Fonts and font files

Victor Eijkhout

August 2004

1 Basic terminology

Terminology of fonts and typefaces is quite confused these days. Traditionally, a typeface was a design, realized in number of fonts, that could be sorted in families, such as roman, and italic. A font would then be a style (medium weight bold italic) in a particular size.

Somewhat surprisingly, once you start throwing computers at this problem, even talking about characters becomes very subtle.

In Unicode, there are abstract characters and characters. They don't differ by much: an abstract character is a concept such as 'Latin lowercase a with accent grave', and a character is that concept plus a position in the Unicode table. The actually visible representation of a character is called a 'glyph'. According to ISO 9541, a glyph is 'A recognizable abstract graphic symbol which is independent of any specific design'.

1.1 The difference between glyphs and characters

Often, the mapping between character and glyph is clear: we all know what we mean by 'Uppercase Roman A'. However, there may be different glyph shapes that correspond to the same character.

An abstract character is defined as

> abstract character: a unit of information used for the organization, control, or representation of textual data.

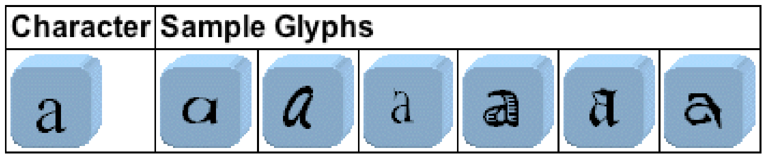


Figure 1: Different shapes of 'lowercase roman a'

This definition has some interesting consequences. Sometimes one glyph can correspond to more than one character, and the other way around.

For example, in Danish, the ligature ‘æ’ is an actual character. On the other hand, the ligature ‘fl’, which appears in English texts, is merely a typographical device to make the

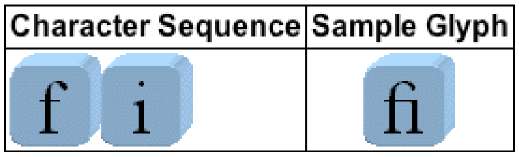


Figure 2: The f-i ligature

combination ‘fl’ look better, so one glyph corresponds to two characters.

The opposite case is rarer. In Tamil, a certain character is split, because it is positioned *around* other characters. It can then even happen that one of the split parts forms a ligature with adjacent characters.

A tricker question is how to handle accented letters: is ‘é’ one character or a combination of two? In math, is the relation in $a \neq b$ *one* symbol, or an overstrike of one over another?

Another problem with ligatures is that a single glyph needs to be displayed, but two glyphs need to be stored to make searching for the string possible.

1.2 The identity of a character

Another problem in defining a character is whether two glyphs that look the same, or sometimes ever *are* the same, should be the same character. For example, uppercase Latin a, uppercase Greek α, and uppercase Cyrillic a, are all rendered ‘A’. Still, in Unicode they are three distinct characters.

Similarly, in ASCII, there are no separate glyphs for minus, hyphen, and dash. In Unicode, these are three characters. Is the character ‘superscript ^{2}’ a separate glyph, or a typographical variant of the character ‘digit 2’? The latter should be the logical solution, but for compatibility reasons with other standards it is defined as a separate glyph. There are quite a few of these ‘compatibility characters.

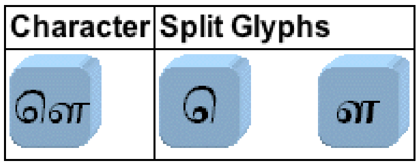


Figure 3: A split character in Tamil

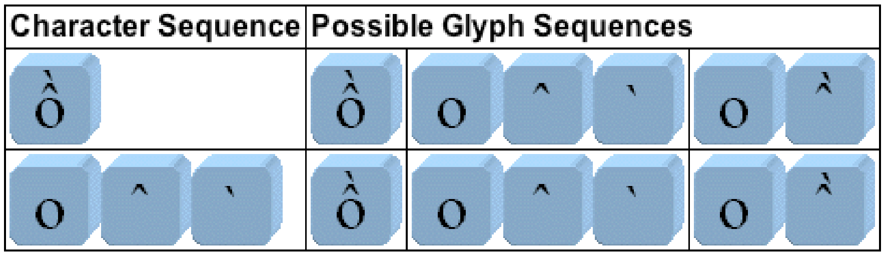


Figure 4: Different interpretations of an accented character glyph

Yet another example is the Greek letter Ω, which can be that letter, or the sign for electrical resistance in physics texts. Unicode defines them as two characters, but with identical glyphs.

A capital 'A' in Times Roman and in Helvetica are the same character, but what about italic?

All these matters are hard to settle objectively: everything is a matter of definition, or a judgement call. The official Unicode white paper on characters versus glyphs is `http://www.unicode.org/reports/tr17/`.

Here are some of the guidelines of the Unicode project:

- The Unicode Standard encodes characters, not glyphs.
- Characters have well-defined semantics.
- The Unicode Standard encodes plain text.
- And:

  > The Unicode Standard avoids duplicate encoding of characters by unifying them within scripts across languages; characters that are equivalent in form are given a single code. Common letters, punctuation marks, symbols, and diacritics are given one code each, regardless of language, [. . .]

1.3 Diacritics

Unicode, a bit like TEX, has two ways of dealing with diacritics. It has precomposed accented characters, but it can also compose accented characters by listing accents (yes, plural: transliterated Vietnamese regularly has two accents over a letter one relating to vowel quality, and one to tone) after the base symbol. This mechanism can also deal with languages such as Hangul (Korean) which have composite characters.

2 Æsthetics

2.1 Scaling versus Design sizes

Lots of attention is devoted to font scaling, with the implicit assumption that that is the way to get a font to display at different sizes. This is only true to an extent: a small version of a typeface was traditionally of a different design than the same typeface at larger sizes. With metal type, independent designs for the different sizes were of course the only way one could proceed at all, but with photo typesetters and computers the need went away, and with it the realization that independent designs are visually actually a Good Thing. Figure 5 shows the difference between a typeface set at its ‘design size’, and a scaled up

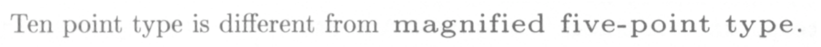


Figure 5: A typeface and a smaller version scaled up

smaller version of it.

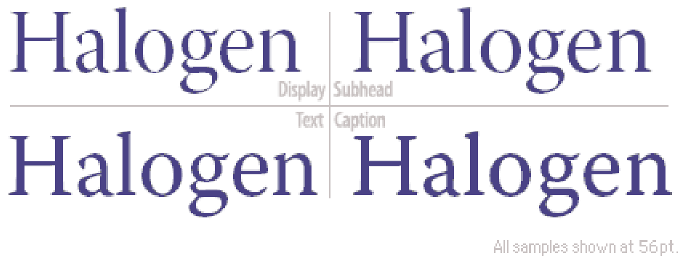


Figure 6: Adobe’s optical masters for a typeface

Adobe incorporated this idea in their Multiple Masters typefaces, which could interpolate between different designs. This technology seems to have been abandoned, but Adobe’s Originals now have so-called ‘Optical masters: four different designs of the same typeface, to be set at different sizes. Adobe labels their purposes as ‘display’, ‘subhead’, ‘text’, and ‘caption’ in decreasing design size; see figure 6.

Apple developed their own version of multiple design sizes in TrueType GX, released in 1994. The ideas in TrueType GX are incorporated in Apple Advanced Typography (AAT) in OS X, but there few AAT typefaces, and certainly very few non-Apple ones.

3 Font technologies

3.1 Unicode in fonts

It is unrealistic to expect any single font to support even a decent fraction of the Unicode character repertoire. However, TrueType and OpenType do support Unicode.

The few fonts that support (almost) the whole of Unicode are called ‘pan-Unicode’. There are only a few of those. However, software these days is pretty sophisticated in gathering together symbols from disparate fonts. Some browsers do this, prompting the user for ‘install on demand’ of fonts if necessary.

3.2 Type 1 and TrueType

Type 1 (‘Postscript fonts’) was the outline font format developed by Adobe that was adopted by Apple in the mid 1980s. Since it was proprietary (Adobe had release the specifications for Type 3 fonts, but not Type 1), Apple and Microsoft later developed TrueType.

With Type 1 fonts, information is stored in two files, one for shape data and one for hinting and such. With TrueType, all information is in the one font file.

3.2.1 Type1

Adobe Type 1 fonts are stored in two common formats, .pfa (PostScript Font ASCII) and .pfb (PostScript Font Binary). These contain descriptions of the character shapes, with each character being generated by a small program that calls on other small programs to compute common parts of the characters in the font. In both cases, the character descriptions are encrypted.

Before such a font can be used, it must be rendered into dots in a bitmap, either by the PostScript interpreter, or by a specialized rendering engine, such as Adobe Type Manager, which is used to generate low-resolution screen fonts on Apple Macintosh and on Microsoft Windows systems.

The Type 1 outline files do not contain sufficient information for typesetting with the font, because they have only limited metric data, and nothing about kerning (position adjustments of particular adjacent characters) or ligatures (replacement of adjacent characters by a single character glyph, those for fi, ffi, fl, and ffl being most common in English typography).

This missing information is supplied in additional files, called .afm (Adobe Font Metric) files. These are ASCII files with a well-defined easy-to-parse structure. Some font vendors, such as Adobe, allow them to be freely distributed; others, such as Bitstream, consider them to be restricted by a font license which must be purchased.

3.2.2 TrueType $\Leftrightarrow$ Type1 conversion

Beware! There is no such thing as a one-to-one reversible conversion. There are several problems:

The outlines are stored in different ways in both formats. In truetype, second-order Bezier curves are used, and in type 1, third-order Bezier curves are employed. One second order Bezier can be transformed into a third-order Bezier, but a third-order Bezier cannot be transformed into one, two or seventeen second-order Beziers–approximations are in order for that conversion. So, type 1 to truetype is problematic, right from the start. For truetype to type 1, there is a snake in the grass, in the form of integer grid rounding (see below).

Both formats require all control points to be integers (whole numbers), falling in a grid. Truetype uses a 2048x2048 grid, type 1 typically a 1000x1000 grid. For the truetype to type 1 direction, one could divide all grid values by two, but then what? Should 183.5 become 183 or 184? The type 1 to truetype direction is easier, at least from this point of view, as we could multiply each grid coordinate by two, so no rounding loss would be involved. However, in the truetype to type 1 direction, the rounding causes additional problems for the new control points needed for the perfect third-order Bezier outlines mentioned above.

Placing ink on paper: the formats have different rules for placing ink on paper in case of outlines that are nested or intersecting. These differences are not caught by many conversion programs. In most cases, the user should not worry about this—only rarely do we have overlapping outlines (I was forced once to have them, for other reasons).

Complexity of the outlines: truetype permits more complex outlines, with more control points. For example, I am sure you have all seen fonts made from scans of pictures of faces of people. Typically, these outlines are beyond the type 1 limit, so this restriction makes the truetype to type 1 conversion impossible for ultra complex fonts.

Encoding: truetype can work with a huge number of glyphs. There are truetype fonts for Chinese and Japanese, for example. In type 1, the number of active glyphs is limited to 256. Again, for most Latin fonts, this is a non-issue.

The remarks about grid rounding also apply to all metrics, the bounding boxes, the character widths, the character spacing, the kerning, and so forth.

Finally, there is the hinting. This is handled very differently in both formats, with truetype being more sophisticated this time. So, in truetype to type 1 conversions of professionally (hand-hinted) fonts, a loss will occur. Luckily, 99% of the truetype fonts do not make use of the fancy hinting possibilities of truetype, and so, one is often safe.

All this to tell people to steer away like the plague from format conversions. And a plea to the font software community to develop one final format. My recommendation: get rid of truetype, tinker with the type 1 format (well, tinker a lot). More about that ideal format elsewhere.

3.2.3 Downsampling bitmaps

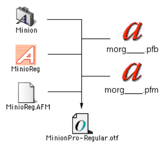
In principle, given adequate resolution, the screen preview quality of documents set in bitmap fonts, and set in outline fonts, should be comparable, since the outline fonts have to be rasterized dynamically anyway for use on a printer or a display screen.

Sadly, this is not the case with versions of Adobe Acrobat Reader, acroread, and Exchange, acroexch (version 5.x or earlier); they do a poor job of downsampling high-resolution bitmap fonts to low-resolution screen fonts. This is particularly inexcusable, inasmuch as the co-founder, and CEO, of Adobe Systems, is the author of one of the earliest publications on the use of gray levels for font display: [John E. Warnock, The display of characters using gray level sample arrays, Computer Graphics, 14 (3), 302–307, July, 1980.]

3.3 FreeType

FreeType is an Open Source implementation of TrueType. Unfortunately this runs into patent problems, since Apple has patented some of the hinting mechanism. Recently FreeType has acquired an automatic hinting engine.

3.4 OpenType



OpenType is a standard developed by Adobe and Microsoft. It combines bitmap, outline, and metric information in a single cross-platform file. It has Unicode support, and can use 'Optical Masters' (section 2.1) multiple designs. It knows about the distinction between code points and glyphs, so applications can render a character differently based on context.

4 Font handling in TEX and LATEX

TEX has fairly sophisticated font handling, in the sense that it knows a lot about the characters in a font. However, its handling of typefaces and relations between fonts is primitive. LATEX has a good mechanism for that.

4.1 TEX font handling

Font outlines can be stored in any number of ways; TEX is only concerned with the 'font metrics', which are stored in a '`tfm` file'. These files contain

- Global information about the font: the `\fontdimen` parameters, which describe the spacing of the font, but also the x-height, and the slant-per-point, which describes the angle of italic and slanted fonts.
- Dimensions and italic corrections of the characters.
- Ligature and kerning programs.

We will look at these in slightly more detail.

4.1.1 Font dimensions

The `tfm` file specifies the natural amount of space, with stretch and shrink for a font, but also a few properties related to the size and shape of letters. For instance, it contains the x-height, which is the height of characters without ascenders and descenders. This is, for instance, used for accents: TEX assumes that accents are at the right height for characters as high as an 'x': for any others the accent is raised or lowered.

The 'slant per point' parameters is also for use in accents: it determines the horizontal offset of a character.

4.1.2 Character dimensions

The height, width, and depth of a character is used to determine the size of the enclosing boxes of words. A non-trivial character dimension is the 'italic correction'. A tall italic character will protrude from its bounding box (which apparently does not always bound). The italic correction can be added to a subsequent space.

'TEX has' versus 'TEX has'

4.1.3 Ligatures and kerning

The `tfm` file contains information that certain sequences of characters can be replaced by another character. The intended use of this is to replace sequences such as `fi` or `fl` by 'fi' or 'fl'.

Kerning is the horizontal spacing that can bring characters closer in certain combinations. Compare

'Von' versus 'Von'

Kerning programs are in the `tfm` file, not accessible to the user.

4.2 Font selection in LaTeX

Font selection in LaTeX (and TeX) was rather crude in the early versions. Commands such as `\bf` and `\it` switched to boldface and italic respectively, but could not be combined to give bold italic. The New Font Selection Scheme improved that situation considerably.

With NFSS, it becomes possible to make orthogonal combinations of the font family (roman, sans serif), series (medium, bold), and shape (upright, italic, small caps). A quick switch back to the main document font is `\textnormal` or `\normalfont`.

4.2.1 Font families

It is not necessary for a typeface to have both serifed and serifless (sans serif) shapes. Often, therefore, these shapes are taken from different, but visually compatible typefaces, for instance combining Times New Roman with Helvetica. This is the combination that results from

```
\usepackage{times}
```

Loading the package `lucidabr` instead, gives Lucida Bright and Lucida Sans.

The available font families are

roman using the command `\textrm` and the declaration `\rmfamily`.
sans serif using the command `\textsf` and the declaration `\sffamily`.
typewriter type using the command `\texttt` and the declaration `\ttfamily`. Typewriter type is usually a monospaced font – all characters of the same width – and is useful for writing about LaTeX or for giving code samples.

4.2.2 Font series: width and weight

The difference between normal and medium width, or normal and bold weight, can be indicated with font series commands:

medium width/weight using the command `\textmd` and the declaration `\mdseries`.
bold using the command `\textbf` and the declaration `\bfseries`.

4.2.3 Font shape

The final parameter with which to classify fonts is their shape.

upright This is the default shape, explicitly available through `\textup` or `\upshape`.

italic and slanted These are often the same; they are available through `\textit`, `\textsl`, and `\itshape`, `\slshape`.

small caps Here text is set through large and small capital letters; this shape is available through `\textsc` and `\scshape`.

Contents