The \texttt{trfrac} package\footnote{This document corresponds to \texttt{trfrac v2.3}, dated 2011/5/20.}

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Abstract

The \texttt{trfrac} package provides convenient mechanisms for typesetting derivation trees in $\LaTeX$. Derivation trees look like nested fractions; thus, the primary contribution of this software is a macro \texttt{trfrac} that functions much like $\LaTeX$’s \texttt{frac} for fractions, but with a number of important differences that make it better suited to tree-like structures.

1 Introduction

Typing rules and typing derivations in formal typing systems are usually written like fractions in which the numerator consists of one or more premise judgments or derivations, and the denominator consists of a single conclusion judgment. For example, the typing rule for application in the simply-typed lambda calculus is typically written

$$
\frac{
\Gamma \vdash e_1 : \tau \to \tau' \quad \Gamma \vdash e_2 : \tau
}{
\Gamma \vdash e_1 e_2 : \tau' \quad (app)
}$$

where $\Gamma \vdash e_1 : \tau \to \tau'$ and $\Gamma \vdash e_2 : \tau$ are the two premise judgments of the rule, and $\Gamma \vdash e_1 e_2 : \tau'$ is the conclusion judgment.

Simple rules like the above are easy to typeset with $\LaTeX$’s built-in \texttt{frac} macro, or with fraction macros like \texttt{dfrac} provided by the \texttt{amslatex} package; but when derivations consist of a tree of nested rules, \texttt{frac} and \texttt{dfrac} often prove inadequate because they yield spacing and alignment that is unsuited to derivation trees. For example, consider the derivation

$$
\frac{
\Gamma \vdash e_1 : \tau \to \tau' \quad \Gamma \vdash e_2 : \tau'' \to \tau \quad \Gamma \vdash e_3 : \tau''
}{
\Gamma \vdash e_2 e_3 : \tau \quad (app)
}$$

$$
\frac{
\Gamma \vdash e_1 : \tau \to \tau' \quad \Gamma \vdash e_2 : \tau'' \to \tau \quad \Gamma \vdash e_3 : \tau''
}{
\Gamma \vdash e_1(e_2 e_3) : \tau' \quad (app)
}$$

which contains a nested subderivation of one of its premise judgments. This was easily typeset using the \texttt{frac} macro provided by the \texttt{trfrac} package. The complete $\LaTeX$ code is as follows:
In contrast, if one writes analogous code using \texttt{\textbackslash frac} instead of \texttt{\textbackslash trfrac}, the result is

\begin{align*}
\Gamma \vdash e_1 : \tau &\rightarrow \tau' \\
\Gamma \vdash e_2 : \tau'' &\rightarrow \tau \\
\Gamma \vdash e_3 : \tau'' \\
\Gamma \vdash e_2 e_3 : \tau
\end{align*}

\begin{align*}
\Gamma \vdash e_1 (e_2 e_3) : \tau'
\end{align*}

which is unsuitable for two reasons: First, the leftmost premise is floating up above the fraction bar when it should be sitting on the bar. Second, the bottom fraction bar is longer than it should be; it has been unnecessarily extended rightward to span the entire “numerator” of the “fraction”. This can become problematic when derivations are large and horizontal space is at a premium.

In addition to providing \texttt{\textbackslash trfrac} as an alternative to fraction macros, the \texttt{\textbackslash trfrac} package also provides two environments that can be helpful for squeezing numerous and/or lengthy premise judgments into a smaller amount of horizontal space. Derivations can sometimes contain long judgments that must be wrapped, or numerous premise judgments that must be placed above one another for lack of space. The \texttt{\textbackslash trfrac} package provides math environments \texttt{\textbackslash trgather} and \texttt{\textbackslash tralign} for stacking sets of judgments vertically within a derivation tree. The \texttt{\textbackslash trgather} environment horizontally centers each judgment in the stack, whereas the \texttt{\textbackslash tralign} environment aligns each judgment at a specified point. For example, the derivation

\begin{align*}
\Gamma \vdash e : \tau_1 + \tau_2 \\
\Gamma[x_1 \mapsto \tau_1] \vdash e_1 : \tau \\
\Gamma[x_2 \mapsto \tau_2] \vdash e_2 : \tau
\end{align*}

\begin{align*}
\Gamma \vdash \texttt{case} e \texttt{ of} \begin{array}{l}
\mid \texttt{in}_1(x_1) \Rightarrow e_1 \\
\mid \texttt{in}_2(x_2) \Rightarrow e_2
\end{array} : \tau
\end{align*}

can be produced with

\begin{verbatim}
\begin{trgather}
\Gamma \vdash e : \tau_1 + \tau_2 \\
\Gamma[x_1 \mapsto \tau_1] \vdash e_1 : \tau \\
\Gamma[x_2 \mapsto \tau_2] \vdash e_2 : \tau
\end{trgather}
\end{verbatim}

\begin{verbatim}
\begin{tralign}
\Gamma \vdash \texttt{case} e \texttt{ of} \begin{array}{l}
\mid \texttt{in}_1(x_1) \Rightarrow e_1 \\
\mid \texttt{in}_2(x_2) \Rightarrow e_2
\end{array} : \tau
\end{tralign}
\end{verbatim}
The \texttt{split} and \texttt{aligned} environments provided by the \texttt{amsmath} package provide facilities for vertically stacking sub-equations in similar ways, but like \texttt{dfrac}, these often prove inadequate for derivation trees because they vertically center the material they typeset, causing any adjacent material to float above the fraction bar.

\section{Usage}

To start using the macros and environments provided by the \texttt{trfrac} package, place the line

\begin{verbatim}
\usepackage{trfrac}
\end{verbatim}

somewhere near the top of your \LaTeX{} file.

Subsequently, within any math environment you can use

\begin{verbatim}
\trfrac\{\langle name\rangle\}\{\langle premises\rangle\}\{\langle consequent\rangle\}
\end{verbatim}

to typeset a derivation rule, where \langle name\rangle is optional material processed in horizontal text mode that is to sit to the right of the fraction bar, \langle premises\rangle is math material that is to sit above the fraction bar, and \langle consequent\rangle is math material that is to sit below the fraction bar. The \langle consequent\rangle and \langle name\rangle may not contain additional \texttt{trfrac} macros, but the \langle premises\rangle may.

The outermost \texttt{trfrac} in a derivation is vertically centered on its fraction bar, but inner \texttt{trfrac}'s in a derivation have baselines at the bottoms of their consequents. This makes it possible to typeset something like

\[
D = \frac{\Gamma \vdash e_1 : \tau \rightarrow \tau'}{\Gamma \vdash e_1(e_2e_3) : \tau'} (app) \quad \frac{\Gamma \vdash e_2 : \tau'' \rightarrow \tau}{\Gamma \vdash e_3 : \tau'' (app)}
\]

in which the material "$D =$" should be vertically centered with respect to the bottom fraction bar, but the left premise should not be centered with respect to the right subderivation's fraction bar.

\begin{verbatim}
\begin{trgather}
\langle eqn_1\rangle \langle[\langle len_1\rangle]\rangle
\langle eqn_2\rangle \langle[\langle len_2\rangle]\rangle
\vdots
\langle eqn_n\rangle \langle[\langle len_n\rangle]\rangle
\end{trgather}
\end{verbatim}

can be used in math mode to stack a set of equations, each of which is to be centered horizontally over one another. Here, \langle eqn_i\rangle is material processed in math mode and \langle len_i\rangle is an optional length that modifies the vertical spacing between
the current equation and the next. The baseline of the resulting stack of equations
is the baseline of the bottom equation in the stack.

\begin{tralign}
⟨\text{left}_1⟩&⟨\text{right}_1⟩ \\[⟨\text{len}_1⟩]\n⟨\text{left}_2⟩&⟨\text{right}_2⟩ \\[⟨\text{len}_2⟩]\n\vdots
⟨\text{left}_n⟩&⟨\text{right}_n⟩ \\[⟨\text{len}_n⟩]\n\end{tralign}

The environment

\begin{tralign}
⟨\text{left}_1⟩&⟨\text{right}_1⟩ \\[⟨\text{len}_1⟩]\n⟨\text{left}_2⟩&⟨\text{right}_2⟩ \\[⟨\text{len}_2⟩]\n\vdots
⟨\text{left}_n⟩&⟨\text{right}_n⟩ \\[⟨\text{len}_n⟩]\n\end{tralign}

\text{tralign}

The space just above and just below each fraction bar can be adjusted by
changing the values of lengths \texttt{\trtopgap} and \texttt{\trbotgap}. For example, to
decrease the distance between fraction bars and numerators by 2 points and increase
the distance between fraction bars and denominators by 1 point of space, you
could write:

\texttt{\trtopgap=-2pt}
\texttt{\trbotgap=1pt}

3 Implementation

The following is a verbatim listing of the \texttt{trfrac} package implementation with
comments explaining how it works.

\begin{verbatim}
\trtopgap
\trbotgap
\newdimen\trtopgap\trtopgap\z@ 
\newdimen\trbotgap\trbotgap\z@
\TRF@startp
\TRF@endp
\end{verbatim}

\texttt{\trtopgap}
\texttt{\trbotgap}

Declare dimension registers that allow users to control the amount of space above
and below fraction bars.

1 \texttt{\newdimen\trtopgap\trtopgap\z@}
2 \texttt{\newdimen\trbotgap\trbotgap\z@}

\TRF@startp
\TRF@endp

When processing a numerator, the \texttt{\TRF@trfrac} code must be able to determine
whether (a) the current derivation is the first thing being added to the current hor-
izontal list, and whether (b) the current horizontal list ends in a derivation. To
accomplish this, two sentinel penalties are added to horizontal lists: \texttt{\TRF@startp} is
added at the beginning of a horizontal list comprising a numerator, and \texttt{\TRF@endp}
is added just after every derivation. Then \texttt{\lastpenalty} can be used to inquire
whether the current horizontal list ends in either penalty. (Since derivations en-
cased within numerators cannot undergo line-breaking, these extra penalties will
have no effect on \LaTeX’s processing of the actual output.)
In accordance with the above, the following conditional remembers whether the current derivation is the first in the horizontal list comprising the numerator of a larger derivation.

The outermost derivation behaves slightly differently than subderivations within a derivation tree. (Its baseline is its fraction bar instead of its denominator’s baseline, and it should not include the spurious \TRF@endp penalty, since line-breaking might occur.) The following conditional therefore remembers whether we’re at the outermost level.

Subderivations are not permitted to appear within denominators or within rule names. The \ifTRF@derivok conditional is set to false when processing such material.

After processing a horizontal list that might contain one or more derivations, \TRF@lhang holds the distance from the left edge of the resulting box to the leftmost item’s denominator (or 0pt if the leftmost list item is not a derivation), and \TRF@rhang holds the distance from the rightmost item’s denominator to the right edge of the resulting box (or 0pt if the rightmost list item is not a derivation).

We also need a place to save the value of \TRF@lhang so that we can (sometimes) restore it to its original value after it has been globally modified by nested trfrac macros.

The temporary registers declared below store the the numerator indentation, bar indentation, and bar width, respectively, when typesetting a derivation rule.

While constructing a derivation, the following three boxes hold the derivation’s numerator, denominator, and rule name, respectively.
The following macro typesets a single derivation rule in a derivation tree. Its arguments are (1) the rule name (processed in horizontal mode), (2) the numerator (processed in math mode), and (3) the denominator (processed in math mode).

\newcommand{\TRF@trfrac}[3]{
\begingroup
We start by saving the original value of \TR@lhang and deciding whether this is the first subderivation in a numerator of a larger derivation. These must come before anything else, and the results used later.

\ifnum\lastpenalty=\TRF@startp\relax
  \TRF@firsttrue\%
\else\%
  \TRF@firstfalse\%
\fi\%
\TRF@lsave\TRF@lhang\%

Typeset the equation number and put it in a box.
\setbox\TRF@eqbox\hbox{\TRF@derivokfalse#1}\%
\ifdim\wd\TRF@eqbox>\z@\%
  \setbox\TRF@eqbox\hbox{\kern\p@\unhbox\TRF@eqbox}\%
\fi\%

Typeset the numerator and put it in a box. We begin the box with the \TRF@startp penalty so that if the first list item is a derivation, it will see that nothing has preceded it and will therefore set \TRF@lhang. We initialize it to zero so that if the first item is not a derivation, \TRF@lhang will remain zero. If the last thing in the numerator is a \TRF@endp penalty, then the list must have ended with a subderivation whose denominator is a distance \TRF@rhang from its right edge. Otherwise the rightmost item was not a subderivation, so we zero \TRF@rhang.

\TRF@lhang\z@\%
\setbox\TRF@numbox\hbox{\TRF@outerfalse%
  \m@th\strut%
  \penalty\TRF@startp\relax%
  #2%
  \ifnum\lastpenalty=\TRF@endp\relax\else%
    \global\TRF@rhang\z@\%
  \fi\%
  \fi\%

Finally, typeset the denominator in a box. Denominators may not contain subderivations, so this preserves the values of \TRF@lhang and \TRF@rhang.

\setbox\TRF@denombox\hbox{\TRF@derivokfalse%
  \m@th\strut#3\%
}

Compute the bar width \(bw = \max(n - l - r, d)\), denominator indentation \(l' = \max((n - r + l) - d, 0)/2\), numerator indentation \(ni = \max(d - (n - r + l), 0)/2\), and bar indentation \(bi = \min(ni + l, di)\), respectively, where \(n\) is the numerator.
width, $d$ is the denominator width, $l$ is the old value of $\text{TRF@lhang}$, and $r$ is $\text{TRF@rhang}$.

\[
\begin{align*}
\text{44} & \quad \text{\textbackslash dimen0\textbackslash wd\textbackslash TRF@numbox}\% \\
\text{45} & \quad \text{\textbackslash advance\textbackslash dimen0-\textbackslash TRF@rhang}\% \\
\text{46} & \quad \text{\textbackslash TRF@bw\textbackslash dimen0}\% \\
\text{47} & \quad \text{\textbackslash advance\textbackslash TRF@bw-\textbackslash TRF@lhang}\% \\
\text{48} & \quad \text{\textbackslash ifdim\textbackslash wd\textbackslash TRF@denombox}>\text{\textbackslash TRF@bw}\text{\textbackslash wd\textbackslash TRF@denombox}\text{\textbackslash fi}\% \\
\text{49} & \quad \text{\textbackslash advance\textbackslash dimen0\textbackslash TRF@lhang}\% \\
\text{50} & \quad \text{\textbackslash advance\textbackslash dimen0-\textbackslash wd\textbackslash TRF@denombox}\% \\
\text{51} & \quad \text{\textbackslash TRF@ni\textbackslash ifdim\textbackslash dimen0><\textbackslash z0\textbackslash else-.5\textbackslash dimen0}\text{\textbackslash fi}\% \\
\text{52} & \quad \text{\textbackslash TRF@bi\textbackslash TRF@ni}\% \\
\text{53} & \quad \text{\textbackslash advance\textbackslash TRF@bi\textbackslash TRF@lhang}\% \\
\text{54} & \quad \text{\textbackslash TRF@lhang\textbackslash ifdim\textbackslash dimen0><\textbackslash z0\textbackslash else-.5\textbackslash dimen0}\text{\textbackslash fi}\% \\
\text{55} & \quad \text{\textbackslash ifdim\textbackslash TRF@bi}\text{\textbackslash TRF@rhang-\textbackslash TRF@lhang}\text{\textbackslash fi}\% \\
\text{56} & \quad \text{\textbackslash global\textbackslash TRF@rhang}\text{\textbackslash TRF@rhang}\% \\
\end{align*}
\]

Compute the new value of $\text{TRF@rhang}$ as $r' = \max(ni + n, bi + bw + e) - l' - d$, where $e$ is the width of the equation number. The final result is globally assigned so that its value will persist beyond the local scope in which numerators are typeset.

\[
\begin{align*}
\text{56} & \quad \text{\textbackslash TRF@rhang}\text{\textbackslash TRF@ni}\% \\
\text{57} & \quad \text{\textbackslash advance\textbackslash TRF@rhang\textbackslash wd\textbackslash TRF@numbox}\% \\
\text{58} & \quad \text{\textbackslash dimen0\textbackslash TRF@bi}\% \\
\text{59} & \quad \text{\textbackslash advance\textbackslash dimen0\textbackslash TRF@bw}\% \\
\text{60} & \quad \text{\textbackslash advance\textbackslash dimen0\textbackslash wd\textbackslash TRF@eqbox}\% \\
\text{61} & \quad \text{\textbackslash ifdim\textbackslash dimen0}>\text{\textbackslash TRF@rhang-\textbackslash TRF@lhang}\text{\textbackslash dimen0}\text{\textbackslash fi}\% \\
\text{62} & \quad \text{\textbackslash advance\textbackslash TRF@rhang-\textbackslash TRF@lhang}\% \\
\text{63} & \quad \text{\textbackslash advance\textbackslash TRF@rhang-\textbackslash wd\textbackslash TRF@denombox}\% \\
\text{64} & \quad \text{\textbackslash global\textbackslash TRF@rhang}\text{\textbackslash TRF@rhang}\% \\
\end{align*}
\]

Begin typesetting the final fraction as a math-inner node. The vbox that comprises the node has an hbox comprising the denominator on the bottom and an hbox comprising everything else on the top. This allows the denominator baseline to become the baseline of the entire fraction. If this is the outermost level, the final box is set with $\text{\textbackslash vtop}$ so that the numerator is the baseline, and then raised a bit so that the fraction bar becomes the baseline.

\[
\begin{align*}
\text{65} & \quad \text{\textbackslash mathinner}\% \\
\text{66} & \quad \text{\textbackslash ifTRF@outer}\% \\
\text{67} & \quad \text{\textbackslash raise\textbackslash fontdimen22\textbackslash textfont\tw\textbackslash vtop}\% \\
\text{68} & \quad \text{\textbackslash else}\% \\
\text{69} & \quad \text{\textbackslash vbox}\% \\
\text{70} & \quad \text{\textbackslash fi}\% \\
\text{71} & \quad \text{%} \\
\text{72} & \quad \text{\textbackslash offinterlineskip}\% \\
\text{73} & \quad \text{\textbackslash hbox}\% \\
\text{74} & \quad \text{\textbackslash vbox}\% \\
\end{align*}
\]

Compute the distance between the numerator and the fraction bar. The formula for computing this number is given in step 15d of Appendix G of *The \TeX{}book* (p. 445).

\[
\begin{align*}
\text{75} & \quad \text{\textbackslash dimen0\textbackslash fontdimen8\textbackslash textfont\tw}\% \\
\text{76} & \quad \text{\textbackslash advance\textbackslash dimen0-\textbackslash fontdimen22\textbackslash textfont\tw}\% \\
\end{align*}
\]
Typeset the numerator part, horizontally centered over the fraction bar (but possibly overhanging the equation number).

\hbox{\kern\TRF@ni\unhbox\TRF@numbox}\%
\kern\dimen@

Typeset the fraction bar followed by the equation number. The height of the fraction bar is based on math font metric 8. The equation number is typeset at zero height so that it does not push the numerator or denominator away from the fraction bar.

\hbox{\kern\TRF@bi\vrule\@width\TRF@bw\@height.5\fontdimen8\textfont\thr@@\@depth.5\fontdimen8\textfont\thr@@\vbox{\dimen@.5\ht\TRF@eqbox\advance\dimen@.5\dp\TRF@eqbox\kern-\dimen@\box\TRF@eqbox\kern-\dimen@}}%

Insert the vertical space that separates a fraction bar from its denominator. See step 15d of Appendix G of *The \TeX\book* (p. 445) for a derivation of this distance.

\dimen@\fontdimen11\textfont\tw@\advance\dimen@\fontdimen22\textfont\tw@
\advance\dimen@-.5\fontdimen8\textfont\thr@@\advance\dimen@-.5\ht\TRF@denombox\ifdim\dimen@<3\fontdimen8\textfont\thr@@\dimen@3\fontdimen8\textfont\thr@@\fi\advance\dimen@\trbotgap\kern\dimen@%

Typeset the denominator horizontally centered below the fraction bar.

\hbox{\kern\TRF@lhang\box\TRF@denombox}\%

If this is a subderivation within another, add a $\texttt{\TRF@endp}$ penalty to the current horizontal list so that if this is the last item in a numerator, the value we computed
for \TRF@rhang will be used by the outer derivation to determine the amount by which its numerator may overhang the fraction bar to the right.

\ifTRF@outer\else%
\penalty\TRF@endp\relax%
\fi%

If this is the leftmost subderivation in the numerator of another derivation, the value of \TRF@lhang must be made global so that it can be used by the outer derivation to compute the amount by which its numerator may overhang the fraction bar to the left. Otherwise \TRF@lhang must be restored to whatever value it had on entrance to this \trfrac. (It is not enough to just let it get restored to whatever it was before the current local scope, since some nested modifications to it might have been global.)

\global\TRF@lhang\ifTRF@first\TRF@lhang\else\TRF@lsave\fi%
\endgroup%
}

The following is the entrypoint to the derivation code. The \trfrac macro takes one optional argument which, if present, is the name of the rule (processed in horizontal mode), followed by two mandatory arguments—the rule's numerator and denominator. Derivations can only appear in math mode, and cannot appear within the denominator of another derivation or within its rule name.

\newcommand\trfrac[3][]%
\ifTRF@derivok%
\ifmmode%
\TRF@trfrac{#1}{#2}{#3}%
\else%
\TRF@mmerr%
\fi%
\else%
\TRF@derr%
\fi%
\fi%
\else%
\TRF@derr%
\fi%
\fi%
\fi%
\endgroup%
}

\TRF@mmerr Produce an error if \trfrac is used outside of math mode.
\newcommand\TRF@mmerr%
\PackageError{trfrac}{\protect\trfrac\space% only allowed in math mode}%
{I encountered a \protect\trfrac\space% macro without first encountering a begin-math token.}%
}

\TRF@derr Subderivations within denominators are not supported because that would require computing chiastic structures rather than tree structures.
\newcommand\TRF@derr%
\PackageError{trfrac}{\protect\trfrac\space% not allowed in the consequent of another \protect\trfrac}%
{\protect\trfrac\space can only appear in the premise (numerator%
The \TRF@next token is here reserved so that it can be used in conjunction with \futurelet (when processing optional arguments).

\TRF@sep

In a \trgather or tralign environment, the \ \ macro is used to delimit lines. It is temporarily set equal to \TRF@sep (below), which is just like \cr in an \halign except that it takes an optional length argument that has the effect of inserting a vertical space between the lines.

\TRF@@sep

The following processes the optional argument to \TRF@sep.

\TRF@separg

The following is the code for a \TRF@sep that has been provided the optional argument.

\TRF@sepnoarg

The following is the code for a \TRF@sep that has not been provided the optional argument. You might think that it would have been simpler to use \let instead of \newcommand in the line below, or even to just use \cr within some of the code above instead of defining this new macro at all, but \cr is a strange beast; it can only be expanded onto the token stream when we’re sure of everything that is to follow it.

\trgather

A \trgather environment is just like amsmath’s \gathered environment except that its baseline is at the bottom instead of in the middle.
A `tralign` environment is like `amsmath`'s `aligned` environment except that its baseline is at the bottom instead of in the middle, and it’s restricted to two columns (for simplicity).

\begin{tralign}{\%}
\vbox\bgroup
\let\TRF@sep\TRF@@sep
\ialign\bgroup\hfil{\m@th$##\null$}&{\m@th$\null##$}\hfil\cr
\egroup\egroup
\end{tralign}

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<td>\TRF@frac . . . . . . . . . 17, 121</td>
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<td>\TRF@frac . . . . . . . . . 118</td>
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<tr>
<td>\ifTRF@firstfalse . 20</td>
<td>\TRF@numbox . . . . 14</td>
<td>\TRF@firsttrue . . . . 155</td>
<td>\TRF@firsttrue . . . . 155</td>
</tr>
</tbody>
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