The concmath package

Ulrik Vieth

1999-03-10 v2.0

1 About this package

The concmath package for LaTeX 2ε provides access to the Concrete Math fonts that were derived from the Concrete Roman fonts designed by Don Knuth [1, 2]. While the Concrete Roman fonts were originally developed as a text fonts to be used in combination with the AMS Euler fonts in math mode, the Concrete Math fonts provides a complementary set of math fonts, so that the Concrete typefaces may be used as a complete replacement for Computer Modern [3].

Loading the concmath package without any options has the effect of switching the default text font family to Concrete Roman and redeclaring the default math symbol fonts and math alphabets to use Concrete Math. In addition, the concmath package also provides the following package options that may be used to activate some extra features:

The 'exscale' option: This option provides the functionality of the 'exscale' package from the LaTeX base distribution, but using scaled sizes of the Concrete version of the math extension font instead of Computer Modern.

The 'amsfonts' and 'amssymb' options: These options provide the functionality of the standard 'amsfonts' and 'amssymb' packages, but using the Concrete versions of the AMS symbol fonts and math alphabets.

The 'sansbold' option: This option redefines the default bold series to use semibold condensed, thereby replacing the bold extended version of Computer Modern Roman by the semibold condensed version of Computer Modern Sans Serif in bold material such as titles and section headings. Since there are different opinions among package writers as to which of these choices is better suited for use in combination with Concrete Roman, both have been used in various LaTeX packages [4, 5, 6] and both are supported in this package as well.

Before we eventually get to the implementation of the concmath package and the corresponding font definition files, we shall first review the history of the Concrete Roman and Concrete Math font families. In particular, we shall discuss the procedure how the Concrete Math fonts were derived from the Concrete Roman fonts by applying systematic changes to the METAFONT parameter files.

2 History of the 'Concrete Roman' fonts

When Don Knuth and his co-authors wrote *Concrete Mathematics* [1, 2], they decided to make their book typographically interesting by making it the first one to use a new family of typefaces. The book was to be set using the AMS Euler fonts designed by Hermann Zapf, replacing the usual Computer Modern fonts in math mode. As for the text font, the original intention was to use Computer Modern Roman as usual. However, the combination of Computer Modern in text mode and Euler in math mode soon turned out to be unsatisfactory, and Don Knuth eventually set out to develop a heavier variant of Computer Modern Roman that was better suited to match the somewhat darker color of the Euler fonts.

The result was a square-serif style typeface named Concrete Roman, along with *italics*, *slanted*, and SMALL-CAPS variants for emphasis and various mark-up elements. Unlike Computer Modern Roman, Concrete Roman features a relatively uniform stroke thickness and does not exhibit strong contrasts between hairlines and stems, making it particularly robust for use in low-resolution printing, but also in display-oriented applications such as transparencies or posters.

The original distribution of Knuth's Concrete fonts consisted exclusively of text fonts. There was no bold series, nor were there any math fonts, since the latter were to be taken from the Euler fonts (or Computer Modern for the geometric math symbols). While there does exists a Concrete Math Italics font shape, `ccmi10`, this does not actually represent a math font and was not designed to be used as such. It only serves as an extra text font that provides access to the oldstyle numerals 0123456789 and miscellaneous text symbols, such as the tie accent. However, given the meta-ness inherent in the designs of the Computer Modern typefaces [3], it is relatively easy to develop a complete set of Concrete math fonts by applying some simple heuristics, as we shall see in the following section.

3 Design of the 'Concrete Math' fonts

The Concrete Math fonts (also known as '`concmath`' fonts) were developed by the author in early 1995, originally for use in a poster presentation. When the use of magnified sizes of Computer Modern math fonts printed at low resolution turned out to be unsatisfactory for comfortable reading in poster sizes, the need for a somewhat darker alternative became apparent. Since the only existing alternative would have been to use the AMS Euler fonts in math mode, which were deemed a little too exotic for the intended application, the author set out to investigate the possibilities of generating a complete set of Concrete Math fonts by applying systematic changes to the METAFONT parameter files.

An initial comparison of the existing parameter files for `ccr10` and `ccmi10` revealed that they were almost identical except for the font identifier, the slant

font encoding:	OT1	OML	OMS	OMX	U+msa	U+msb
font name:	`ccr10`	`xccmi10`	`xccsy10`	`xccex10`	`xccam10`	`xccbm10`
font identifier:	`"CCR"`	`"CCMI"`	`"CCSY"`	`"CCEX"`	`"CCAM"`	`"CCBM"`
parameters:	—	`ccr10`	`ccr10`	`ccr10`	`ccr10`	`ccr10`
fontdimens:	—	—	`cmsy10`	`cmex10`	`cmsy10`	`cmsy10`
slant:	0	0.25	0.25	0	0	0.25
variant_g:	**false**	**true**	irrelevant	irrelevant	irrelevant	irrelevant
math_fitting:	**false**	**true**	**true**	**false**	**true**	**true**
generate:	`roman`	`mathit`	`mathsy`	`mathex`	`amsya`	`amsyb`

Table 1: Comparison of the parameters for the Concrete Math typefaces.

parameter, several boolean variables, and the call to the METAFONT driver file. Unlike in the case of `cmr10` and `cmmi10`, there were no differences in the design parameters governing the appearance of the character shapes, so it became almost trivial to generate a full set of Concrete Math Italics fonts in the usual range of sizes between 5 pt and 10 pt by starting from the `ccr` parameter files and applying the necessary systematic changes listed in Table 1 to produce a math font.

The resulting font shapes were called `xccmi` where the prefix 'x' was used to avoid any potential name conflicts with font shapes from Don Knuth's distribution of the Concrete fonts, particularly in the case of `ccmi10`, which despite its name is not a real math font, as discussed earlier.

After the Concrete Math Italics fonts were in place, the next step was to create suitable math symbol and math extension fonts. Once again, the author started with a comparison of the parameter files of the corresponding Computer Modern fonts, which revealed that `cmmi` and `cmsy` were identical except for the font identifier, the driver file, and the extra `\fontdimen` parameters in `cmsy` that are required for use as a math symbol font in `\textfont2`. Similarly, the parameters of `cmex` matched those of `cmr` except for the font identifier, the driver file, and the `\fontdimens` in `cmex` for a math extension font in `\textfont3`.

In both cases, the corresponding Concrete versions, named `xccsy` and `xccex`, could be derived easily by starting from `xccmi`, applying some systematic changes, and merging in the code for the `\fontdimen` parameters from `cmsy` or `cmex`. Since the details of these parameter calculations weren't documented anywhere, not even in Knuth's *Computer Modern Typefaces* [3], the author unfortunately had to rely on adapting whatever was there and hoping that it would somehow work for Concrete Math just as well.

Finally, to round off the collection, the author also generated Concrete versions of the AMS math symbol fonts `msam` and `msbm`, which were called `xccam` and `xccbm`. As in the previous cases, the METAFONT parameter files of the fonts in question were compared to those of the Computer Modern math fonts, and it was found that

both AMS symbol fonts were based on the cmsy parameters. The corresponding Concrete versions were then generated by starting from xccsy and applying the usual systematic changes. In the case of xccam, which also contains some text symbols '®' and '©' based on small-caps parameters, the "lower" parameters were taken from cccsc10 in the 10 pt version, but from msam in the smaller sizes for lack of any other alternatives. While this may not give optimal results for the circled letters, it shouldn't have any adverse effect on the math symbols.

4 The implementation

After having reviewed the history of the Concrete Roman and Concrete Math fonts, we now turn to the implementation of the concmath LaTeX package and the corresponding font definition files.

4.1 Hello, World!

First, we announce the package and the font definition files.

```
⟨package⟩\NeedsTeXFormat{LaTeX2e}[1996/12/01]
⟨package⟩\ProvidesPackage{concmath}
⟨OT1ccr⟩\ProvidesFile{ot1ccr.fd}
⟨OMLccr⟩\ProvidesFile{omlccr.fd}
⟨OMSccr⟩\ProvidesFile{omsccr.fd}
⟨OMLccm⟩\ProvidesFile{omlccm.fd}
⟨OMSccsy⟩\ProvidesFile{omsccsy.fd}
⟨OMXccex⟩\ProvidesFile{omxccex.fd}
⟨Ucca⟩\ProvidesFile{ucca.fd}
⟨Uccb⟩\ProvidesFile{uccb.fd}
⟨+package⟩[1999/03/10 v2.0b LaTeX package for Concrete math fonts]
⟨−package⟩[1999/03/10 v2.0b LaTeX font defs for Concrete math fonts]
```

4.2 Font definition files

4.2.1 Concrete Roman

Here are the standard font definitions for Concrete Roman, including the *italics*, *slanted*, and SMALL-CAPS variants, which are usually only available in 10 pt size. While it would be a trivial exercise to create a full set of slanted fonts by taking the ccr parameter files and setting the slant parameter to 1/6 in the ccsl parameter files, we shall only use the sizes provided in Knuth's official distribution. As for the italics and small-caps versions, there is no way to generate appropriate smaller sizes without extensive tuning and testing to derive new parameter sets.

```
⟨*OT1ccr⟩
```

```
\DeclareFontFamily{OT1}{ccr}{\hyphenchar\font45 }
\DeclareFontShape{OT1}{ccr}{m}{n}{
  <5> <6> <7> <8> <9> gen * ccr
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> ccr10}{}
\DeclareFontShape{OT1}{ccr}{m}{sl}{
  <5> <6> <7> <8> <9> ccsl9
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> ccsl10}{}
\DeclareFontShape{OT1}{ccr}{m}{it}{
  <5> <6> <7> <8> <9>
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> ccti10}{}
\DeclareFontShape{OT1}{ccr}{m}{sc}{
  <5> <6> <7> <8> <9>
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> cccsc10}{}
```

Next, here are the font substitutions for the bold series. Since there is no bold series in Concrete, we will use the corresponding Computer Modern fonts.

```
\DeclareFontShape{OT1}{ccr}{bx}{n} {<-> ssub * cmr/bx/n}{}
\DeclareFontShape{OT1}{ccr}{bx}{sl}{<-> ssub * cmr/bx/sl}{}
\DeclareFontShape{OT1}{ccr}{bx}{it}{<-> ssub * cmr/bx/it}{}
```

Next, here are the font substitutions for the semibold series. As we shall see below, the `concmath` package provides a 'boldsans' option which redefines `\bfdefault` and thus turns all bold material into semibold condensed (which will then be substituted by semibold condensed sans serif). Since some people prefer to use semibold condensed Computer Modern Sans Serif in combination with Concrete Roman, this unusual substitution allows to switch between both choices by selecting or omitting a package option.

```
\DeclareFontShape{OT1}{ccr}{sbc}{n} {<-> ssub * cmss/sbc/n}{}
\DeclareFontShape{OT1}{ccr}{sbc}{sl}{<-> ssub * cmss/sbc/n}{}
\DeclareFontShape{OT1}{ccr}{sbc}{it}{<-> ssub * cmss/sbc/n}{}
```

Finally, here is the font shape declaration for the special purpose condensed slanted font that was used in *Concrete Mathematics* for so-called 'graffiti'. The `concmath` package does not bother to provide macros for such kinds of marginal notes, thus users who want to use this feature will have to develop their own.

```
\DeclareFontShape{OT1}{ccr}{c}{sl}{<9> ccslc9}{}
```
⟨/OT1ccr⟩

4.2.2 Concrete Roman Font Substitutions

For technical reasons it necessary to provide font substitutions for Concrete Roman text symbols in the 'OML' and 'OMS' encodings. Any references to `ccr` in these encodings will be substituted by references to the corresponding Concrete math italics and math symbol fonts.

```
⟨*OMLccr⟩
\DeclareFontFamily{OML}{ccr}{\skewchar\font127 }
\DeclareFontShape{OML}{ccr}{m}{it}  {<->ssub * ccm/m/it}{}
\DeclareFontShape{OML}{ccr}{bx}{it} {<->ssub * ccm/b/it}{}
\DeclareFontShape{OML}{ccr}{sbc}{it}{<->ssub * ccm/m/it}{}
⟨/OMLccr⟩
⟨*OMSccr⟩
\DeclareFontFamily{OMS}{ccr}{\skewchar\font48 }
\DeclareFontShape{OMS}{ccr}{m}{n}  {<->ssub * ccsy/m/n}{}
\DeclareFontShape{OMS}{ccr}{bx}{n} {<->ssub * ccsy/b/n}{}
\DeclareFontShape{OMS}{ccr}{sbc}{n}{<->ssub * ccsy/m/n}{}
⟨/OMSccr⟩
```

4.2.3 Concrete Math Italics

Now, we turn to the font definitions for Concrete Math Italics. Since the `xccmi` parameters were derived from `ccr` with some systematic changes, these fonts are available in the same range of sizes, i.e. between 5 pt and 10 pt.

```
⟨*OMLccm⟩
\DeclareFontFamily{OML}{ccm}{\skewchar\font127 }
\DeclareFontShape{OML}{ccm}{m}{it}{
  <5> <6> <7> <8> <9> gen * xccmi
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> xccmi10}{}
\DeclareFontShape{OML}{ccm}{b}{it}{<-> ssub * cmm/b/it}{}
```

Similar to the 9 pt slanted condensed text font for use in 'graffiti', there also exists a 9 pt slanted condensed version of Concrete Math Italics, stripped down to the oldstyle numerals only. This font shape is included here only for completeness, and users should be aware that it won't be usable as a math font.

```
\DeclareFontShape{OML}{ccm}{c}{it}{<9> ccmic9}{}
⟨/OMLccm⟩
```

4.2.4 Concrete Math Symbols

Here are the font definitions for the Concrete Math Symbol fonts. Since the `xccsy` parameters are identical to those of `xccmi` except for the extra `\fontdimen` parameters (which were adapted from `cmsy`), these fonts are available in the same range of sizes as Concrete Roman and Concrete Math Italics.

Most of the geometric math symbols that depend only on the rule thickness will probably turn out to be identical to their Computer Modern counterparts. However, since the 'OMS' encoding also contains a few greek-like symbols such as '∇' and '$\amalg$' that are clearly affected by the parameter changes, a Concrete version of the math symbol font is obviously necessary.

```
⟨*OMSccsy⟩
\DeclareFontFamily{OMS}{ccsy}{\skewchar\font48 }
\DeclareFontShape{OMS}{ccsy}{m}{n}{
  <5> <6> <7> <8> <9> gen * xccsy
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> xccsy10}{}
\DeclareFontShape{OMS}{ccsy}{b}{n}{<-> ssub * cmsy/b/n}{}
⟨/OMSccsy⟩
```

4.2.5 Concrete Math Extension

Here are the font definitions for the Concrete Math Extension fonts. Since the xccex parameters are identical to those of ccr except for the extra \fontdimen parameters (which are adapted from cmex), these fonts are available in the same range of sizes as Computer Modern Math Extension, i.e. between 7 pt and 10 pt. By default, the math extension font is loaded only in a fixed size at 10 pt. However, the concmath package also provides an 'exscale' option to load the math extension font in scaled sizes.

```
⟨*OMXccex⟩
\DeclareFontFamily{OMX}{ccex}{}
\DeclareFontShape{OMX}{ccex}{m}{n}{<-> sfixed * xccex10}{}
⟨/OMXccex⟩
```

4.2.6 Concrete AMS Symbols

Finally, here are the font definitions for the Concrete versions of the AMS symbol fonts, msam and msbm. Since the parameters of xccam and xccbm are directly derived from xccsy, these fonts are provided in the full range of sizes between 5 pt and 10 pt.

As in the case of the Concrete Math Symbol font, most of the geometric math symbols will probably remain unchanged from the Computer Modern version, but letter-like symbols such as '¥', '℧', 'ð' or 'ɘ' will obviously be subject to the parameter changes in the Concrete version, making it necessary to have Concrete versions of the AMS symbol fonts in the first place.

Unfortunately, it appears that some of the characters in the AMS symbol fonts do not work out very well in the Concrete version or suffer from undesirable side-effects. One such problem is that wide accents are getting much heavier than usual:

$$\tilde{i} \quad \widetilde{ii} \quad \widetilde{iii} \quad \widetilde{iiii} \quad \widetilde{iiiiii} \quad \widetilde{iiiiiii}$$

Another problem is that some characters, such as '$\varkappa$' or '$\digamma$', do not reflect the parameter changes for a Concrete version and still exhibit noticeable contrasts between stems and hairlines typical of Computer Modern fonts. It is possible that this behavior may be due to sub-optimal or inappropriate METAFONT coding.

However, the author decided to refrain from changes to the AMS font sources for the sake of compatibility.

```
⟨*Ucca⟩
\DeclareFontFamily{U}{cca}{}
\DeclareFontShape{U}{cca}{m}{n}{
  <5> <6> <7> <8> <9> gen * xccam
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> xccam10}{}
⟨/Ucca⟩
```

```
⟨*Uccb⟩
\DeclareFontFamily{U}{ccb}{}
\DeclareFontShape{U}{ccb}{m}{n}{
  <5> <6> <7> <8> <9> gen * xccbm
  <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> xccbm10}{}
⟨/Uccb⟩
```

4.3 The concmath package

After we have discussed the font definition files, we now turn to the concmath package itself, starting with the declaration of package options.

4.3.1 Declaring package options

As mentioned in the introduction, the concmath package provides an 'exscale' option that provides the functionality of the 'exscale' package from the LaTeX base distribution, but using the Concrete version of the math extension font.

Since it doesn't seem to be possible to nest a \DeclareFontShape declaration within the \AtBeginDocument hook, we have to make use of a global switch \ifcc@exscale and put the relevant code directly into the package file to be executed immediately after \ProcessOptions. Apart from this minor complication, the code for this option is relatively simple. We just load the default LaTeX 'exscale' package and redeclare the largesymbols symbol font afterwards.

```
⟨*package⟩
\newif\ifcc@exscale \cc@exscalefalse
\DeclareOption{exscale}{%
  \cc@exscaletrue % something to do after \ProcessOptions
  \AtBeginDocument{\RequirePackage{exscale}
    \DeclareSymbolFont{largesymbols}{OMX}{ccex}{m}{n}}}
```

The declaration of 'amsfonts' and 'amssymb' options is similar, but slightly easier. Here, wee simply load the relevant LaTeX package files and redeclare the AMS Symbol fonts afterwards using the Concrete versions.

```
\DeclareOption{amsfonts}{%
  \AtBeginDocument{\RequirePackage{amsfonts}
```

```
    \DeclareSymbolFont{AMSa}{U}{cca}{m}{n}
    \DeclareSymbolFont{AMSb}{U}{ccb}{m}{n}
    \DeclareSymbolFontAlphabet{\mathbb}{AMSb}}}
\DeclareOption{amssymb}{%
  \AtBeginDocument{\RequirePackage{amssymb}
    \DeclareSymbolFont{AMSa}{U}{cca}{m}{n}
    \DeclareSymbolFont{AMSb}{U}{ccb}{m}{n}
    \DeclareSymbolFontAlphabet{\mathbb}{AMSb}}}
```

Finally, here is the declaration of the 'boldsans' option that allows to globally turn bold titles and headings into sans serif semibold condensed, if that is what you prefer to use in combination with a Concrete Roman text font.

```
\DeclareOption{boldsans}{%
  \renewcommand{\bfdefault}{sbc}}
```

4.3.2 Setting up defaults for text and math mode

Now, let's finish off the package file with the code to set up the defaults to use Concrete Roman and Concrete Math. For the text, we begin by setting the default text font family to Concrete Roman.

```
\renewcommand{\rmdefault}{ccr}
```

For the math, we redeclare all the standard symbol fonts using the Concrete versions. Since the encodings of these fonts are exactly the same as those of their Computer Modern counterparts, there is fortunately no need to repeat all the tedious `\DeclareMathSymbol` commands from `fontmath.ltx`.

```
\DeclareSymbolFont{operators}   {OT1}{ccr} {m}{n}
\DeclareSymbolFont{letters}     {OML}{ccm} {m}{it}
\DeclareSymbolFont{symbols}     {OMS}{ccsy}{m}{n}
\DeclareSymbolFont{largesymbols}{OMX}{ccex}{m}{n}

\SetSymbolFont{operators} {bold}{OT1}{ccr} {bx}{n}
\SetSymbolFont{letters}   {bold}{OML}{ccm} {b}{it}
\SetSymbolFont{symbols}   {bold}{OMS}{ccsy}{b}{n}
```

After the math symbol fonts have been set up, we also have to redeclare the math alphabets to use the newly defined Concrete versions.

```
\DeclareSymbolFontAlphabet{\mathrm}    {operators}
\DeclareSymbolFontAlphabet{\mathnormal}{letters}
\DeclareSymbolFontAlphabet{\mathcal}   {symbols}
\DeclareMathAlphabet       {\mathbf}{OT1}{ccr}{bx}{n}
\DeclareMathAlphabet       {\mathit}{OT1}{ccr}{m}{it}
```

Finally, we have to adapt the definition of `\oldstylenums` from the LaTeX format to use the Concrete version of the oldstyle numerals 0123456789. It is a little unfortunate that there is still one last remaining hard-wired reference to

Computer Modern fonts in `latex.ltx`, making it necessary to repeat the whole definition with trivial changes, but there's little we can do about it.

Since this package does not try to imitate the look and feel of Knuth's *Concrete Mathematics*, we don't bother about setting up equation numbers to be printed using oldstyle numbers. The latter is a design decision independent of the choice of fonts that's probably better left to the individual application.

```
\def\oldstylenums#1{%
  \begingroup
    \spaceskip\fontdimen\tw@\font
    \usefont{OML}{ccm}{\f@series}{it}%
    \mathgroup\symletters #1%
  \endgroup}
```

4.3.3 Executing options

After all the default values have been set up for Concrete Roman and Concrete Math, all that's left to do is to process the options and take special care of the 'exscale' option. The font shape declarations for the scaled version of the Concrete Math Extension font are embedded directly in the package file rather than an external font definition file, but they will be executed only if the `\ifcc@exscale` flag has been set true during the option processing.

```
\ProcessOptions
\ifcc@exscale
  \DeclareFontFamily{OMX}{ccex}{}
  \DeclareFontShape{OMX}{ccex}{m}{n}{
    <-8> sfixed * xccex7 <8> xccex8 <9> xccex9
    <10> <10.95> <12> <14.4> <17.28> <20.74> <24.88> xccex10}{}
\fi
⟨/package⟩
```

This concludes the implementation of the `concmath` package.

Acknowledgement

Many features implemented in this package have been influenced by several other LaTeX packages [4, 5, 6] that provide a more or less similar functionality. The author has tried to remain compatible with these packages wherever possible, although some design decisions have been taken that may lead to subtle differences. Potential users are invited to analyze and compare these packages, and to choose whatever suits them best. We hope that even if you found that another package provides a better solution for your needs, you may have still learned something interesting about the background of the Concrete Roman and Concrete Math fonts from reading this documentation.

References

[1] Ronald L. Graham, Donald E. Knuth, and Oren Patashnik. *Concrete Mathematics*. Addison-Wesley, 1989.

[2] Donald E. Knuth. *Typesetting Concrete Mathematics*. *TUGboat* 10#1, 31–36, 1989.

[3] Donald E. Knuth. *Computer Mordern Typefaces*. Volume E of *Computers & Typesetting*. Addison-Wesley, 1986.

[4] Frank Jensen. The beton package.
CTAN:macros/latex/contrib/supported/beton/.

[5] Frank Jensen. The euler package.
CTAN:macros/latex/contrib/supported/euler/.

[6] Walter Schmidt. The ccfonts package.
CTAN:macros/latex/contrib/supported/ccfonts/.