The calculation environment
formatting reasoned calculations and calculational proofs

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Abstract
The calculation environment formats reasoned calculations, also called calculational proofs. The notion of reasoned calculations was originally advocated by Wim Feijen and Edsger Dijkstra. The calculation package accepts options fleqn and leqno (with the same effect as \LaTeX options fleqn and leqno, and inherits these from the document class), it allows steps and expressions to be numbered (by \LaTeX equation numbers, obeying the \LaTeX \label command to refer to these numbers), and a step doesn’t take vertical space if its hint is empty. An expression in a calculation can be given a comment; it is placed at the side opposite to the equation numbers.

Calculations are allowed inside hints although numbering and commenting is then disabled.

1 User manual

This package provides the calculation environment, to format reasoned calculations, also called calculational proofs. The steps in the calculation are vertically listed, and each step is accompanied by a (possibly empty) hint, explaining why the step is valid. This style was originally advocated by Wim Feijen and Edsger Dijkstra. The calculation package accepts options fleqn and leqno (with the same effect as \LaTeX options fleqn and leqno, and inherits these from the document class), it allows steps and expressions to be numbered (obeying \LaTeX’s \label command to refer to these numbers). A step doesn’t take vertical space if its hint is empty. An expression in a calculation can be given a comment; it is placed at the side opposite to the equation numbers.

Calculations are allowed inside hints by the subcalculation environment (for small calculations which do not deserve a separate discussion before or after the main calculation), although numbering and commenting is then disabled.

1.1 Example

Here is an example (with options fleqn, leqno, and block, and default step symbol ‘=’); \LaTeX source on the left, output on the right:
1.2 Usage

The \texttt{calculation} environment is used in its most simple form as follows:

\begin{calculation}
\text{EXPRESSION}
\step{HINT}
\text{EXPRESSION}
\step{HINT}
\text{EXPRESSION}
...
\end{calculation}

Each \texttt{HINT} is normal text, each \texttt{EXPRESSION} is mathematical text. Depending on various parameters, the output is, more or less, like this:
Command \stepsymbol defines the default step symbol, = in the above example; it can be
redefined with \renewcommand. Moreover, the calculation environment itself has an
optional parameter, overriding the default step symbol in this specific calculation, and even
each step has an optional parameter giving the step symbol for that particular step. Command
\step* produces a step that is numbered with an equation number, as in LATEX; LATEX
command \label may be used to label the number so that references can be made to it. Command \doNumber inside an EXPRESSION produces an equation number. Command
\comment{TEXT} inside an EXPRESSION produces TEXT at the side of the paper opposite
to the equation number side. So, in full glory, the environment has the following appearance:

\begin{calculation}$[SYMBOL]$
\begin{EXPRESSSION} <-- may contain \doNumber and \comment{TEXT}
\step*[SYMBOL]{HINT}
\begin{EXPRESSSION} <-- may contain \doNumber and \comment{TEXT}
\step*[SYMBOL]{HINT}
\begin{EXPRESSSION} <-- may contain \doNumber and \comment{TEXT}
\end{calculation}

An empty HINT takes no vertical space while the SYMBOL is still vertically centered in between
the two EXPRESSIONs. Both in EXPRESSION and in HINT new lines may be generated by \.
As in LATEX, EXPRESSION may not contain empty lines. Hints may have empty lines, even at
the beginning.

Option block makes the entire hint (possibly several lines) into one block which, as a
whole, is surrounded by delimiters.

Page breaks will occur only immediately after a step-plus-hint; a page break within or
after an expression would be confusing for the reader.

1.3 Options and document style parameters

By default, calculations are placed horizontally centered on the page, but when the entire
document has option fleqn ("flush left equations"), or when the package is given this option
explicitly, then calculations are placed flush left.

By default, calculations have their step and expression numbers at the right side of the
page (just as in LATEX), but when the entire document has option leqno ("left equation
numbers"), or when the package is given this option explicitly, then calculations are placed
at the left side of the page.

By default, the first line of a HINT is opened by \Hlineopen and the last one is closed by \Hlineclose (braces in the above example), but when option block is given to the package,
then the entire hint is made into one block surrounded by \Hblockopen and \Hblockclose.
Both \texttt{\Hblockopen} and \texttt{\Hblockclose} must be “delimiters” so that they can be stretched vertically. At least the following symbols are delimiters: braces \{ \}, brackets \[ \], vertical bar |, vertical double bar \|, angles \langle \rangle, and “nothing” (in \LaTeX indicated by a dot .). These commands can be redefined with \texttt{\renewcommand}.

The amount of space between \texttt{\Hlineopen} and the first token of the hint is given by \texttt{\Hsep}. The amount of indentation of the text of a hint, relative to the expressions, is given by \texttt{\Hindent} plus \texttt{\Hsep} (plus the width of \texttt{\Hblockopen} if option \texttt{block} is valid).

In summary, the following are the style parameters and options:

\begin{verbatim}
\% -------------- DOCUMENT STYLE PARAMETERS ------------------------
\% options:
\% fleqn, leqno, block
\% commands:
\% \newcommand{\stepsymbol}{=}
\% \newcommand{\Hblockopen}{|}
\% \newcommand{\Hblockclose}{.}
\% \newcommand{\Hlineopen}{\lbrace}
\% \newcommand{\Hlineclose}{\rbrace}
\% \newcommand{\Hindent}{1em}
\% \newcommand{\Hsep}{1ex}
\% \newcommand{\calculcolsep}{\arraycolsep}
\% \newcommand{\Hposv}{t}
\% \texttt{\%} vertical position of the step symbol in front of a block hint
\% These default values may be redefined by "\renewcommand".
\end{verbatim}

2 The \LaTeX code for the macros

\begin{verbatim}
\def\fileversion{1.00}
\def\filedate{5 Jan 2015}
\def\docdate{5 Jan 2015}
\ProvidesPackage{calculation}[2014/12/05 Format reasoned calculations]

All auxiliary variables specific to this package are named as follows:
\begin{verbatim}
\calc@.... or
\subcalc@... or
\ifcalc@... or
\endcalc@...
\end{verbatim}

Here are the options \texttt{fleqn}, \texttt{leqno}, and \texttt{block}, and their effect:
\begin{verbatim}
\DeclareOption{fleqn}{\calc@fleqn}
\DeclareOption{leqno}{\calc@leqno}
\DeclareOption{block}{\calc@blocktrue}
\end{verbatim}
\end{verbatim}
2.1 Preliminary auxiliaries

To place comments and step/expr numbers at opposite sides, we place them in a very wide box at the right side of the page, and surround them by suitable fill’s:

\[ \ldots \text{calc@eqnoLfil} <exprno> \text{calc@eqnoRfil} \ldots \]
\[ \ldots \text{calc@eqnoLfil} <stepno> \text{calc@eqnoRfil} \ldots \]
\[ \ldots \text{calc@eqnoRfil} <comment> \text{calc@eqnoLfil} \ldots \]

Depending on the options, these “fill’s” are set to \texttt{\hfil} or \{\}. We first check that these fill commands are not yet in use:

\newcommand{\calc@fill}{\relax}
\newcommand{\calc@eqnoLfil}{\relax}
\newcommand{\calc@eqnoRfil}{\relax}

Eqno’s at the left side means no fill at the L side and a real fill at the R side:

\newcommand{\calc@leqno}{\def\calc@eqnoLfil{}\def\calc@eqnoRfil{\hfil}}

Eqno’s at the right side:

\newcommand{\calc@reqno}{\def\calc@eqnoRfil{}\def\calc@eqnoLfil{\hfil}}

Calculations horizontally centered on the page:

\newcommand{\calc@ceqn}{\def\calc@fill{fil}}

Calculations flush left: set \texttt{\calc@indent} to \texttt{\mathindent}. However, global document option fleqn defines \texttt{\mathindent}; if global option fleqn is not used, \texttt{\mathindent} is defined now:

\newcommand{\calc@fleqn}{\@ifundefined{mathindent}{\calc@indent\leftmargini}{\calc@indent\mathindent}
\def\calc@fill{fill}}

2.2 Default settings related to the options

By default, calculations are centered and eqno’s at the right (LaTeX’ default); and by default no block hints (so \texttt{\Hlineopen} at the very first line and \texttt{\Hlineclose} at the very last line):

\calc@ceqn
\calc@reqno
\newif{\ifcalc@block} \calc@blockfalse
\newif{\ifcalc@blockfalse}
\newif{\ifcalc@blockfalse}
\newif{\ifcalc@blockfalse}
\newdimen{\calc@indent}{\calc@indent\z@skip
Recall that \calc@indent is set to \mathindent if fleqn is valid.

\ProcessOptions

2.3 Auxiliary commands of general use

\RequirePackage{delarray}

Package delarray (and hence package array) is required for \left and \right delimiters for array’s and tabulars — which we will exploit for hints. With this package, the delimiters come out well if the array (tabular, in our case) has option [t] (top alignment). Command \@ifmtarg is my poor man’s way to test for an empty argument; it should be \protect ed in moving arguments. Note: the command \@ifmtarg provided by \RequirePackage{ifmtarg} doesn’t work if the argument (a HINT in our case) contains ‘&’ symbols.

\newcommand\@ifmtarg[3]{\def\myempty{}\def\myarg{#1}\ifx\myempty\myarg{#2}\else{#3}\fi}

%% usage: \@ifmtarg {arg} {then} {else}

2.4 Default values for the document style parameters

| NAMING CONVENTION: EXPR = Expression, H = Hint |
|------------------------------------------------|--|

\newcommand{\stepsymbol}{=} \newcommand{\Hblockopen}{|} \newcommand{\Hblockclose}{.} \newcommand{\Hlineopen}{\lbrace} \newcommand{\Hlineclose}{\rbrace} \newcommand{\Hindent}{1em} \newcommand{\Hsep}{1ex} \newcommand{\Hposv}{t} \newcommand{\calculcolsep}{\arraycolsep}

The delimiters need some preprocessing in view of the way they will be used (in command \calc@@@step). In particular, the spaces at the beginning of a hint will be ignored (see \HlineOPEN below).

\newcommand{\Hsepskip}{\hbox to \Hsep {}} \newcommand{\HlineOPEN}{\ifcalc@block\else\makebox[0pt][r]{\m@th$\Hlineopen$\Hsepskip}\fi \ignorespaces\fi} \newcommand{\HlineCLOSE}{\ifcalc@block\else\makebox[0pt][l]{\m@th$\Hlineclose$\Hsepskip}\fi}

\HlineOPEN

NOTE: The else clause in \HlineCLOSE, above, assumes that the last hint line is not empty. In order to get \Hlineopen and \Hlineclose vertically aligned in case the last hint line is empty, the else clause should read in that case:
Alas, I don’t know how to check “the preceding line is empty” in the definition of \calc@@@step below, just in front of \HlineCLOSE.

2.5 Specific auxiliaries

Some sanity checks, and several auxiliaries:

2.6 Main code: calculation and step

The main idea of the calculation environment is to adapt \LaTeX’s way of formatting math expressions, and eqnarray in particular. Thus calculation sets up a \halign with three columns:

The 1st one for the step symbol (math mode)
The 2nd for the hint and expression (math mode)
The 3rd one for the comment and step/expr number (LR mode)

An eqno is placed in a large \hbox of length \linewidth which itself is considered of zero length and placed at the right in the last column. By suitable fill’s the eqno then appears either at the left or right side of that large \hbox, and thus at the left or right side of the page.

Command \step will be invoked inside an expression; thus, briefly said, it should have this effect: “end the expression, begin a new line, print the step symbol and hint, and begin a new expression”.

\newcommand{\HblockOPEN}{\ifcalc@block\Hblockopen\else.\fi}
\newcommand{\HblockCLOSE}{\ifcalc@block\Hblockclose\else.\fi}
\newcommand{\calc@origmath}{\relax}
\newcommand{\calc@stepsymbol}{\relax}
\newlength{\calc@math} % to store the value of \mathsurround
\newif{\calc@emptyH} % for temporary local use only
\newif{\calc@numberedstep} % true if currently in \step*
\newif{\calc@eqnoswitch} % true if an eqno will be produced
\newcommand{\calc@emptyHskip}{-0.5\baselineskip}% for empty hints
\calc@eqnoswitchfalse

By default the expressions in a calculation are not numbered. Whenever an expression is to be numbered, the switch is set true. This is done by \doNumber, which will be made available inside expressions of a calculation. Doing \doNumber twice should have the same effect as doing it once!

\newcommand{\calc@doNumber}{\ifcalc@eqnoswitch \else
\global\calc@eqnoswitchtrue
\stepcounter{equation}
\gdef{\@currentlabel}{\p@equation\theequation}
\fi}
2.6.1 The calculation environment

The calculation environment has one optional argument, for the step symbol, the default being \stepsymbol; within the code for the environment, the step symbol is known as \calc@stepsymbol. Because the step symbol and expr/hint must be set with zero mathsurround, we set mathsurround to zero (by \TeX's \m@th), but take measures to reset \mathsurround to its original value inside hints.

A newline command \\ inside expressions is delegated to \calc@cr (defined below).

Inside the environment, command \step and environment subcalculation are made available; outside the environment \step and subcalculation may have another meaning.

\newenvironment{calculation}{[1]\stepsymbol}{\setlength\calc@math\mathsurround\def\calc@origmath{\mathsurround\calc@math} \abovedisplayskip\topsep \ifvmode\advance\abovedisplayskip\partopsep\fi \belowdisplayskip\abovedisplayskip \belowdisplayshortskip\abovedisplayskip \abovedisplayshortskip\abovedisplayskip \def\calc@stepsymbol{#1} \tabskip\calc@indent plus 1fil \let\\=\calc@cr \def\step{\calc@step}% Make \step available inside calculations \def\subcalculation{\calc@subcalculation}% similarly subcalculation \def\endsubcalculation{\endcalc@subcalculation}% \halign to \displaywidth \bgroup \tabskip\z@ \hfil\m@th$ ## \hfil$% \tabskip0pt plus 1\calc@fill\cr \calc@beginEXPR}

In the preceding line, the \halign declaration ends with the beginning of a math expression (\calc@beginEXPR, which will skip to the the 2nd column, that is, the column for expressions). The following line closes the environment; it ends the last math expression (\calc@endEXPR, which will step over to the last column, and print the eqno and comment):

\{\calc@endEXPR
\egroup $$ \global@ignoretrue\ignorespaces}

The command \\ within expressions is delegated to \calc@cr; it ends the current expression, gives a little extra vspace, and begins a new line of the expression:

\newcommand\calc@cr{\calc@endEXPR \noinline\nopagebreak\vskip\jot}\calc@beginEXPR

\calc@cr

\calc@cr

\calc@cr

\calc@cr
From \LaTeX we've taken over the idea of extra \texttt{jot} vertical space between lines of one mathematical expression. The \texttt{nopagebreak} prevents a calculation to be split within or just after an expression; that would be too confusing for the reader.

### 2.6.2 The step command

\texttt{\ldots step} Most of the work for the calculation environment, is done in command \texttt{\step} or its companions \texttt{\calc@step}, \texttt{\calc@@step} and \texttt{\calc@@@step}. Recall that \texttt{\step} has been made available inside calculation by a local definition that simply calls \texttt{\calc@step}. This latter one first checks whether the next token is a star * (and stores this information in the global \texttt{\calc@numberedstep}) and then calls \texttt{\calc@step}. This \texttt{\calc@step} has one optional argument, the default being \texttt{\calc@stepsymbol} (set by the calculation environment); it calls \texttt{\calc@step} with the step symbol:

\begin{verbatim}
149 \newcommand{\calc@step}{\@ifstar{\global\calc@numberedsteptrue\calc@@step}{\global\calc@numberedstepfalse\calc@@step}}
150 \newcommand{\calc@@step}[1]\[1]{\calc@stepsymbol}{\calc@@@step{#1}}
151 \newcommand{\calc@@@step}[2]{\@ifmtarg{#2}{\global\calc@emptyHtrue}{\global\calc@emptyHfalse}
152 \calc@endEXPR
153 \ifcalc@emptyH
154 \noalign{\vskip \calc@emptyHskip}
155 \else
156 \noalign{\nopagebreak\vskip\jot}
157 \fi
158 \ifcalc@numberedstep
159 \refstepcounter{equation}
160 \gdef\@currentlabel{\p@equation\theequation}
161 \gdef\calc@stepno{\theequation}
162 \fi
163 \ifcalc@numberedstep
164 \refstepcounter{equation}
165 \gdef\@currentlabel{\p@equation\theequation}
166 \gdef\calc@stepno{\theequation}
167 \fi
168 \endverbatim

\texttt{\calc@@@step} Now, the final \texttt{\calc@@@step} has two obligatory arguments:

- \texttt{#1} = step symbol
- \texttt{#2} = hint lines possibly including several \\s

As a preparation it checks whether the hint is empty and stores this in \texttt{\calc@emptyH}. Then it ends the current expression, does a negative vskip if the hint is empty, and increases the equation counter if the step is numbered:

\begin{verbatim}
156 \newcommand{\calc@@@step}[2]{\@ifmtarg{#2}{\global\calc@emptyHtrue}{\global\calc@emptyHfalse}
157 \calc@endEXPR
158 \ifcalc@emptyH
159 \noalign{\vskip \calc@emptyHskip}
160 \else
161 \noalign{\nopagebreak\vskip\jot}
162 \fi
163 \ifcalc@numberedstep
164 \refstepcounter{equation}
165 \gdef\@currentlabel{\p@equation\theequation}
166 \gdef\calc@stepno{\theequation}
167 \fi
168 \endverbatim

After these preparations, print the step symbol in the 1st column:

- \texttt{#1} &

Now print the hint, if not empty. First take care of the indentation, then take the hint lines as body of a tabular which has \texttt{HblockOPEN} and \texttt{HblockCLOSE} as delimiters and put \texttt{HlineOPEN} in front of the 1st line and \texttt{HlineCLOSE} after the last line. These delimiters have been defined to be null depending on the validity of option block. The \texttt{tabular} comes from package \texttt{delarray}, and thus has the feature of allowing the delimiters around the column specification. We also take care to restore \texttt{mathsurround} to its original value within each hint line.
2.6.3 Remaining auxiliary commands

\calc@beginEXPR \halign When \calc@beginEXPR is called, a new line of the \halign of calculation is to be filled. Since no step symbol has to be printed, we skip over to the next column (the 2nd one). This column is processed in math mode, so nothing has to be done, except for making \doNumber and \comment available and resetting the current comment to “nothing, yet”:

\newcommand{\calc@beginEXPR}
{&
\def\doNumber{\calc@doNumber}
\def\comment{gdef\calc@comment}
\gdef\calc@comment{}}
\calc@endEXPR

When \calc@endEXPR is called, we simply step over to the last (3rd) column by \& and print the eqno and comment (possibly null), and close the line with \cr:

\newcommand{\calc@endEXPR}
{ & \calc@@eqno\calc@@comment \cr}
\calc@@comment

The type setting of comments and numbers is rather straightforward: at the very right end of a wide \hbox, which is pretended to be of zero width, and surrounded by suitable fill’s to shift them to the other side, if needed.

\newcommand{\calc@@comment}
{\lap{\hbox to\linewidth}
{\calc@eqnoRfil \normalfont\normalcolor\calc@comment
\calc@eqnoLfil}}}
3 Subcalculation

There are several problems in using the \texttt{calculation} environment within hints. First, the width need be determined. (When option \texttt{fleqn} is valid, then the width is more or less the line length minus these three: \texttt{calc@indent}, width of widest step symbol, \texttt{Hindent}.) Second, even if the width for the sub calculation is known, it is hard to get the eqno and comment at the right place on the page. Third, in all my attempts, a sub calculation in the hint of a numbered step takes the number for it self. (This could be solved by implementing a stack or push down store in \TeX{} or a kind of recursive commands that build their own stack.) In view of all this, we forbid sub calculations to have numbered steps, numbered expressions, and comments in expressions. (This seems reasonable; after all, a subcalculation within a hint should be very simple and not “view-able” from the outside.) Also, we pretend the calculation to have zero width; it is the users responsibility to observe overfull lines! Finally, as a kind of fine tuning the lay-out, we halve the indentation for the calculation, and make sub calculations flush left. Actions within \texttt{subcalculation} must not overwrite gobal variables of environment \texttt{calculation}, of course. So, we have to introduce some new global variables:

Since numbering and comments are not allowed, we use only two columns.

\begin{minipage}{c}
\abovedisplayskip 0pt \belowdisplayskip \abovedisplayskip
\belowdisplayskip\belowdisplayshortskip \abovedisplayshortskip \abovedisplayskip
\def\subcalc@stepsymbol{#1}%
\divide\calc@indent by 2 \tabskip\calc@indent plus 1fil \let\\=\subcalc@cr
\def\step{\subcalc@step}% Make \step available \def\comment{\@latexerror{No \string\comment\space in subcalculations}}%
\m@th
\end{minipage}%
How to deal with \\ (which will invoke \subcalc@cr) in hints and exprs: Close the current line (of the \halign) and in the next line skip the column for the step symbol:

\newcommand{\subcalc@cr}
{\cr
\noalign{\nopagebreak\vskip\jot}
&
\global\@ignoretrue\ignorespaces
}

\subcalc@step
A step in a subcalculation is more or less the same as a step in the normal calculation, except that numbering is not allowed:

\newcommand{\subcalc@step}
{\@ifstar{\subcalc@@stepSTAR}{\subcalc@@step}}
\newcommand{\subcalc@@stepSTAR}[1]
{\@latex@error{No \string\step* in subcalculations; use \string\step.}}
\newcommand{\subcalc@@step}[1][\@gobble]
{\subcalc@@@step{#1}}
\newcommand{\subcalc@@@step}[2]
\@ifmtarg{#2}
{\global\subcalc@emptyHtrue}{\global\subcalc@emptyHfalse}
\cr
\if\subcalc@emptyH
\noalign{\vskip\calc@emptyHskip}
\else
\noalign{\nopagebreak\vskip\jot}
\fi
#1 &
\if\subcalc@emptyH
\else
\hskip\Hindent
\hbox to 0pt {%}
\fi
\begin{tabular}{Hposv}
\HblockOPEN{>{\calc@origmath\Hsepskip}l<{\Hsepskip}}
\HblockCLOSE
\HblockOPEN{\Hposv}
\HblockCLOSE
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Numbers written in italic refer to the page where the corresponding entry is described; numbers underlined refer to the code line of the definition; numbers in roman refer to the code lines where the entry is used.

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Change History

v1.00
  Original idea implemented anew 4

v0.x
  Ugly constructed, ugly to use, nice output 4