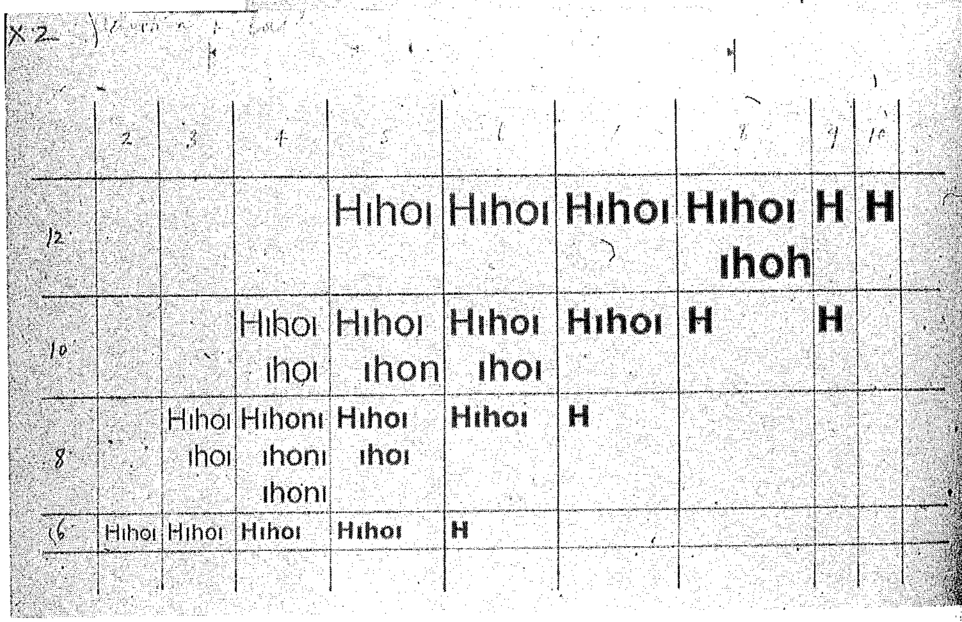
Figures 8-10

8 left, 24' @ 300dpi
9 middle, 12' @ 300dpi
10 right, 6' @ 300dpi

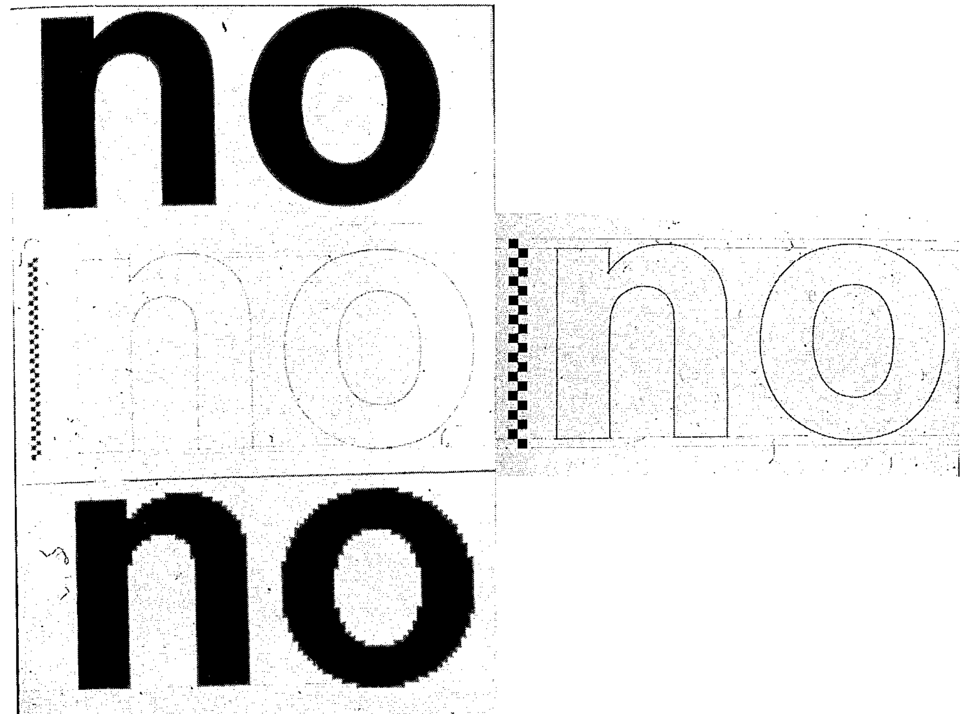
figures 11-12

11 top
12 below





A problem exists in attempting to design an evenly graded series of point sizes at coarse resolution. In the chart in Figure 11, the upper progression plots the analog x -heights and stem weights of Helvetica lower case as the face was designed. Below is shown the closest match at 300 lpi in the coarse steps imposed by the raster. The uneven gradation at the low end and the middle of the range is obvious. The chart in Figure 12, again of Helvetica, shows all the possible choices at 300 lpi, plotted point size against stem weight.



Figures 13-14

Another problem in adapting type to low-resolution reproduction appears when round letterforms need to be designed slightly bigger than square ones in order to look the same size. At 18 point, 300 lpi, the raster step diagrammed in the ladder at the left of Figure 13, is at exactly the right intervals to represent the difference in height between square and round in the original design. This is not so at 9 point: design and raster do not coincide (Figure 14). The smallest step, one line, is too big. As so often in coarse resolution design there is no perfect answer, the best solution is the least bad.

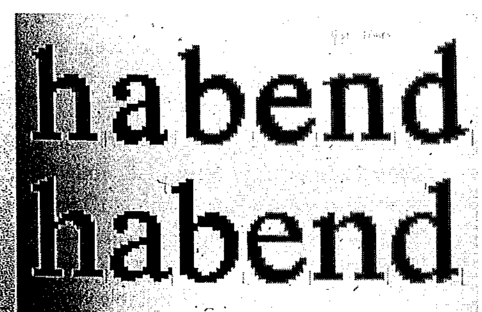


Figure 15

Figure 15 shows a before-and-after comparison. The upper line is the product of an algorithm that has scanned 9 point Times Roman one character at a time and generated a bitmap of each individual letter without considering the relationship between them. The lower word has been edited to make the spacing regular, the weight consistent, and to make common elements repeat.

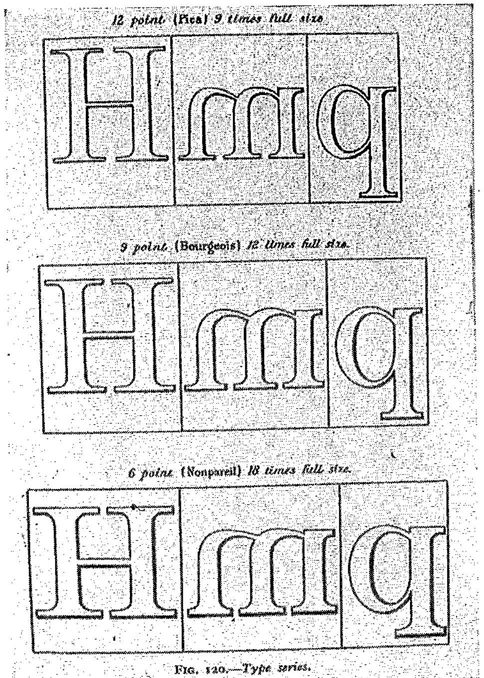


Figure 16

Figure 16, taken from Legros and Grant's *Typographical Printing Surfaces* published in 1916, shows a comparison between 6, 9 and 12 point in foundry type. It is clear that the proportions of face to body vary as a function of point size – the smaller the point size the larger the face in proportion.

If, for example, one compares the lower-case alphabet lengths of Linotype Primer, a finely planned foundry type series, one finds that 6 point, far from being 50% of 12 point, is in fact 64Y. This practice, the non-linear scaling of small sizes, has fallen out of use in photocomposition – the 6 point is now 60% of 12 point, with the result that it is too small, too light, and too hard to read.

In low-resolution typography where the lack of pixels at small sizes makes the construction of clearly articulated letterforms extremely difficult, the time-honored idea of increasing the proportion of face to body has been revived in the interests of legibility.

One example shows bitmaps for a 6 point type at 240 lpi with photocomp proportions (i.e. the face size is 50% of 12 point), and the bitmaps have been produced by a simple conversion from outline to raster without any form of compensation or correction. The results are horrible: stem weights fluctuate, hairlines and serifs have failed.

Another example is a different 6 point type (from the same outline source and the same 240 line printer) was produced with an algorithm that increases the face size by 20%, regularizes stem weights and side-bearings, and preserves the finer elements. The bitmap conversion was done 'on the fly' without any manual intervention . Other examples show 9 and 10 point by the same programmed method. These are preliminary test runs, the product of a collaboration between Symbolics and Bitstream that has resulted in an automated bitmap editing program now running on a Symbolics 3600 workstation at Bitstream.

In converting an outline into a bitmap, the position of the image with respect to the raster is critical. Figure 17, using one of the routines within the Symbolics program, shows the same outline (a 9 point "n," blacked in for clarity) and the same raster grid are shifted laterally to give three very different bitmaps. In two of the positions the sidebearings on either side have been locked to a raster line causing obvious and unacceptable variations in weight between the two upright stems of the "n." In the third case the letter has been centered on the grid to give a better bitmap. The lateral displacement that has given these three drastically different bitmaps is very

Figure 17

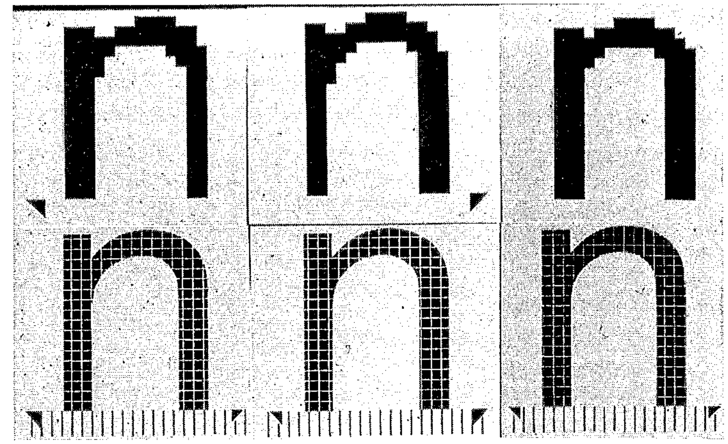
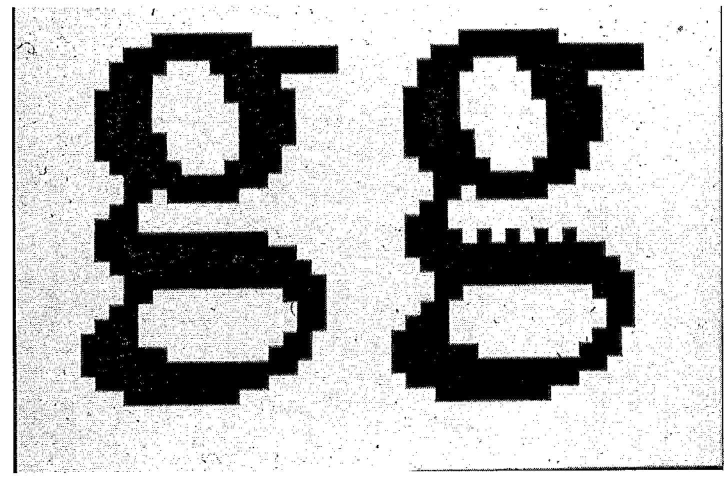


Figure 18



slight – less than half the raster pitch. It is the task of the program to cause the optimum fit of image to raster and to force even stem weights.

Figure 18 illustrates a design technique that has come to be known as half-bitting. At a thickness of four lines, the horizontal stroke in the middle of the "g" is too heavy. At three lines it would be too light. By omitting every other pixel, an impression of an intermediate weight – 3 1/2 lines – is created at the output resolution of 300 lpi.

Another image-to-raster technique was developed to improve the definition of letter arms on video screens of coarse resolution such as standard television receivers. Pioneering work was done by Wendy Richmond at MIT: adding two tones of grey to the bitmap to achieve a degree of subtlety impossible in plain black and white. The choice of tone in each cell is determined by what percentage of its area is occupied by image and what by ground. The resulting letter is constantly updated and visible to the designer at actual screen size in the lower part of the editing screen.

Figure 19 shows a sample of grey- scaling done at Atex: a lowercase "e" in black and white, with tones of grey added. Similarly, a few characters from a single-bit font are shown in Figure 20 with the same letters in a 4-bit version in Figure 21, giving far higher definition from the same screen.

Figure 19

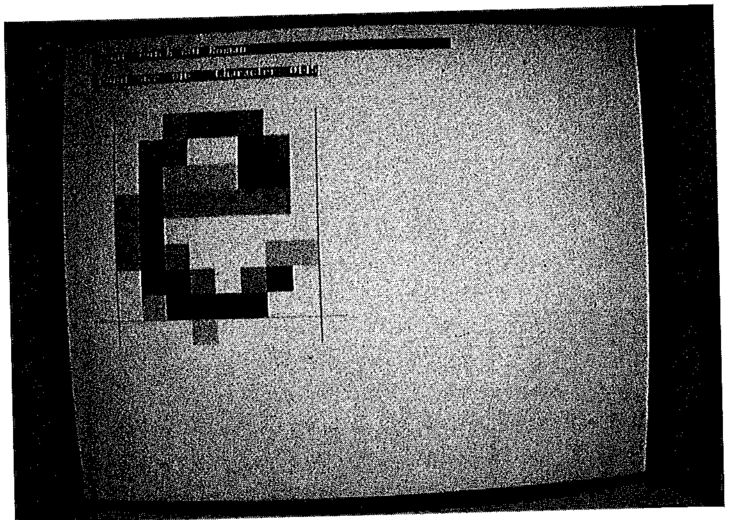


Figure 20

Figure 21

The importance of these techniques for combatting the effects of low output resolution (automated bitmap editing, half-bitting, greyscaling) is that they convert the outline into a truly resolution independent font. Instead of storing separate fonts for each output device, a single outline can reside in the RIP and serve all applications.

Author

Matthew Carter is a type designer with 60 years' experience in typographic technologies, ranging from hand-cut punches to computer fonts. After a long association with the Linotype companies he was a co-founder of Bitstream Inc. in 1981, a digital type foundry where he worked for ten years. Carter is now a principal of Carter & Cone Type Inc., designers and producers of original typefaces, in Cambridge, Massachusetts.

Carter's type designs include ITC Galliard, Snell Roundhand and Shelley scripts, Helvetica Compressed, Olympian, Bell Centennial, ITC Charter, Mantinia, Sophia, Big Caslon, Big Moore, Miller, Roster, Georgia, Verdana, Tahoma, Sitka and Carter Sans.