Diversity in math fonts

Thierry Bouche

Abstract

We will examine the issues raised when modifying (LA)TEX fonts within math environments, and attempt to suggest effective means of accessing a larger variety of font options, while avoiding typographic nonsense.

> "*Don't mix faces haphazardly when specialized sorts are required*"
>
> — Robert BRINGHURST [9]

1 Stating the problem

The advent of LATEX 2ε has resulted in a type of 'standardizing' of font selection schemes (NFSS, in other words). The advantages are many, but the main one for me is this: unlike other software that's more expensive and of poorer quality, changing fonts is as easy as changing your socks. In fact, the 'heroic' days of *plain* are just a memory, where changing from the default \textfont0 meant generating a new format, not to mention various encodings ... The temptation to play is therefore very great, especially if you want to break with the monotony of countless preprints and other (LA)TEX documents.[1] I won't say much about anything other than POSTSCRIPT fonts, mainly because I can only test my hypotheses on them. Sebastian Rahtz' *psfonts* now allows anyone equipped with a POSTSCRIPT printer to choose their text fonts for use with LATEX: Times, Bookman, New Century Schoolbook, Palatino. You can ftp to CTAN sites to pick up everything you need to use a wide variety of commercial fonts. Alan Jeffrey's *fontinst* program makes it easier to create the interface needed to use POSTSCRIPT fonts with LATEX. The choices are almost limitless, with some 20,000 fonts to choose from for your document.[2]

Unfortunately, if your document has equations, this diversity is pretty much an illusion. There are actually very few math fonts, and of these, only a few are designed to work with TEX. To my knowledge, here are the font collections that provide a significant set of mathematical glyphs:

The native TEX fonts: these are, of course, cmmi/cmsy/cmex, with the addition of the AMS symbol fonts (msam/msbm);

Some non-native TEX fonts: initially developped in MetaFont format to complement the Concrete text fonts by Knuth, are the Euler fonts, which aren't coded in quite the same way as the standard TEX fonts, and do not really provide a replacement, as so many extra symbols are missing. There is an option available on CTAN, euler.sty by F. Jensen and F. Mittelbach, which makes installing the Euler fonts easier. However, the Eulers weren't designed to be combined with any particular text fonts — the best you can say is that they 'work' with Bitstream Charter or, of course, Concrete. Karl Berry has recently used Euler with Palatino, a valid combination since both font families were designed by Hermann Zapf. U. Vieth designed a math font based on Knuth's Concrete fonts. It is also missing many variants and glyphs, but enjoying an NFSS support package;

MathTime: this family is a full alternative to the CM collection, but is missing some glyphs from the AMS collection;

Lucida New Math: this family is as comprehensive as possible;

PostScript Symbol font: almost as widespread as Courier, it yields upright Greek letters, and includes a number of basic math symbols;

Mathematical Pi: usually used by (photo)typesetting software, this is a collection of six fonts whose glyph set is rather extensive;

and some more: let us also notice that many scientific software programs use proprietary fonts to display equations on-screen or print them on paper.[3] Not to mention the specific proprietary fonts used by some publishers.

In current (LA)TEX, a math font family needs to have at least three members: math italic (cmmi is the default), symbols (cmsy), and extensions for building different-sized symbols (cmex). Taking design consistency and glyph set exhaustivity into account, of the fonts listed above, we are effectively left with with three font families, alternatives which are both complete and unified (well, one less so than the others):

[1] Note that 'LATEX' can be understood as having two relatively independent meanings: it's a program to typeset scientific texts, and it's also a standard in the electronic exchange of documents. This article is concerned with the former: producing documents which are to be printed and thereby benefit from typographic programs adapted to the purpose.

[2] This count, based on Unique IDs, is relatively outdated, as recent fonts IDs would imply that we've reached a count approaching 90,000!

[3] Among them, Mathematica provides a font set with a rather rich set of glyphs. U. Vieth has made TEX virtual fonts for them, along the lines of mathptm; see below.

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- $\Omega_\alpha \neq \emptyset$ (Ω_α *is* not *empty*),
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$$\prod_{j\geqslant 0} \left(\sum_{k\geqslant 0} f_{jk} z^k \right) = \sum_{k\geqslant 0} z^n \left(\sum_{\substack{k_0,k_1,\ldots \geqslant 0 \\ k_0+k_1+\cdots = n}} f_{0k_0} f_{1k_1} \ldots \right) \tag{2}$$

(3) Look at the product ffi, $\underbrace{\{\overbrace{g,\ldots,g}^{k\ g},\overbrace{h,\ldots,h}^{\ell\ h}\}}_{k+\ell\text{ elements}}$ *taken in the basis* $(\vec{\imath}, \vec{\jmath})$.

Moreover, eq. (1) yields $\pm \sqrt{\begin{vmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \end{vmatrix}} > 0.$

Figure 1: The (LA)TEX default: Computer Modern.

- the standard fonts based on Knuth's CM[4]
- Lucida, a slightly more complete set from Bigelow and Holmes, is now quite extensive
- MathTime,[5] an alternative from Michael Spivak; nevertheless can't be as general as the previous two, since it wasn't designed to complement anything beyond the Times text font (the Times was never seen as the roman version of a family with sans serif, and typewriter versions). The current situation, where combining Times with Helvetica and Courier is seen as 'natural', is more the result of commercial suppliers making this combination available in most word-processing programs and in printers.

[4] As I am primarily interested here in font *design* rather than implementation, I won't spend much time distinguishing fonts from various vendors, or in various formats. For instance, here I don't distinguish between Knuth's CM fonts and Knappen's EC, which is largely based on the former. The slanted CM smallcaps are from the EC font.

[5] Linotype's Mathematical Pi, which has no arrows or italics, is insufficient for use with TEX; we only consider it as a *complement* to MathTime.

From this point on, I will take it as a given[6] that these three font families offer everyone a professional level of quality and consistency of style. The remainder of this article is for adventurous spirits or dissatisfied putterers, especially for those who have become jaded by the over-use of the currently available options. One way to describe the problem we face is "What can I do if I want to use a different font for the text, without spending a lot of time and energy designing the corresponding math symbols?"

2 Typographic limitations

There are three main features or characteristics which limit font combinations: color, style, and proportions. For two fonts to work together inobtrusively, these three traits should be as close as possible. This doesn't mean avoid contrasting fonts — just use contrasts with care. For example, you may want chapter titles to be clearly separate from the text, or have visually obvious heading levels (of course, such a contrast should not be used

[6] This view is shared by Berthold Horn[6], whose article in *TUGboat* provides useful details on TEX math fonts.

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$$\text{Look at the product} \quad ffi, \quad \{\underbrace{\overbrace{g,\ldots,g}^{k\ g},\overbrace{h,\ldots,h}^{\ell\ h}}_{k+\ell\ \text{elements}}\} \qquad \textit{taken in the basis}\ (\vec{\imath},\vec{\jmath}). \tag{3}$$

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Figure 2: The same example as Figure 1, done in Lucida.

within paragraphs). We shouldn't forget that combining similar fonts was common practice in printing and publishing. Printers of lead type had far fewer font typefaces available to them than our computers usually provide: a 17pt Caslon in the title combined with Garamond for the text, or bold italic Plantin used with Granjon were perfectly reasonable — if you had no other choice! The first example is a deliberate attempt to startle the reader of today, when vendors pretend that their fonts are infinitely scalable: it's better to use a 17pt font at its design size than to scale the text font up, which is sure to yield something too bold, too round, and with too large an x-height.

2.1 Color

A font that is more or less bold or condensed determines the grayness or 'color' of a page of text. Other parameters — interline space, interword space, margins — all affect color. Keep in mind that the LaTeX default page makeup parameters assume CM fonts. Using another font family may require adjustments to some of these parameters. Grayness is determined

Let x, y, $z \in \mathbb{Z}$; *for* f, α

Figure 3: Text done in Times, math in Computer Modern.

by the white spaces, which are therefore important parameters for typography. Variations in color are often inevitable in math: equations, for example, can change the interline spacing or force large white spaces. At the same time, though, in-line equations should have a minimum effect on the surrounding text.

A typical example would be a math article set with `times.sty`: since Times is a very "black" font, the material in math mode quite literally gives the impression that there's a hole in the page! Fig. 3 shows this, to a certain extent. Other than the perennial Times, books are often set with less dense fonts, such as Baskerville, Plantin, Minion, or Garamond. Depending on which one is used, these fonts have a color which is slightly darker than CM, while still being lighter than either Times or Lucida. It is

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Figure 4: Again the same example, done in MathTime.

the use of such font families that is at the heart of our problem.

2.2 Style

Font *style* is what I call the design specifics of a font's characters. It's not a quantifiable feature or trait — although, one can consult classifications such as the one by Maximilien Vox to identify fonts of relatively similar styles. Strictly speaking, CM is a "Didone" font, although it has more in common with fonts of the Century/De Vinne type than with Bodoni; considered Transitional Mécane (a hybrid category between Mécane and Didone, which isn't itself in the Vox AtypI classification). That's as far as any classification can help — nothing can replace education and experience. All the same, character design can be a significant obstacle to combining fonts. In particular, if we follow the standard practice of using italics in math and theorems, we run the risk of having two different styles in the same sentence, the proximity causing a rather jarring contrast, an effect which can be heighted since italics are often where design idiosyncracies are most obvious. FIG. 5 shows that it's not a simple problem.

afghkmpwyz, *afghkmpwyz*,
afghkmpwyz, *afghkmpwyz*,
afghkmpwyz,
afghkmpwyz, ***afghkmpwyz***,
afghkmpwyz, *afghkmpwyz*.

Figure 5: Apollo, Baskerville, Computer Modern, Adobe Garamond, Lucida, Minion, Plantin, Times, and Utopia (all at 21pts).

2.3 Proportions

The last of the three features concerns character proportions. A font style establishes the relationships of the various dimensions of its face: x-height, height of uppercase letters, ascenders, descenders. For POSTSCRIPT fonts, dimensions are specified in

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Figure 6: Again the same example, done with Mathptm (& dotlessj).

the afm file[7] in terms of 1000pts for each given character, referring to, respectively, the XHeight, CapHeight, Ascender, and Descender.

Each of these parameters can vary independently of the others, as a quick glance through any font catalogue will prove. French printing tradition, going back to Garamont and Granjon, favors what are called 'humanist' characteristics: a fairly small x-height, with uppercase letters below the height of the tallest ascenders, and with generous descenders. In contrast, twentieth-century faces typically have short descenders, ascenders that seem almost atrophied and reduced in size, for what appear to be reasons of efficiency, rationalization of paper savings... In the italic examples in FIG. 5 (all fonts are in the same size), Adobe Garamond and Lucida represent diametrically opposed concepts. Clearly, one shouldn't mix fonts with x-heights that vary too widely, especially in mathematics material, where alignments must default to precise positions (superscripts, for example). You can always bring two

Mixing italic fonts draws attention to their differences.

Figure 7: Garamond and Lucida scaled to the same x-height as Lucida at 20pts.

fonts of different x-heights together by changing the scale but the results can be unpleasant if their respective proportions are too divergent. The example in FIG. 7 demonstrates yet another factor: the slope of the italic characters (ItalicAngle).[8]

[7] A good qualitative description of what should be expected from the metrics of a font is provided in [10]. For a more technical approach, see [1].

[8] TEX is satisfied with slightly less specific information, which is stored in the tfm file, for its seven \fontdimen values: the value of an em (the size of a given font, implicit in the afm), the value of an ex (XHeight), and the tangent of ItalicAngle. The remaining dimensions concern spacing, whereas a POSTSCRIPT afm file specifies the width of the space character, but does not control the elasticity of an interword space.

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Figure 8: Text in Apollo, math in Computer Modern.

3 Customizing a suitable math font

In light of these negative aspects to the problem, we will discuss two methods which each provide a "solution". The examples have been tested, in that they provide a reasonable level of quality in documents containing mathematics. However, neither can pretend to address either the reliability or the quality of the three math font families discussed in our first section. Keeping in mind the remarks attached to its presentation, I would be willing to print a book using the second method (§ 3.3), but I'd only make photocopies if the first method (§ 3.1) had been used. In order of increasing difficulty in implementation, we'll start with Alan Jeffrey's mathptm option, then we'll examine how simple NFSS commands or a virtual font created via fontinst allows us to choose, character by character, each font used within a math environment.

3.1 Mathptm

The mathptm distribution includes virtual fonts created by using fontinst, as well as the style option mathptm.sty, which makes it possible to use the glyphs of Times in math mode with LaTeX. The font is a marvel in that it manages to simulate the majority of the 384 glyphs found in the three math font families, by accessing the Times and Symbol fonts available on any PostScript printer (the calligraphic uppercase letters, accessed via the \mathcal command, come out in Zapf Chancery); as a last resort, some characters are taken from Computer Modern. The style option modifies the LaTeX defaults by invoking these various math font families, adjusting spacing parameters in math mode, and modifying the size of the type body for first- and second-order exponents. This last operation is interesting, because it pushes the 'standard' PostScript fonts to their limits for typesetting mathematics. At 10pts, (LA)TeX uses fonts at point sizes 10, 7, and 5, for normal text, super- and subscripts, and second-order super- and sub-scripts, respectively. Each of these sizes corresponds to a distinct font in the Knuth distribution, since it's necessary to make optical corrections in a 5pt font so that it's readable. PostScript printers have only one font (designed at a 12pt size) for each variant in the Times family. This means the only way to get a

5pt Times font is by applying a scaling but without optical correction, which in turn means the characters are difficult to read. Mathptm.sty redefines these sizes to 10, 7.4 and 6pts, which reduces — but does not eliminate — the visual problems. Mathematical Pi, Lucida, and MathTime will all show this flaw, hence the user will always have to adapt type body sizes with reference to readability. A few of the PostScript Multiple-Master fonts address the optical scaling issue, and while support for use with TEX is a bit tentative, I am convinced that within a few years, expert sets for these fonts will include all the refinements one could wish for.[9]

Mathptm is a free alternative to the MathTime fonts, but there are some drawbacks to it. The most obvious is that the Symbol font, which may be adequate for showing the characters available in the more popular word-processing programs, is decidedly smaller than the needs and possibilities available with TEX. For example, cmex has large expandable delimiters (the ones accessed via \big or \left) whereas Symbol only has the regular parentheses, and the elements needed to create large parentheses; other expanded characters are simply scaled versions of the Symbol character. The other problem is that the lowercase Greek characters are upright. Now, almost all letters inside math mode are presented in italics: upright lowercase Greek letters may require italic corrections, which is fairly bizarre. Generating a slanted version of Symbol (using the SlantFont operation in dvips for example), might work, but the result wouldn't be very good, especially if the slant was pushed to the values usually assigned to true italic fonts (roughly 15° vs. less than 10 for slanted fonts, to get something one could call 'acceptable'). Moreover, this would introduce yet another slope in math equations, which should be avoided as much as possible.

In summary, then, mathptm doesn't really offer a solution to the problem as outlined initially, but it does contain the kernel of two possible approaches to it: (1) a style option relying on NFSS commands to modify math fonts, and (2) creating (via fontinst) virtual math fonts which address specific requirements. As I study the mathptm virtual fonts, I am convinced that there is no other satisfactory alternative to symbol and extension fonts: for such fonts, the issues of style, color, and proportion are not present, so the point is to ensure that their design is consistent and of good quality. My own approach is to use members of one of the three basic families in terms of what works best — using the serifs of \prod as a guide, for example. The Computer Modern versions are adequate for the majority of cases I've run into. The problem of uniformity of typographic characteristics is crucial for alphabets (letters, in other words) such as the Roman and Greek italic letters in the math italics fonts, and then on to the uppercase calligraphic letters, located in the symbol fonts, and uppercase Greek letters, which should appear in OT1-encoded text fonts (such as cmr). For example, for a professional-looking text, one might prefer to use \mathcal to access the uppercase cursive characters in the rsfs font or the Commercial Script font (as shown in the examples on figures 11–13). It seems obvious to me that the preference will always be to choose the italic version of the text font for use in math mode. Below are two methods of achieving that goal.

[9] Provided someone feels the urge to produce the missing mathematical symbols . . .

3.2 Mathfont

I call mathfont.sty a 'generic' extension to access the necessary glyphs in math mode (its main features are discussed here, while the details are left for the reader to study).[10] The essentials are covered in the *LATEX Companion*. LATEX (essentially NFSS) introduces two concepts for fonts in math mode: *alphabets* and *symbols*. An alphabet is explicitly invoked by commands such as \mathbf. Assuming one has a text font, the math version of \mathbf can always be defined by means of a declaration such as:

```
\def\ED{\encodingdefault}% shorter!
\DeclareMathAlphabet{\mathbf}{\ED}%
  {\rmdefault}{b}{n}.
```

In this fashion, you can redefine \mathcal to access the ornamented letters one prefers. Additionally, if you want alphabets defined in this way to respond to the \boldmath command (to put mathematics material into boldface), you could do the following:

```
\DeclareMathAlphabet{\mathsf}{\ED}%
  {\sfdefault}{m}{n}
\SetMathAlphabet{\mathbf}{bold}{\ED}%
  {\rmdefault}{b}{n}
\SetMathAlphabet{\mathsf}{bold}{\ED}%
  {\sfdefault}{b}{n}.
```

We're more interested in symbols, but note that \mathversion already exists (\boldmath is the same as saying \mathversion{bold}). All fonts used in math mode can have a different version, depending on what is specified by \mathversion: for example, a textmathitalics or textmathupright version could be

[10] It should be noted that a ready-to-use minimal adaptation of math italic for text italic can be found at: ftp://fourier.ujf-grenoble.fr/pub/contrib-tex.

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Figure 9: Text in Utopia, math in Computer Modern.

defined so that math italics would be accessed in a font invoked after \mathversion{textmathitalics}. This means it's possible to have several versions coexisting in the same document, just as it's possible to have several encodings for the text material. However, you have to be careful of TEX's limitations in this area: \mathversion can only be changed outside math mode, but never within an equation. Fonts invoked via this method must therefore be acceptable for such usage: if you've created a textmathupright version which replaces math italics by upright characters, these latter must be in a OML-encoded font in order to access such characters as lowercase Greek.

The following declarations introduce the four default symbol fonts:

```
\DeclareSymbolFont{operators}%
  {OT1}{cmr}{m}{n}
\DeclareSymbolFont{letters}%
  {OML}{cmm}{m}{it}
\DeclareSymbolFont{symbols}%
  {OMS}{cmsy}{m}{n}
\DeclareSymbolFont{largesymbols}%
  {OMX}{cmex}{m}{n}
\SetSymbolFont{operators}{bold}%
  {OT1}{cmr}{bx}{n}
\SetSymbolFont{letters}{bold}%
  {OML}{cmm}{b}{it}
\SetSymbolFont{symbols}{bold}%
  {OMS}{cmsy}{b}{n}
\DeclareSymbolFontAlphabet{\mathrm}%
  {operators}
\DeclareSymbolFontAlphabet{\mathnormal}%
  {letters}
\DeclareSymbolFontAlphabet{\mathcal}%
  {symbols}.
```

To obtain the results we want, we select the most suitable symbols font (or largesymbols) font which works the best. What concerns us here are the operators and letters. By default, LATEX uses the cmr operators font for:

1. digits 0–9
2. small delimiters (parentheses, brackets, etc.)
3. punctuation, including ; :
4. uppercase Greek letters
5. most accents
6. the + = signs

CONJECTURE 1.— *Let x, y, z, be integers; for* $\alpha \in \mathbb{N}$, *denote by* $\Omega_\alpha \subset \mathbb{N}$ *the set of prime integers p (called p-primes in the sequel) such that the following equation (known as* Frimas' last equation*)* $x^p + y^p = z^p$ *admits infinitely many solutions divisible by* α. *We conjecture:*

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Evidence for the conjecture.— Denoted by $\mathcal{A}$, $\mathcal{M}$, $\mathcal{O}$, the famous *inferior constants of* WHYLLES, the three following formulae are *very* instructive:

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$$\prod_{j\geqslant 0}\left(\sum_{k\geqslant 0} f_{jk}z^k\right) = \sum_{k\geqslant 0} z^n \left(\sum_{\substack{k_0,k_1,\ldots\geqslant 0\\ k_0+k_1+\cdots=n}} f_{0k_0}f_{1k_1}\ldots\right) \tag{2}$$

$$\text{Look at the product} \quad \textit{ffi}, \quad \{\underbrace{\overbrace{g,\ldots,g}^{k\ g},\overbrace{h,\ldots,h}^{\ell\ h}}_{k+\ell \text{ elements}}\} \quad \textit{taken in the basis } (\vec{\imath},\vec{\jmath}). \tag{3}$$

Moreover, eq. (1) yields
$$\pm\sqrt{\begin{vmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \end{vmatrix}} > 0.$$

Figure 10: Text in Utopia, with the mathfont option.

This extensive use of text characters in math mode is one of TEX's pitfalls (font changes are therefore very risky, particularly in plain).[11] While it may be natural to use the digits from the default text font, it's not likely that uppercase Greek letters will be found there. Parentheses and the + and = signs warrant a brief detour. Parentheses should be consistent with their larger versions, and thus should come from the text font and matching extension font, all within the same font family (just as cmr and cmex are part of the CM family). The = sign is rather critical in that it joins the combinations $\Leftarrow$ and $\Rightarrow$ to produce $\Longleftrightarrow$. Thus, it's really part of math characters; unfortunate that it's not part of a specific math font (the − sign has the same function in simple arrows such as $\longleftrightarrow$ even though it's part of the symbols font).

What mathfont does is define a second set of operators, called *textoperators*, and then it tells LATEX to take the digits and accents from there (which is a bit risky if you're accenting letters in math mode that aren't from the same font ...). This yields:

```
\DeclareSymbolFont{textoperators}   {\ED}%
  {\rmdefault}{m}{n}
\SetSymbolFont{textoperators}{normal}{\ED}
  {\rmdefault}{m}{n}
\SetSymbolFont{textoperators}{bold} {\ED}%
  {\rmdefault}{b}{n}
\DeclareMathSymbol{0}{\mathalpha}%
    {textoperators}{`0}
  (...)
\DeclareMathSymbol{;}{\mathpunct}%
    {textoperators}{"3B}
  (...)
% Attention: only in OT1 encoding
\DeclareMathAccent{\hat}{\mathalpha}%
    {textoperators}{"5E}
  (...)
```

Thus, using fontmath.ltx as a guide, it's possible to create a new symbols font, selecting the characters that will be in it.

[11] This can only be addressed by the development of new font encodings, clearly differentiating text fonts (T1, for example) from text symbol complements (as in TS1) and math symbols (MC, MSP, currently being worked on by a TEX Users Group Technical Working Group).

The math italic font can be copied in the same way. By default, LaTeX uses the letters font (cmmi) for the following:

1. regular letters (without accents)
2. a few punctuation signs, such as , .
3. the italic Greek letters
4. some letter-type symbols that are very useful, such as \imath ($\imath$), \jmath ($\jmath$), \ell (ℓ), \partial (∂), some of the "harpoons" (e.g., \leftharpoonup ($\leftharpoonup$)
5. some of the relatively useless symbols, such as \smile ($\smile$);
6. the only 'accent' that's not in a text font: \vec ($\vec{}$)

If the selected font is a standard PostScript font, it will only include letters and punctuation signs — the rest have to be found elsewhere. For example, in mathfont.sty:

```
\DeclareSymbolFont{textletters}{\ED}%
  {\rmdefault}{m}{it}
\SetSymbolFont{textletters}{normal}{\ED}%
  {\rmdefault}{m}{it}
\SetSymbolFont{textletters}{bold}{\ED}%
  {\rmdefault}{b}{it}
\DeclareMathSymbol{a}{\mathalpha}%
    {textletters}{`a}
  (...)
\DeclareMathSymbol{A}{\mathalpha}%
    {textletters}{`A}
  (...)
\DeclareMathSymbol{,}{\mathpunct}%
    {textletters}{"3B}.
```

A word on the specific case of \imath and \jmath: the first is standard in PostScript fonts (under the name *dotlessi*), whereas the second is absent.[12] Using the base ($\vec{\imath}, \vec{\jmath}$) as a reference, it's clear that you can't use characters that are too different. As well, a word of warning about my decision to use a text font family *with its default encoding* — the choice was made purely as a way of limiting the amount of memory TeX would allocate to the font metrics. Unlike the other characters modified up to this point in the article, $\imath$ without a dot does not occupy the same slot in T1 or OT1 encodings. This method raises two additional problems:

- the number of font families declared at the same time is limited to sixteen. Each new declaration takes up one of these slots, so the method is not economic and carries certain risks.

- Math fonts and text fonts do not adhere to the same imperatives. We have to keep in mind that our initial problem revolves around the aesthetic impressions some glyphs have over others, whereas TeX doesn't really care about glyphs, just their 'metrics', via the tfm file. In math mode, each character is an atom, which must be placed relative to other such characters, according to its type (relation, delimiter, etc.). This is why \fontdimens 2, 3, 4 and 7 have a zero value in cmmi.[13] Although one can modify these global parameters dynamically from the (LA)TeX source (in the .fd file, for example), they would be attached to the font being loaded once only, which means it's not possible to call up the same font twice, using two different names, and assigning each one different parameters. Thus, to preserve the normal italics for text, the mathfont option produces atypical italics for math. The \fontdimen issue isn't too troubling since TeX suppresses spaces in math mode; at the same time, though, it's not possible to suppress kerning or ligatures between letters, which can lead to some odd results for something like Te or ffi: *Te ffi*. Similarly, TeX assumes that the side bearings (the lateral space which a designer adds to ensure that two characters of the same font don't touch) are as generous as those of its default fonts, which isn't really the general case. Super- and subscripts can end up looking like they're touching. If you use mathfont, you have to keep these points in mind: don't hesitate to include explicit kerning instructions (\mkern) to avoid inopportune ligatures and adjust the spacing.

The only way to get a math font, in terms of glyphs, similar to the one I've tried to obtain with mathfont (but uniform in terms of its metrics and independent of coding hazards) is to create a virtual font by using the same scheme, but making it more solid — and thus less flexible.

[12] The 'successful' examples presented here demonstrate three reasonable alternatives for *dotlessj*. (1) Since Utopia's $\imath$ is fairly similar to the $\jmath$ in Lucida, I used these two glyphs (of different origins) in Fig. 11. (2) This ruse is not possible for Apollo, so I simply edited the Apollo font and created a new character, copying j and removing the dot. (3) For Fig. 13, I was able to directly parameterize the PostScript fonts, using a *header* that Bernard Desruisseaux graciously provided, and thus magically removed the dot from the j and made it the same height as a virtual $\jmath$.

[13] Respectively, these \fontdimen establish the space to put between words, the maximum space to add or take away, and the special spaces after punctuation (as used in Anglo-Saxon typography).

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$$\prod_{j \geqslant 0} \left(\sum_{k \geqslant 0} f_{jk} z^k \right) = \sum_{k \geqslant 0} z^n \left(\sum_{\substack{k_0, k_1, \ldots \geqslant 0 \\ k_0 + k_1 + \cdots = n}} f_{0k_0} f_{1k_1} \ldots \right) \tag{2}$$

$$\text{Look at the product} \quad f\, f\, i, \quad \underbrace{\{\overbrace{g, \ldots, g}^{k\, g}, \overbrace{h, \ldots, h}^{\ell\, h}\}}_{k+\ell \text{ elements}} \quad \textit{taken in the basis } (\vec{\imath}, \vec{\jmath}). \tag{3}$$

Moreover, eq. (1) yields $\pm \sqrt{\begin{vmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \end{vmatrix}} > 0.$

Figure 11: Text in Utopia, math fonts based on Lucida and Computer Modern.

3.3 Virtual fonts

Creating a virtual font with fontinst [7] (see [5] for many concrete examples similar to the ones presented here) essentially comes down to understanding the \installfont command. This generates a vpl file, which is a human-readable equivalent of the virtual font (vf). The following shows how the two fonts we're using from the mathptm distribution are created:

```
\installfamily{OT1}{ptmcm}{}
\transformfont{ptmr8r}{\reencodefont{8r}%
                       {\fromafm{ptmr8a}}}
\installfont{zptmcmr}%
  {ptmr8r,psyr,latin,zrhax,kernoff,cmr10}%
  {OT1}{OT1}{ptmcm}{m}{n}{}

\installfamily{OML}{ptmcm}%
          {\skewchar\font=127}
\transformfont{ptmri8r}{\reencodefont{8r}%
                        {\fromafm{ptmri8a}}}
\installfont{zptmcmrm}
  {kernoff,cmmi10,kernon,unsetalf,%
   unsethum,ptmri8r,psyr,mathit,%
   zrmhax}%
  {OML}{OML}{ptmcm}{m}{it}{}.
```

As you can see, the \installfont command has eight arguments:

- the first is the name (for the tfm and vf files for the font being generated)
- the second argument contains the set of file names (with extension .mtx) needed for creating *metrics* for each character
- the third indicates the internal coding used by fontinst for the font in question
- the next four arguments specify the parameters which allow LaTeX to identify the font via the fd file, created by the \installfamily command
- the last argument makes it possible to configure the declaration contained in the fd file. This argument can be very useful for installing several virtual fonts that address optical scaling.

It's now possible to see that mathptm will install its operators font (replacing cmr in math) by using characters taken from ptmr8r, psyr and cmr10 (that is, Times Roman re-encoded as 8r for all the glyphs, Symbol, and Computer Modern roman). The order of these is important because all the glyphs required

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$$\prod_{j\geqslant 0}\left(\sum_{k\geqslant 0} f_{jk}z^k\right) = \sum_{k\geqslant 0} z^n \left(\sum_{\substack{k_0,k_1,\ldots\geqslant 0\\ k_0+k_1+\cdots=n}} f_{0k_0}f_{1k_1}\ldots\right) \tag{2}$$

(3) Look at the product $ffi,\quad \underbrace{\{\overbrace{g,\ldots,g}^{k\ g},\overbrace{h,\ldots,h}^{\ell\ h}\}}_{k+\ell\ \text{elements}}$ *taken in the basis* $(\vec{\imath},\vec{\jmath})$.

Moreover, eq. (1) yields $\pm\sqrt{\begin{vmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \end{vmatrix}} > 0.$

Figure 12: Text in Apollo, math fonts based on Computer Modern.

by an OT1 font are present in cmr10, yet fontinst follows the order in which it finds the glyphs needed for the encoding: letters are thus acquired from Times or, if they aren't there, they have to be 'simulated', thanks to macros in the file latin.mtx; the Greek uppercase letters come from the Symbol font. However, as mentioned previously, it can be risky using some Times glyphs, such as `( ) [ ] + =`, so the zrhax.mtx file removes them from fontinst's memory so that they're selected from cmr10 instead. The kernoff.mtx file in turn suppresses the kerning that comes from cmr10; the resultant zptmcmrm font which is thus created will therefore be an *ersatz* font, providing symbols usable as operators without risk. The characters are accessed by the following declaration (which appears in mathptm.sty):

```
\DeclareSymbolFont{operators}%
  {OT1}{ptmcm}{m}{n}
```

The font zptmcmrm which replaces cmmi is obtained in the same way: you take all the glyphs from cmmi10 (but leave their kerning behind), the unsetalf and unsethum files remove the lowercase Greek letters, and the italics provided by Symbol and Times Italic (respectively), mathit plays the role of latin for the OML fonts, and zrmhax adjusts certain spacing parameters which would not be acceptable if this font were nothing but a regrouping of characters from different sources. For the same reasons as we saw with mathfont, the side-bearings, which are distinctly more restricted in Times than in Computer Modern, are enlarged; accent positions in math mode, which are controlled through a special mechanism: pseudo kern pairs, with the so-called \skewchar, are enhanced. Thanks to fontinst, it's possible to correct all the shortcomings of the mathfont option, i.e., by specifically using glyphs chosen for aesthetic reasons (but arranged in the standard LaTeX encoding), and by adjusting all the metric parameters (kerning, side-bearings, etc.), so they can be made to work optimally in mathematics. The only thing missing from these examples is the command *scaled*, which makes it possible to adjust to the same value the x-heights of the various fonts mixed into a single font. Another advantage not to be discounted with the 'virtual font' solution: since it yields fonts which can replace the 'original versions' of Computer Modern, it is also very easy to use with *all* TEX dialects or formats (even *plain*). On the other hand, one could say that adjusting metric parameters is a subtle business, and should be left to a true typographer ...

The examples I've presented throughout this article were produced with a certain degree of haste — they are far from being optimal. It's not really feasible for me to distribute the virtual fonts I've been describing, because most are just the result of combining various bits of commercial fonts — which is why a finished package is not available. On the other hand, I will try to share the skills I've acquired with difficulty. I don't believe in a set of macros that can systematically generate virtual math fonts for, say, Palatino, Times, and New Century Schoolbook. These fonts are too different: it's impossible for any given symbol not to clash with any one of them. As well, there are problems adjusting the x-heights and side-bearings that simply can't be dealt with in a generic way.

I'll finish off this presentation with a concrete demonstration (used in *plain* TEX by the secretaries at the Fourier Institute). The text font is T1 Utopia Expert scaled down to the x-height of cmr10. Utopia, which has a dark color to it, doesn't really work with cmmi, although the symbols in cmsy/cmex don't clash once they've been scaled down. After a few attempts, I finally chose Lucida for the upper- and lowercase Greek letters, Utopia Italic for math italics, and Utopia Expert for *oldstyle* digits. This yields the following:

```
\installfamily{OML}{putluc}%
  {\skewchar\font=127}
\transformfont{putri8r}{\reencodefont{8r}%
                        {\fromafm{putri8a}}}
\installfont{zputlucm}%
  {kernoff,hlcrim scaled 804,kernon,%
   unsetalmf,unsetos,putri8r scaled 880,%
   putr8x scaled 880,utmathit,zrmuthax}%
  {OML}{OML}{putluc}{m}{it}{}
\installfamily{OT1}{putluc}{}
\transformfont{putr8r}{\reencodefont{8r}%
                       {\fromafm{putr8a}}}
\transformfont{hlcr7t}{\reencodefont
                               {OT1luc}%
                       {\fromafm{hlcr8a}}}
\installfont{zputluc7t}
  {putr8r scaled 880,putr8x scaled 880,%
   hlcr7t scaled 840,latin,zrhax,%
   kernoff,cmr10}%
  {OT1}{OT1}{putluc}{m}{n}{}
```

You can see that I've modified a few mathptm files, and have introduced a new unsetos to suppress the oldstyle digits, so that they come from the expert font rather than from cmmi.[14] One final example with Apollo. Since this is a lighter face, I decided to plunder Computer Modern for all the math symbols that don't exist in Apollo.

```
\installfamily{OML}{mapcm}%
  {\skewchar\font=127}
\transformfont{mapri8r}{\reencodefont{8r}%
                        {\fromafm{mapri8a}}}
\installfont{zmapcmm}
  {kernoff,cmmi10,kernon,unsetalmf,%
   unsetos,mapri8r scaled 1067,%
   mapr8x scaled 1067,apmathit,zrmaphax}%
  {OML}{OML}{mapcm}{m}{it}{}
\installfamily{OT1}{mapcm}{}
\transformfont{mapr8r}{\reencodefont{8r}%
                       {\fromafm{mapr8a}}}
\installfont{zmapcm7t}
  {mapr8r scaled 1067,mapr8x scaled 1067,%
   cmlatin,zrhax,kernoff,cmr10}%
  {OT1}{OT1}{mapcm}{m}{n}{}
```

4 Conclusion

I've illustrated different possible solutions in the above examples for Utopia and Apollo.[15] The principle behind these various illustrations has been the following: maintain the identical text each time, and change only the preamble, which takes care of modifying the fonts to be used via 'standard' NFSS (the equivalent of times.sty; see FIG. 8, 9), macros such as mathfont (FIG. 10), and ending up with composite virtual fonts, as described above (FIG. 11, 12). While the defects in mathfont are obvious enough (poor spacing around parentheses, the *ffi* ligature problem), you have to keep in mind that they can be fixed manually, which is a do-able operation in a document without a lot of math formulae and typeset by someone who knows what they're doing. After demonstrating the three comprehensive font systems available — Computer Modern (FIG. 1), Lucida (FIG. 2) and MathTime (FIG. 4), plus Mathptm (FIG. 6) — I have shown what you can get, starting from two text fonts of incompatible design with math characters from either Computer Modern or Lucida.

The Apollo example, although somewhat marginal (I don't see it used that often), does show the benefits of the approach I use. Its style is wildly

[14] This manoeuver doesn't really have any bearing on LATEX but it does allow the plain TEX \oldstyle command to work.

[15] A related discussion can be found in [2]. The task there was to modify not only the typography but also the layout of a LATEX book.

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$$\prod_{j \geqslant 0} \left(\sum_{k \geqslant 0} f_{jk} z^k \right) = \sum_{k \geqslant 0} z^n \left(\sum_{\substack{k_0, k_1, \ldots \geqslant 0 \\ k_0 + k_1 + \cdots = n}} f_{0k_0} f_{1k_1} \ldots \right) \tag{2}$$

$$\text{Look at the product} \quad f\,f\,i, \quad \{\underbrace{\overbrace{g, \ldots, g}^{k\ g}, \overbrace{h, \ldots, h}^{\ell\ h}}_{k+\ell \text{ elements}}\} \quad \textit{taken in the basis } (\vec{\imath}, \vec{\;}). \tag{3}$$

$$\text{Moreover, eq. (1) yields} \qquad \pm \sqrt{\begin{vmatrix} x_1 - x_2 & y_1 - y_2 & z_1 - z_2 \\ l_1 & m_1 & n_1 \\ l_2 & m_2 & n_2 \end{vmatrix}} > 0.$$

Figure 13: Text in Minion MM, math fonts based on Computer Modern.

incompatible with Computer Modern yet its proportions and, above all, its color, are quite similar: once you remove the style incompatibility between them by using text italics in math, you get an undeniable uniformity and quality. Here's a list of fonts often used in books, which seem to me to lend themselves, without too much damage, to the games I've been playing with Apollo: Bembo, Adobe Garamond, Garamond Three, Granjon, Plantin *Light*, Times *Light*. Also possible, but probably without the same degree of uniformity, are Adobe Caslon, Galliard, or Baskerville. To complement Palatino, Melior, Stempel Schneidler, New Century Schoolbook, I'd think of Lucida. While Stone or Rotis could prefer MathTime symbols.

To conclude on a more pessimistic note: the French version of this article [3] was typeset in Minion — for me, one of the most beautiful fonts currently available, remarkably readable and elegant at the same time.[16] Today, I would choose it without hesitation for a good-quality journal. Unfortunately, the Minion design displays its acknowledgement of the Italian and French Renaissance too clearly. The initial version of this article had been prepared with the *Single Master* version (used by the journal *Libération*), which gave the page a relatively dark color, but not as dark as either Times or Lucida. And for this reason, none of the three basic fonts can complete it, even though MathTime is probably the least problematic. Just as this article was being finished, I installed the *Multiple Master* version of Minion, which makes it possible to incrementally vary the thickness, the width, and the optical size yet still maintain a consistent design. As we've seen, this last property is crucial for the readability of smaller point sizes (superscripts, for example), and it's one of this font's undeniable advantages.

I've tried to experiment with the thinnest and widest instances so that color and proportion converged as much as possible with those of Computer Modern.[17] It's interesting to note that Hilmar Schlegel reports getting quite satisfactory results by

[16] They say that Minion's on its way to becoming the 'Times of the 21st century', which is why I'm in a hurry to use it now before it becomes too passé!

[17] The complete interface for production of the French version of this article will eventually become available on CTAN, as an example. A pre-version is already somewhere on my home site: see `ftp://fourier.ujf-grenoble.fr/pub/contrib-tex/psfonts/adobe`.

using a similar method, but with a combination of a fairly bold and slightly narrowed Minion face with MathTime. Fig. 13 shows how this "works" quite respectably under 'real' conditions. Nevertheless, one can see that each glyph from the Computer Modern family is a surprise to the eye, and that there really is no alternative to it, at least regarding Greek letters.

Thanks — I went into this article without any idea where it would all end. Since I'm neither a programmer nor a typographer, nor a (LA)TEX guru (much less one in PostScript), a certain number of unexpected roadblocks came up along the way. I'd like to thank everyone who helped me over these hurdles. In particular, I'd like to mention Jacques André, Bernard Desruisseaux and Hilmar Schlegel for their constructive criticisms and technical help, which made it possible for me to write this paper. Last but not least, it's a pleasure to thank Christina Thiele who undertook the present translation with patience & skill.

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