EDITORIAL

Why Meta-Font Struck a Nerve

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What's old is old. But what's new is also old. One could argue that there are a limited number of concepts in our world and that time simply rehashes new iterations of existing concepts. And while one might argue that's not proof that it's true, Douglas R. Hofstadter's article reprinted following this introduction is one data point of evidence to support that what's new really is old. It is 44 years old but explains something important unfolding today: AI.

Reprint of this article was instigated by a routine figure reproduction request from an old article, in this case, Hofstadter's 1982 article "Metafont, Metamathematics, and Metaphysics: Comments on Donald Knuth's 1982 Article 'The Concept of a Meta-Font'" from *Visible Language* 16.4 (see Figure 1). My memory was not good enough to recall much of Hofstadter's article at first, so I re-read it. When I did, I immediately asked him for permission to reprint it because even though it was from years ago it so directly addressed essential issues concerning AI today. To put that in perspective, Apple computer was founded just six years prior to Hofstadter's insightful article and is today the company with either the world's largest or second largest market cap depending on NVIDIA's, and NVIDIA is an AI company. To say that 44 years ago Hofstadter foresaw issues of at least economic significance, is a vast understatement.

Hofstadter (1982/2026) articulated in understandable language AI challenges that most of us only feel intuitively. He makes clear, in a non-trivial way, that machines are limited by being… machines. He explains that starting with a machine is to start with a very limited set of assumptions, mechanisms, and relationships with one target in mind and because one target is the focus other targets are of necessity excluded. But what's excluded may be critical. He said, "No matter how many new knobs—or even families

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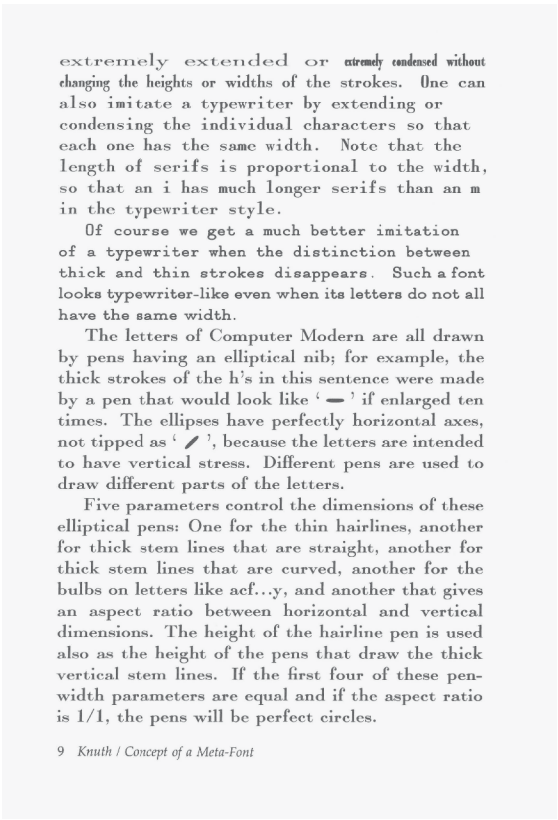


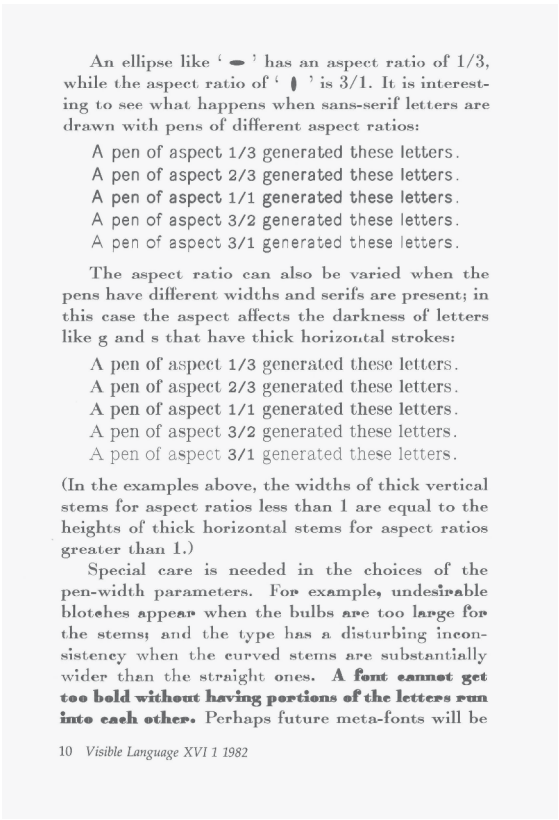
extremely extended or extremely condensed without changing the heights or widths of the strokes. One can also imitate a typewriter by extending or condensing the individual characters so that each one has the same width. Note that the length of serifs is proportional to the width, so that an i has much longer serifs than an m in the typewriter style.

Of course we get a much better imitation of a typewriter when the distinction between thick and thin strokes disappears. Such a font looks typewriter-like even when its letters do not all have the same width.

The letters of Computer Modern are all drawn by pens having an elliptical nib; for example, the thick strokes of the h's in this sentence were made by a pen that would look like ' ▬ ' if enlarged ten times. The ellipses have perfectly horizontal axes, not tipped as ' ◢ ', because the letters are intended to have vertical stress. Different pens are used to draw different parts of the letters.

Five parameters control the dimensions of these elliptical pens: One for the thin hairlines, another for thick stem lines that are straight, another for thick stem lines that are curved, another for the bulbs on letters like acf…y, and another that gives an aspect ratio between horizontal and vertical dimensions. The height of the hairline pen is used also as the height of the pens that draw the thick vertical stem lines. If the first four of these pen-width parameters are equal and if the aspect ratio is 1/1, the pens will be perfect circles.

9 *Knuth / Concept of a Meta-Font*



An ellipse like ' ▬ ' has an aspect ratio of 1/3, while the aspect ratio of ' ▮ ' is 3/1. It is interesting to see what happens when sans-serif letters are drawn with pens of different aspect ratios:

A pen of aspect 1/3 generated these letters.
A pen of aspect 2/3 generated these letters.
A pen of aspect 1/1 generated these letters.
A pen of aspect 3/2 generated these letters.
A pen of aspect 3/1 generated these letters.

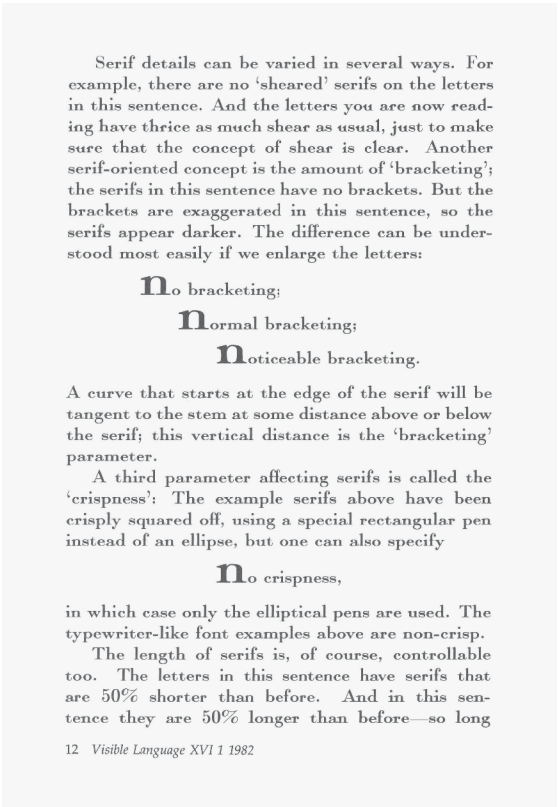
The aspect ratio can also be varied when the pens have different widths and serifs are present; in this case the aspect affects the darkness of letters like g and s that have thick horizontal strokes:

A pen of aspect 1/3 generated these letters.
A pen of aspect 2/3 generated these letters.
A pen of aspect 1/1 generated these letters.
A pen of aspect 3/2 generated these letters.
A pen of aspect 3/1 generated these letters.

(In the examples above, the widths of thick vertical stems for aspect ratios less than 1 are equal to the heights of thick horizontal stems for aspect ratios greater than 1.)

Special care is needed in the choices of the pen-width parameters. For example, undesirable blotches appear when the bulbs are too large for the stems; and the type has a disturbing inconsisteney when the curved stems are substantially wider than the straight ones. **A font cannot get too bold without having portions of the letters run into each other.** Perhaps future meta-fonts will be

10 *Visible Language XVI 1 1982*



Serif details can be varied in several ways. For example, there are no 'sheared' serifs on the letters in this sentence. And the letters you are now reading have thrice as much shear as usual, just to make sure that the concept of shear is clear. Another serif-oriented concept is the amount of 'bracketing'; the serifs in this sentence have no brackets. But the brackets are exaggerated in this sentence, so the serifs appear darker. The difference can be understood most easily if we enlarge the letters:

no bracketing;
normal bracketing;
noticeable bracketing.

A curve that starts at the edge of the serif will be tangent to the stem at some distance above or below the serif; this vertical distance is the 'bracketing' parameter.

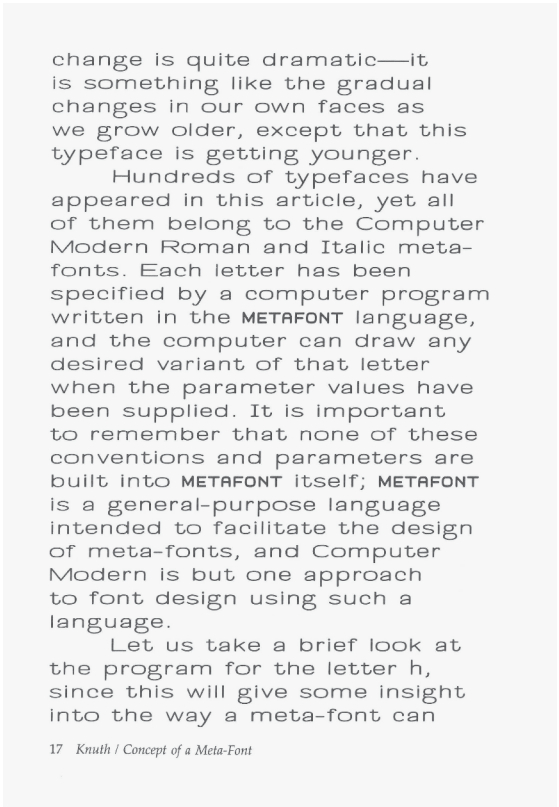
A third parameter affecting serifs is called the 'crispness': The example serifs above have been crisply squared off, using a special rectangular pen instead of an ellipse, but one can also specify

no crispness,

in which case only the elliptical pens are used. The typewriter-like font examples above are non-crisp.

The length of serifs is, of course, controllable too. The letters in this sentence have serifs that are 50% shorter than before. And in this sentence they are 50% longer than before—so long

12 *Visible Language XVI 1 1982*



change is quite dramatic—it is something like the gradual changes in our own faces as we grow older, except that this typeface is getting younger.

Hundreds of typefaces have appeared in this article, yet all of them belong to the Computer Modern Roman and Italic meta-fonts. Each letter has been specified by a computer program written in the METAFONT language, and the computer can draw any desired variant of that letter when the parameter values have been supplied. It is important to remember that none of these conventions and parameters are built into METAFONT itself; METAFONT is a general-purpose language intended to facilitate the design of meta-fonts, and Computer Modern is but one approach to font design using such a language.

Let us take a brief look at the program for the letter h, since this will give some insight into the way a meta-font can

17 *Knuth / Concept of a Meta-Font*

Figure 1. Pages 9, 10, 12, and 17 from Knuth (1982).

of knobs—you add to your… machine, you will have left out some possibilities" (p. 104). In the back of our minds, we fear that non-machine possibilities not only matter, they may be the most significant parts. The beauty of Hofstadter's article for designers facing an AI world is that it's centered on letterforms:

> Clearly there is much more going on in typefaces than meets the eye—literally. The shape of letterforms is a surface manifestation of deep mental abstractions. It is determined by conceptual considerations and balances that no set of merely geometric knobs could capture. Underneath or behind each instance of **A** there lurks a concept… (p. 109)

He moves on to say that the spirit of a letter is defined not by geometry but by roles that visual forms play and he doesn't stop at that, he describes that roles are modular and that they "overlap and mingle in a subtle way" within a context (p. 109).

Hofstadter's thoughts about "deep mental abstractions" reinforce several lines of thinking about typefaces and design that have developed in the past 20 years that I am personally familiar with. One is the concept of a letterform skeleton that embodies the essential qualities of each letter. The starting point for Donald Knuth's Meta-Font to which Hostadter was responding, was a pen stroke. By providing his parameterized letterform generating system with a pen stroke Knuth bypassed the important question of what exactly an **A** is. At the heart of a typeface generator lies some definition of the features that constitute **A**-ness or, as Hofstadter might say, the essential visual "roles" needed for an **A** to be recognized as an **A**. While many would argue that we still don't know exactly what defines an **A** (a good opportunity for research!), the last 100 years have seen some progress toward such a definition.

Edward Johnson's 1906 book *Writing, Illuminating, and Lettering* described a letterform "skeleton or structural plan" as the essence of a letterform and illustrated this using single line pencil strokes as capturing letters "essential forms" (Johnson, 1906/1948, p. 240). In a sense, Knuth's "pen-stroke" was simply putting Johnson into a computer. Several decades later, Adrian Frutiger, the designer of many prominent 20th century typefaces (Univers, Frutiger, and Avenir among them), defined the most elemental shapes of letterforms by overlapping the letterforms of "the most widely used typefaces in the world" in his 1979 book *Type Sign Symbol.* Frutiger said that the areas of overlap in all the different typefaces defined "a kind of basic skeleton" that had engraved themselves "in the subconscious of the reader as a kind of elemental form" (Frutiger, 1979, p. 64). Building upon Johnson and Frutiger in my 2019 *Visible Language* article "Letterform Legibility and Visual Perception: A Speculation" (see Figure 2), I speculated that the essential features of letterforms, that is their "skeletons," mapped nicely onto distinct combinations of early features detected in the process of visual perception. Those early features are: horizontal, vertical, angular, diagonal, circle, open-form,

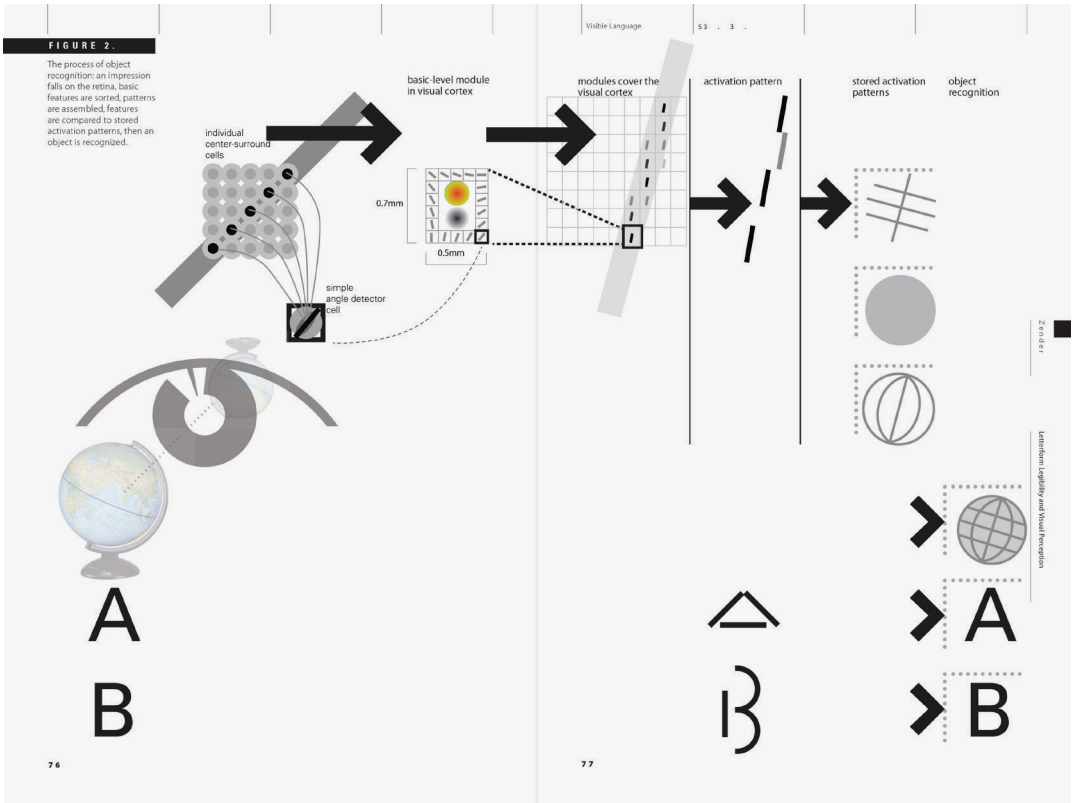


Figure 2. Pages 70/71 and 76/77 from Zender (2019).

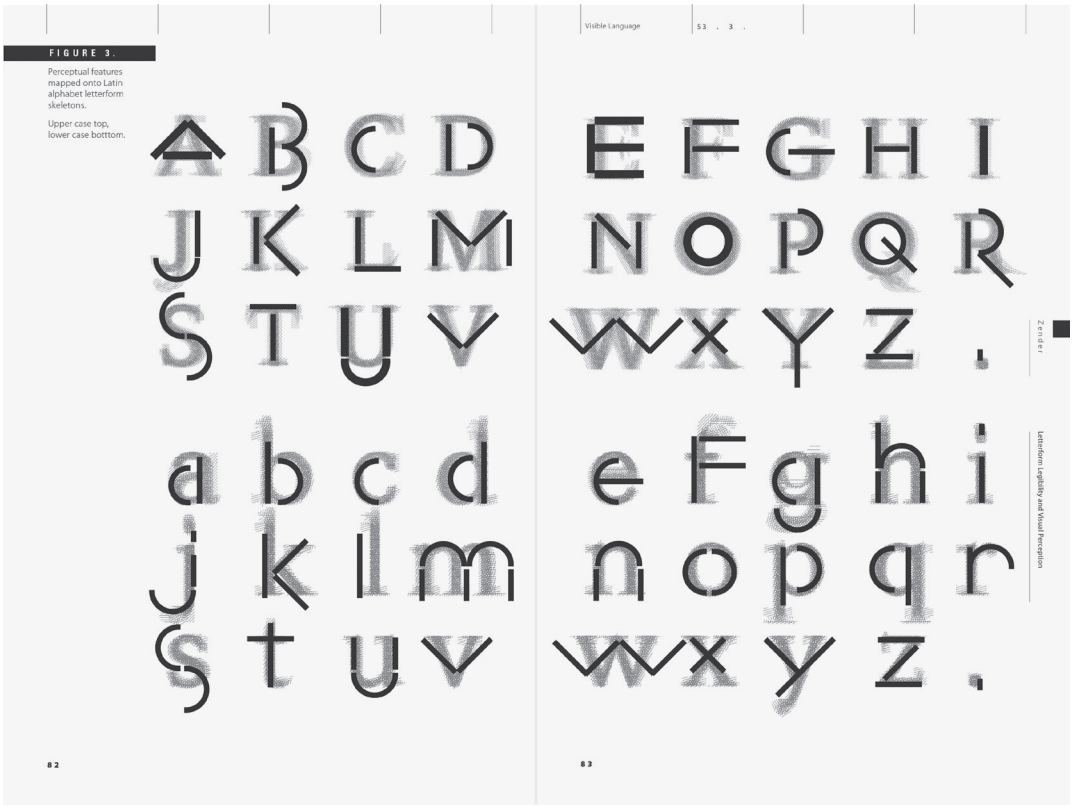


Figure 3. Pages 82/83 from Zender (2019).

closed-form (Figure 3). I guessed that each letterform activated the base mechanisms of visual perception and that various combinations of these essential features may be part of what makes an **A** an **A** versus an **O**.

Hofstadter's article invokes the suggestion that "roles," perhaps in the sense of the interaction of basic visual forms like key perceptual features, are what define a letterform more than mere mechanical geometry. Abstracted further, it may be that verbs, actions of interaction, are more important conceptually than physical geometry to what makes an **A** an **A**. If true, then one might create an AI typeface generator based on the interaction of key features rather than on Knuth's pen strokes or geometric mechanisms. Why someone would want to do this is another question, as is the part the designer plays in this whole AI generated typeface enterprise.

Because Hofstadter's article is brilliant, he also grounds this with Gödel's theorem that any system cannot be both complete and provable within itself and links that to the concepts of *completeness*—a system which presents every true positive—and *consistency*—a system with no false positives. These concepts are so critical to defining current AI system performance. If you're not an AI person, forgive the lingo. We do not wish to over-simplify a very deep article that is none the less highly readable. After all,

Hofstadter won the Pulitzer prize for his 1979 book on Gödel and the Los Angeles Times Book Prize for his 2007 *I Am a Strange Loop*.

In addition to being pleased to have a track record of publishing concepts that stand the test of time, *Visible Language* is very honored to have had people the stature of Douglas R. Hofstadter and Donald E. Knuth contribute as authors in the past (though we do not include a reprint of Knuth's article here, it's available in our archive). We're also so honored to have had letter writers of such high stature as those who sent in additional letters in response to Knuth's article: Bigelow, Karow, Unger, and Zapf (Baudin et al., 1982; summarized in Littlejohn, 2026). They are all truly world-class thinkers as their contributions demonstrate. We re-present their work here not in the spirit of resting on our laurels but as intellectuals ourselves who believe that connecting concepts across time is something every scholar, and scholarly journal, should strive to do.

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