An environment for multicolumn output

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Abstract

This article describes the use and the implementation of the \texttt{multicols} environment. This environment allows switching between one and multicolumn format on the same page. Footnotes are handled correctly (for the most part), but will be placed at the bottom of the page and not under each column. \LaTeX{}’s float mechanism, however, is partly disabled in this implementation. At the moment only page-wide floats (i.e., star-forms) can be used within the scope of the environment.

Preface to version 1.8

The 1.8 release improves on the balancing approach. If due to a limited number of break points (e.g., due to large objects) the balanced columns exceed the available vertical space, then balancing is canceled and a normal page is produced first. Some overflow is allowed (controlled by the parameter \texttt{\maxbalancingoverflow} which defaults to 12pt). This ensures that we only cut a normal page if we get enough material carried over to next page.

Also added was support for \texttt{\enlargethispage}. This means it is now possible to request a page to be artificially enlarged or shortened. Note that if you enlarge pages by more than one line you may have to increase the \texttt{collectmore} counter value to ensure that enough material is being picked up.

This command was used on the second page of this manual to shorten it by one line, in order to get rid of a number of widow lines on the following pages.

There are also some small enhancements to the balancing algorithm including a ways to require a minimum number of rows in the result.

Finally, version 1.8 adds the command \texttt{\docolaction} to help with more complicated actions that depend on the current column. This command expects 3 arguments: code that is executed if we are in the “first” column, code to execute if we end up in any “middle” column (if there are more than two) and finally code to execute if we are in the “last” column. Thus

\begin{verbatim}
\docolaction{first}
{middle}{last}
\end{verbatim}

would typeset a different word depending the type of column this code is executed. Using it like this is probably pointless, but you can imagine applications like writing something into the nearest margin, etc.

As this feature needs at least two \LaTeX{} runs to produce correct results and as it adds to the processing complexity it is only made available if one add the option \texttt{colaction} when loading the package.
Preface to version 1.7 (right to left support)

The 1.7 release adds support for languages that are typeset right-to-left. For those languages the order of the columns on the page also need to be reversed—something that wasn’t supported before. The next paragraph demonstrates the result (as it is typeset as if we are writing in a left-to-right language—so read the rightmost column first). The change is initialized via \RLmulticolcolumns and returning to left-right (default) is done via \LRmulticolcolumns.

For example:
\begin{verbatim}
\renewcommand \footnoterule{\
 \kern-3pt\hbox to\textwidth{\hskip .6\textwidth\\%\rule{.6\textwidth}{\kern2.6pt}}}\end{verbatim}

Preface to version 1.5 + 1.6

The 1.5 release contains two major changes: multicols will now support up to 10 columns and two more tuning possibilities have been added to the balancing routine. The balancing routine now checks the badness of the resulting columns and rejects solutions that are larger than a certain threshold. At the same time multicols has been upgraded to run under \LaTeX 2ε.

Later changes to 1.5 include \columnbreak and multicols*.

For version 1.6 micro-spacing around the boxes produced by multicols has been improved to allow for baseline-grid typesetting.

1 Introduction

Switching between two-column and one-column layout is possible in \LaTeX, but every use of \twocolumn or \onecolumn starts a new page. Moreover, the last page of two-column output isn’t balanced and this often results in an empty, or nearly empty, right column. When I started to write macros for doc.sty (see “The doc-Option”, TUGboat volume 10 #2, pp. 245–273) I thought that it would be nice to place the index on the same page as the bibliography. And balancing the last page would not only look better, it also would save space; provided of course that it is also possible to start the next article on the same page. Rewriting the index environment was comparatively easy, but the next goal, designing an environment which takes care of footnotes, floats, etc., was a harder task. It took me a whole weekend\(^1\) to get together the few lines of code below and there is still a good chance that I missed something after all.

Try it and, hopefully, enjoy it; and please direct bug reports and suggestions back to Mainz.

2 The User Interface

To use the environment one simply says
\begin{verbatim}
\begin{multicols}{⟨number⟩}
⟨multicolumn text⟩
\end{multicols}
\end{verbatim}

where ⟨number⟩ is the required number of columns and ⟨multicolumn text⟩ may contain arbitrary \LaTeX commands, except that floats and marginpars are not allowed in the current implementation\(^2\).

As its first action, the multicols environment measures the current page to determine whether there is enough room for some portion of multicolumn out-

\(^1\)I started with the algorithm given in the \TeXbook on page 417. Without this help a weekend would not have been enough. (This remark was made in the documentation of the initial release, since then several hundreds more hours went into improving the original code.)

\(^2\)This is dictated by lack of time. To implement floats one has to reimplement the whole \LaTeX output routine.
The space between columns is controlled by the \( \texttt{\textbackslash columnsep} \) parameter. The width for the individual columns is automatically calculated from this parameter and the current \( \texttt{\textbackslash linewidth} \). In this article a value of 18.0pt was used.

Separation of columns with vertical rules is achieved by setting the parameter \( \texttt{\textbackslash columnseprule} \) to some positive value. In this article a value of 4pt was used.

The color of the rules separating the columns can be specified through \( \texttt{\textbackslash columnseprulecolor} \). The default value is \texttt{\textbackslash normalcolor}.

Since narrow columns tend to need adjustments in interline spacing we also provide a \( \texttt{(skip)} \) parameter called \( \texttt{\textbackslash multicolbaselineskip} \) which is added to the \( \texttt{\textbackslash baselineskip} \) parameter inside the \texttt{\textbackslash multicols} environment. Please use this parameter with care or leave it alone; it is intended only for package file designers since even small changes might produce totally unexpected changes to your document.

### 2.1 Balancing columns

Besides the previously mentioned parameters, some others are provided to influence the layout of the columns generated.

Paragraphing in \( \LaTeX \) is controlled by several parameters. One of the most important is called \texttt{\textbackslash tolerance}: this controls the allowed ‘looseness’ (i.e. the amount of blank space between words). Its default value is 200 (the \( \LaTeX \) \texttt{\textbackslash fussy} which is too small for narrow columns. On the other hand the \texttt{\textbackslash sloppy} declaration (which sets \texttt{\textbackslash tolerance} to 10000 = \( \infty \)) is too large, allowing really bad spacing.

We therefore use a \( \texttt{\textbackslash multicoltolerance} \) parameter for the \texttt{\textbackslash tolerance} value inside the \texttt{\textbackslash multicols} environment. Its default value is 9999 which is less than infinity but ‘bad’ enough for most paragraphs in a multicolumn environment. Changing its value should be done outside the \texttt{\textbackslash multicols} environment. Since \texttt{\textbackslash tolerance} is set to \texttt{\textbackslash multicoltolerance} at the beginning of every \texttt{\textbackslash multicols} environment one can locally overwrite this default by assigning \( \texttt{\textbackslash tolerance} = \langle \texttt{desired value} \rangle \). There also exists a \( \texttt{\textbackslash multicoltolerance} \) parameter holding the value for \texttt{\textbackslash pretolerance} within a \texttt{\textbackslash multicols} environment. Both parameters are usually used only by package designers.

Generation of multicolumn output can be divided into two parts. In the first part we are collecting material for a page, shipping it out, collecting material for the next page, and so on. As a second step, balancing will be done when the end of the \texttt{\textbackslash multicols} environment is reached. In the first step \( \LaTeX \) might consider more material whilst finding the final column content than it actually uses when shipping out the page. This might cause a problem if a footnote is encountered in the part of the input considered, but not used, on the current page. In this case the footnote might show up on the current page, while the footnotemark
corresponding to this footnote might be set on the next one.\footnote{5} Therefore the \texttt{multicol} environment gives a warning message\footnote{6} whenever it is unable to use all the material considered so far.

If you don’t use footnotes too often the chances of something actually going wrong are very slim, but if this happens you can help \TeX{} by using a \texttt{\pagebreak} command in the final document. Another way to influence the behavior of \TeX{} in this respect is given by the counter variable \texttt{collectmore}. If you use the \texttt{\setcounter} declaration to set this counter to \texttt{(number)}, \TeX{} will consider \texttt{(number)} more (or less) lines before making its final decision. So a value of \texttt{-1} may solve all your problems at the cost of slightly less optimal columns.

In the second step (balancing columns) we have other bells and whistles. First of all you can say \texttt{\raggedcolumns} if you don’t want the bottom lines to be aligned. The default is \texttt{\flushcolumns}, so \TeX{} will normally try to make both the top and bottom baselines of all columns align.

If there is only a small amount of material available for balancing then you may end up with very few lines per column. In an extreme case there may be only one line which looks distinctly odd. In that case it might be better to have more material distributed to the earlier columns even if that means that later columns are empty or partially empty. This is controlled through the counter \texttt{minrows} (default 1). If set to a higher value then the balancing will have at least that many rows in the first column (and also all further columns until it runs out of material).

Additionally you can set another counter, the \texttt{unbalance} counter, to some positive \texttt{(number)}. This will make all but the right-most column \texttt{(number)} of lines longer than they would normally have been. ‘Lines’ in this context refer to normal text lines (i.e. one \texttt{\baselineskip} apart); thus, if your columns contain displays, for example, you may need a higher \texttt{(number)} to shift something from one column into another. A negative value can make sense if you have set \texttt{minrows} and want to locally adjust that.

Unlike \texttt{collectmore}, the \texttt{unbalance} counter is reset to zero at the end of the environment so it only applies to one \texttt{multicol} environment.

The two methods may be combined but I suggest using these features only when fine tuning important publications.

Two more general tuning possibilities were added with version 1.5. \TeX{} allows to measure the badness of a column in terms of an integer value, where 0 means optimal and any higher value means a certain amount of extra white space. 10000 is considered to be infinitely bad. In that case the algorithm aborts altogether, it is impossible to find a solution that distributes the text evenly over all columns. If that is the case the last column usually has less text than the others. In the earlier releases this text was stretched to produce a column with the same height as all others, sometimes resulting in really ugly looking columns.

In the new release this stretching is only done if the badness of the final column is not larger than the value of the counter \texttt{finalcolumnbadness}. The default setting is 9999, thus preventing the stretching for all columns that \TeX{} would consider infinitely bad. In that case the final column is allowed to run short which gives a much better result.

And there are two more parameters of some experimental nature, one called \texttt{\multicolovershoot} the other \texttt{\multicolundershoot}. They control the amount of space a column within the \texttt{multicol} environment is allowed to be “too full” or “too short” without affecting the column badness. They are set to 0pt and 2pt, respectively.

Finally, when doing the balancing at the end, columns may become higher than the remaining available space. In that case the algorithm aborts and instead generates a normal page. However, if the amount is not too large, e.g., a line or so, then it might be better to keep everything on the same page instead of starting a new page with just one line after balancing. So the parameter \texttt{\maxbalancingoverflow} governs this process: only when the excess gets larger than its value balancing is aborted.
2.2 Not balancing the columns

Although this package was written to solve the problem of balancing columns, I got repeated requests to provide a version where all white space is automatically placed in the last column or columns. Since version v1.5u this now exists: if you use \multicols* instead of the usual environment the columns on the last page are not balanced. Of course, this environment only works on top-level, e.g., inside a box one has to balance to determine a column height in absence of a fixed value.

2.3 Manually breaking columns

Another request often voiced was: “How do I tell \LaTeX\ that it should break the first column after this particular line?” The \pagebreak command (which works with the two-column option of \LaTeX) is of no use here since it would end the collection phase of \multicols and thus all columns on that page. So with version 1.5u the \columnbreak command was added. If used within a paragraph it marks the end of the current line as the desired breakpoint. You can observe its effect on the previous page where three lines of text have been artificially forced into the second column (resulting in some white space between paragraphs in the first column).

From version 1.9 onwards \columnbreak accepts an optional argument (just like \pagebreak) in which you can specify the desirability to break the column at that point: supported values are 0 (slightly desirable) to 4 (forced). This version also adds \newcolumn which forces a column break but runs the column short (comparable to \newpage).

2.4 Floats inside a \multicols environment

Within the \multicols environment the usual star float commands are available but their function is somewhat different as in the two-column mode of standard \LaTeX. Starred floats, e.g., \figure*, denote page wide floats that are handled in a similar fashion as normal floats outside the \multicols environment. However, they will never show up on the page where they are encountered. In other words, one can influence their placement by specifying a combination of t, b, and/or p in their optional argument, but h doesn’t work because the first possible place is the top of the next page. One should also note, that this means that their placement behavior is determined by the values of \topfraction, etc. rather than by \dbl... .

2.5 Support for right-to-left typesetting

In right-to-left typesetting the order of the columns on the page also need to be reversed, i.e., the first column has to appear on the far right and the last column on the left. This is supported through the commands \RLmulticolcolumns (switching to right-to-left typesetting) and \LRmulticolcolumns (switching to left-to-right typesetting) the latter being the default.

2.6 Warnings

Under certain circumstances the use of the \multicols environment may result in some warnings from \TeX or \LaTeX. Here is a list of the important ones and the possible causes:

Underfull \hbox (badness ...

As the columns are often very narrow \TeX wasn’t able to find a good way to break the paragraph. Underfull denotes a loose line but as long as the badness value is below 10000 the result is probably acceptable.

Underfull \vbox ... while \output is active

If a column contains a character with an unusual depth, for example a ‘(’, in the bottom line then this message may show up. It usually has no significance as long as the value is not more than a few points.

\LaTeX Warning: I moved some lines to the next page

As mentioned above, \multicols sometimes screws up the footnote numbering. As a precaution, whenever there is a footnote on a page where \multicols had to leave a remainder for the following page this warning appears. Check the footnote numbering on this page. If it turns out that it is wrong, you have to manually break the page using \newpage or \pagebreak[...].

Floats and marginpars not allowed inside ‘multicols’ environment!

This message appears if you try to use the \marginpar command or an unstarrred version of the \figure or \table environment. Such floats will disappear!

Very deep columns! Grid alignment might be broken

This message can only appear if the option grid was chosen. In that case it will show up if a column has a very large depth so that \multicols is unable to back up to its baseline. This is only relevant if one tries to produce
a document where all text lines are aligned at an invisible grid, something that requires careful adjustment of many parameters and macros, e.g., heading definitions.

2.7 Tracing the output

To understand the reasoning behind the decisions TeX makes when processing a multicols environment, a tracing mechanism is provided. If you set the counter `tracingmulticols' to a positive ⟨number⟩ you then will get some tracing information on the terminal and in the transcript file:

⟨number⟩ = 1. TeX will now tell you, whenever it enters or leaves a multicols environment, the number of columns it is working on and its decision about starting a new page before or after the environment.

⟨number⟩ = 2. In this case you also get information from the balancing routine: the heights tried for the left and right-most columns, information about shrinking if the \raggedcolumns declaration is in force and the value of the `unbalance' counter if positive.

⟨number⟩ = 3. Setting ⟨number⟩ to this value will additionally trace the mark handling algorithm. It will show what marks are found, what marks are considered, etc. To fully understand this information you will probably have to read carefully through the implementation.

⟨number⟩ ≥ 4. Setting ⟨number⟩ to such a high value will additionally place an \hrule into your output, separating the part of text which had already been considered on the previous page from the rest. Clearly this setting should not be used for the final output. It will also activate even more debugging code for mark handling.

3 Prefaces to older versions

3.1 Preface to version 1.4

Beside fixing some bugs as mentioned in the multicol.bug file this new release enhances the multicols environment by allowing for balancing in arbitrary contexts. It is now, for example, possible to balance text within a multicols or a minipage as shown in 2 where a multicols environment within a quote environment was used. It is now even possible to nest multicols environments.

The only restriction to such inner multicols environments (nested, or within TeX’s internal vertical mode) is that such variants will produce a box with the balanced material in it, so that they can not be broken across pages or columns.

Additionally I rewrote the algorithm for balancing so that it will now produce slightly better results.

I updated the source documentation but like to apologize in advance for some ‘left over’ parts that slipped through the revision.

A note to people who like to improve the balancing algorithm of multicols: The balancing routine is now placed into a single macro which is called \balance@columns. This means that one can easily try different balancing routines by rewriting this macro. The interface for it is explained in table 1. There are several improvements possible, one can think of integrating the \badness function of TeX3, define a faster algorithm for finding the right column height, etc.

If somebody thinks he/she has an enhancement I would be pleased to learn about it. But please obey the copyright notice and don’t change multicol.dtx directly!

3.2 Preface to version 1.2

After the article about the multicols environment was published in TUGboat 10#3, I got numerous requests for these macros. However, I also got a changed version of my style file, together with a letter asking me if I would include the changes to get better paragraphing results in the case of narrow lines. The main differences to my original style option were additional parameters (like \multicoladjdemerits to be used for \adjdemerits, etc.) which would influence the line breaking algorithm.

But actually resetting such parameters to zero or even worse to a negative value won’t give better line breaks inside the multicols environment. TeX’s line breaking algorithm will only look at those possible line breaks which can be reached without a badness higher than the current value of \tolerance (or \pretolerance in the first pass). If this isn’t pos-
The macro \balance@columns that contains the code for balancing gathered material is a macro without parameters. It assumes that the material for balancing is stored in the box \mult@box which is a \vbox. It also "knows" about all parameters set up by the \multicols environment, like \col@number, etc. It can also assume that \@colroom is the still available space on the current page.

When it finishes it must return the individual columns in boxes suitable for further processing with \page@sofar. This means that the left column should be stored in box register \mult@firstbox, the next in register \mult@firstbox + 2, ..., only the last one as an exception in register \mult@grightbox. Furthermore it has to set up the two macros \kept@firstmark and \kept@botmark to hold the values for the first and bottom mark as found in the individual columns. There are some helper functions defined in section 5.1 which may be used for this. Getting the marks right "by hand" is non-trivial and it may pay off to first take a look at the documentation and implementation of \balance@columns below before trying anew.

Table 1: Interface description for \balance@columns

Table 1: Interface description for \balance@columns

possible, then, as a last resort, \TeX will produce overfull boxes. All those (and only those) possible break points will be considered and finally the sequence which results in the fewest demerits will be chosen. This means that a value of $-1000$ for \adjdemerits instructs \TeX to prefer visibly incompatible lines instead of producing better line breaks.

However, with \TeX 3.0 it is possible to get decent line breaks even in small columns by setting \emergencystretch to an appropriate value. I implemented a version which is capable of running both in the old and the new \TeX (actually it will simply ignore the new feature if it is not available). The calculation of \emergencystretch is probably incorrect. I made a few tests but of course one has to have much more experience with the new possibilities to achieve the maximum quality.

Version 1.1a had a nice ‘feature’: the penalty for using the forbidden floats was their ultimate removal from \TeXs \@freelist so that after a few \marginpars inside the \multicols environment floats where disabled forever. (Thanks to Chris Rowley for pointing this out.) I removed this misbehavior and at the same time decided to allow at least floats spanning all columns, e.g., generated by the figure* environment. You can see the new functionality in table 2 which was inserted at this very point. However single column floats are still forbidden and I don’t think I will have time to tackle this problem in the near future. As an advice for all who want to try: wait for \TeX 3.0. It has a few features which will make life much easier in multi-column surroundings. Nevertheless we are working here at the edge of \TeXs capabilities, really perfect solutions would need a different approach than it was done in \TeXs page builder.

The text below is nearly unchanged, I only added documentation at places where new code was added.

4 The Implementation

We are now switching to two-column output to show the abilities of this environment (and bad layout decisions).

4.1 The documentation driver file

The next bit of code contains the documentation driver file for \TeX, i.e., the file that will produce the documentation you are currently reading. It will be extracted from this file by the docstrip program. Since this is the first code in this file one can produce the documentation simply by running \TeX on the \dtx file.

```
1 ⟨∗driver⟩
2 \documentclass{ltxdoc}
```

We use the balancingshow option when loading \multicols so that full tracing is produced. This has to be done before the doc package is loaded, since doc
\setemergencystretch: This is a hook for people who like to play around. It is supposed to set the \emergencystretch (dimen) register provided in the new \TeX{} 3.0. The first argument is the number of columns and the second one is the current \hsize. At the moment the default definition is 4pt \#1, i.e. the \hsize isn't used at all. But maybe there are better formulae.

\set@floatcmds: This is the hook for the experts who like to implement a full float mechanism for the \texttt{multicols} environment. The \@ in the name should signal that this might not be easy.

Table 2: The new commands of \texttt{multicol.sty} version 1.2. Both commands might be removed if good solutions to these open problems are found. I hope that these commands will prevent that nearly identical style files derived from this one are floating around.

otherwise requires \texttt{multicol} without any options.

\begin{verbatim}
\setlength{\textwidth}{39pc}
\setlength{\textheight}{54pc}
\setlength{\parindent}{1em}
\setlength{\parskip}{0pt plus 1pt}
\setlength{\oddsidemargin}{0pc}
\setlength{\marginparwidth}{0pc}
\setlength{\topmargin}{-2.5pc}
\setlength{\headsep}{20pt}
\setlength{\columnsep}{1.5pc}
\end{verbatim}

We want a rule between columns.

\begin{verbatim}
\setlength{\columnseprule}{.4pt}
\end{verbatim}

We also want to ensure that a new \texttt{multicols} environment finds enough space at the bottom of the page.

\begin{verbatim}
\setlength{\premulticols}{0\baselineskip}
\end{verbatim}

When balancing columns we disregard solutions that are too bad. Also, if the last column is too bad we typeset it without stretch.

4.2 Identification and option processing

We start by identifying the package. Since it makes use of features only available in \TeX{} 2e we ensure that this format is available. (Now this is done earlier in the file.)

\begin{verbatim}
\NeedsTeXFormat{LaTeX2e}
\ProvidesPackage{multicol} [.../... multicolumn formatting]
\end{verbatim}

Next we declare options supported by \texttt{multicol}. Two-column mode and \texttt{multicols} do not work together so we warn about possible problems. However, since you can revert to \texttt{onecolumn} in which case \texttt{multicols} does work, we don’t make this an error.

\begin{verbatim}
\DeclareOption{twocolumn}{\PackageWarning{multicol}{May not work with the twocolumn option}}
\end{verbatim}

Line numbers are very small for this article.

\begin{verbatim}
\DocInput{multicol.dtx}
\end{verbatim}
The next option is intended for typesetting on a \baselineskip grid. Right now it doesn’t do anything other than warning if it thinks that the grid got lost.

Next option enables the \docolaction command. As this changes the .aux file content this is not automatically enabled.

4.3 Starting and Ending the multicol Environment

\multicols

As mentioned before, the \multicols environment has one mandatory argument (the number of columns) and up to two optional ones. We start by reading the number of columns into the \col@number register.

If the user forgot the argument, \TeX will complain about a missing number at this point. The error recovery mechanism will then use zero, which isn’t a good choice in this case. So we should now test whether everything is okay. The minimum is two columns at the moment.

We have only enough box registers for twenty columns, so we need to check that the user hasn’t asked for more.

Within the environment we need a special version of the kernel \@footnotetext command since the original sets the \hsize to \columnwidth which is not correct in the multicol environment. Here \columnwidth refers to the width of the individual column and the footnote should be in \textwidth. Since \@footnotetext has a different definition inside a minipage environment we do not redefine it directly. Instead we locally set \columnwidth to \textwidth and call the original (current) definition stored in \orig@footnotetext. If the \multicols environment is nested inside another \multicols environment then the redefinition has already happened. So be better test for this situation. Otherwise, we will get a \TeX stack overflow as this would generate a self-referencing definition.

Now we can safely look for the optional arguments. We can only safely look for the optional arguments. The \multicols macro grabs the first optional argument (if any) and looks for the second one.

This argument should be a ⟨dimen⟩ denoting the minimum free space needed on the current page to start the environment. If the user didn’t supply one, we use \premulticols as a default.

After removing all arguments from the input we are able to start with \multicols.
with \par since otherwise the test for “inner” mode wouldn’t show if we are in a box.

99 \par
100 \ifinner \boxedmulticolstrue

Otherwise we check \doublecol@number. This counter is zero outside a multicols environment but positive inside (this happens a little later on). In the second case we need to process the current multicols also in “boxed mode” and so change the switch accordingly.

101 \else
102 \ifnum \doublecol@number>\z@
103 \boxedmulticolstrue
104 \fi
105 \fi

Then we look to see if statistics are requested:

106 \mult@info\z@
107 \{Starting environment with \the\col@number space columns\%

In boxed mode we add some more info.

109 \if@boxedmulticols\MessageBreak
110 \text{(boxed mode)}\fi
111 \%

Then we measure the current page to see whether a useful portion of the multicolumn environment can be typeset. This routine might start a new page.

112 \enough@room\#2\%

Now we output the first argument and produce vertical space above the columns. (Note that this argument corresponds to the first optional argument of the multicols environment.) For many releases this argument was typeset in a group to get a similar effect as \twocolumn[...] where the argument is also implicitly surrounded by braces. However, this conflicts with local changes done by things like sectioning commands (which account for the majority of commands used in that argument) messing up vertical spacing etc. later in the document so that from version v1.5q on this argument is again typeset at the outer level.

113 \#1\par\addvspace\multicolsep
114 \if@boxedmulticols\MessageBreak

When the last line of a paragraph had a positive depth then this depth normally taken into account by the baselineskip calculation for the next line. However, the columns produced by a following \multicol are rigid and thus the distance from the baseline of a previous text line to the first line in a \multicol would differ depending on the depth of the previous line. To account for this we add a negative space unless the depth is -1000pt which signals something special to \TeX and is not supposed to be a real depth.

115 \else
116 \ifdim \prevdepth = -\@m\p@
117 \else

The actual generation of this corrective space is a little bit more complicated as it doesn’t make sense to always back up to the previous baseline (in case an object with a very large depth was placed there, e.g., a centered tabular). So we only back up to the extent that we are within the \baselineskip grid. We know that the box produced by multicols has \topskip at its top so that also needs to be taken into account.

118 \@tempcnta \prevdepth
119 \divide \@tempcnta \baselineskip
120 \advance \@tempcnta \one
121 \advance \@tempcnta \baselineskip
122 \advance \@tempcnta \topskip
123 \kern -\dimen@ \fi

We start a new grouping level to hide all subsequent changes (done in \prepare@multicols for example).

124 \begingroup
125 \prepare@multicols
126 \if@boxedmulticols
127 \setbox \mult@box \vbox \bgroup
128 \color@setgroup

We may have to reset some parameters at this point, perhaps \@parboxrestore would be the right action but I leave it for the moment.

130 \fi

We finish by suppressing initial spaces.

131 \ignorespaces}

Here is the switch and the box for “boxed” multicols code.

132 \newif \if@boxedmulticols
133 \@boxedmulticolsfalse
134 \newbox \mult@box

The \enough@room macro used above isn’t perfect but works reasonably well in this context. We measure the free space on the current page by subtracting \pagetotal from \pagegoal. This isn’t entirely correct since it doesn’t take the ‘shrinking’

\footnote{See the documentation of \endmulticols for further details.}
(i.e. \pageshrink) into account. The recent contribution list might be nonempty so we start with \par and an explicit \penalty. Actually, we use \addpenalty to ensure that a following \addvspace will see the vertical space that might be present. The use of \addpenalty will have the effect that all items from the recent contributions will be moved to the main vertical list and the \pagetotal value will be updated correctly. However, the penalty will be placed in front of any dangling glue item with the result that the main vertical list may already be overfull even if \TeX is not invoking the output routine.

135 \def\enough@room#1{% Measuring makes only sense when we are not in “boxed mode” so the routine does nothing if the switch is true.
136 \if@boxedmulticols\else
137 \par
To empty the contribution list the first release contained a penalty zero but this had the result that \addvspace couldn’t detect preceding glue. So this was changed to \addpenalty. But this turned out to be not enough as \addpenalty will not add a penalty when @nobreak is true. Therefore we force this switch locally to false. As a result there may be a break between preceding text and the start of a multicols environment, but this seems acceptable since there is the optional argument for exactly this reason.
138 \bgroup@nobreakfalse\addpenalty\z@\egroup
139 \page@free \pagegoal
140 \advance \page@free \- \pagetotal
To be able to output the value we need to assign it to a register first since it might be a register (default) in which case we need to use \the or it might be a plain value in which case \the would be wrong.
141 \mult@info\z@
142 {Current page:\MessageBreak
143 \the\pagegoal: used \the\pagetotal
144 \space -> free=\the\page@free
145 \MessageBreak
146 needed \the@tempskipa
147 \space(for #1)%}
Our last action is to force a page break if there isn’t enough room left.
150 \ifdim \page@free <\#1\newpage \fi
When preparing for multicolumn output several things must be done.
152 \def\prepare@multicols{% We start saving the current \@totalleftmargin and then resetting the \parshape in case we are inside some list environment. The correct indentation for the multicols environment in such a case will be produced by moving the result to the right by \multicol@leftmargin later on. If we would use the value of \@totalleftmargin directly then lists inside the multicols environment could cause a shift of the output.
153 \multicol@leftmargin\@totalleftmargin
154 \@totalleftmargin\z@
155 \parshape\z@
We also set the register \doublecol@number for later use. This register should contain 2 × \col@number. This is also an indicator that we are within a multicols environment as mentioned above.
156 \doublecol@number\col@number
157 \multiply\doublecol@number\tw@
158 \advance\doublecol@number\mult@rightbox
159 \if@boxedmulticols
160 \let\l@kept@firstmark\kept@firstmark
161 \let\l@kept@botmark\kept@botmark
162 \global\let\kept@firstmark\@empty
163 \global\let\kept@botmark\@empty
164 \else
We add an empty box to the main vertical list to ensure that we catch any insertions (held over or inserted at the top of the page). Otherwise it might happen that the \eject is discarded without calling the output routine. Inside the output routine we remove this box again. Again this code applies only if we are on the main vertical list and not within a box. However, it is not enough to turn off interline spacing, we also have to clear \topskip before adding this box, since \topskip is always inserted before the first box on a page which would leave us with an extra space of \topskip if multicols start on a fresh sheet.
165 \nointerlineskip{\topskip\z@\null}%
166 \output{%
167 \global\setbox\partial@page\vbox{
168 %} Now we have to make sure that we catch one special situation which may result in loss of text! If the user has a huge amount of vertical material within the first optional argument that is larger then \premulticols and we are near the bottom of the page then it can happen that not the \eject is triggering this special output routine but rather the
overfull main vertical list. In that case we get another breakpoint through the \texttt{\textbackslash eject} penalty. As a result this special output routine would be called twice and the contents of \texttt{\partial@page}, i.e. the material before the \texttt{multicols} environment gets lost. There are several solutions to avoid this problem, but for now we will simply detect this and inform the user that he/she has to enlarge the \texttt{\premulticols} by using a suitable value for the second argument.

Finally we need to record the marks that are present by using a suitable value for the second argument. By using a suitable value for the second argument.

\begin{verbatim}
169  (*check*)
170  \ifvoid\partial@page\else
171  \PackageError{multicol}{
172  {Error saving partial page}%
173  {The part of the page before
174  the multicols environment was
175  nearly full with \texttt{\textbackslash the} result
176  that starting the environment
177  will produce an overfull
178  page. Some \texttt{\textbackslash the} text may be lost!
179  Please increase \texttt{\premulticols}
180  either generally or for this
181  \texttt{\textbackslash multicols} environment by specifying a
182  suitable value in the second
183  optional argument to \texttt{\textbackslash multicols} environment.}
184  \unvbox\partial@page
185  \box\last@line
186  \fi
187  (/check)
188  \unvbox\@clv
189  \global\setbox\last@line\lastbox
190  \vsize
191  \relax
\end{verbatim}

Finally we need to record the marks that are present within the \texttt{\partial@page} so that we can construct correct first and bottom marks later on. This is done by the following code.

\begin{verbatim}
192 \prep@keptmarks
\end{verbatim}

Finally we have to initialize \texttt{\kept@topmark} which should ideally be initialized with the mark that is current on “top” of this page. Unfortunately we can’t use \texttt{\topmark} because this register will not always contain what its name promises because \TeX{} sometimes calls the output routine for float management.\footnote{During such a call the \texttt{\botmark} gets globally copied to \texttt{\topmark} by the \TeX{} program.} Therefore we use the second best solution by initializing it with \texttt{\firstmark}. In fact, for our purpose this doesn’t matter as we use \texttt{\kept@topmark} only to initialize \texttt{\firstmark} and \texttt{\botmark} of a following page if we don’t find any marks on the current one.

\begin{verbatim}
193 \global\let\kept@topmark=\firstmark
194 \eject
\end{verbatim}

The next thing to do is to assign a new value to \texttt{\vsize}. \TeX{} maintains the free room on the page (i.e. the page height without the space for already contributed floats) in the register \texttt{\@colroom}. We must subtract the height of \texttt{\partial@page} to put the actual free room into this variable.

\begin{verbatim}
195 \advance\@colroom\ht\partial@page
\end{verbatim}

Then we have to calculate the \texttt{\vsize} value to use during column assembly. \texttt{\set@mult@vsize} takes an argument which allows to make the setting local (\texttt{\relax}) or global (\texttt{\global}). The latter variant is used inside the output routine below. At this point here we have to make a local change to \texttt{\vsize} because we want to get the original value for \texttt{\vsize} restored in case this \texttt{multicols} environment ends on the same page where it has started.

\begin{verbatim}
196 \set@mult@vsize\relax
\end{verbatim}

Now we switch to a new \texttt{\output} routine which will be used to put the gathered column material together.

\begin{verbatim}
197 \output{\multi@column@out}
\end{verbatim}

Finally we handle the footnote insertions. We have to multiply the magnification factor and the extra skip by the number of columns since each footnote reduces the space for every column (remember that we have page-wide footnotes). If, on the other hand, footnotes are typeset at the very end of the document, our scheme still works since \texttt{\count@footins} is zero then, so it will not change. To allow even further customization the setting of the \texttt{\footins} parameters is done in a separate macro.

\begin{verbatim}
198 \init@mult@footins
\end{verbatim}

For the same reason (page-wide footnotes), the \texttt{\dimexpr} register controlling the maximum space used for footnotes isn’t changed. Having done this, we must reinsert all the footnotes which are already present (i.e. those encountered when the material saved in \texttt{\partial@page} was first processed). This will reduce the free space (i.e. \texttt{\pagetotal}) by the appropriate amount since we have changed the magnification factor, etc. above.

\begin{verbatim}
199 \reinsert@footnotes
\end{verbatim}

Inside \texttt{multicols} a \texttt{\clearpage} is fairly useless as we aren’t supporting floats. In fact, it can cause harm as it doesn’t know about the \texttt{\partial@page} and may therefore result in making columns too long. So we change that to behave like \texttt{\newpage} but also check if there are any deferred floats. If so, perhaps the user tried to place them through that \texttt{\clearpage} (but that needs to be done before starting the \texttt{multicols} environment.

\begin{verbatim}
200 \def\clearpage{%
\end{verbatim}

\footnote{\texttt{multicols} environment.}
Additionally, we advance \baselineskip by \multicolbaselineskip to allow corrections for narrow columns.

\@dblfloat
\@enddblfloat
\end@dblfloat_environment

The $hsize$ of the columns is given by the formula:
\[
\text{\linewidth} = (col\@number - 1) \times \text{\columnsep}
\]

The formula above has changed from release to release. We now start with the current value of $\text{\linewidth}$ so that the column width is properly calculated when we are inside a minipage or a list or some other environment. This will be achieved with:

\hspace{\linewidth}advance\hspace{\columnsep}
\advance\linewidth-\col@number\columnsep
\divide\linewidth by\col@number

We also set $\text{\linewidth}$ and $\text{\columnwidth}$ to $\text{\linewidth}$ in the past $\text{\columnwidth}$ was left unchanged. This is inconsistent, but $\text{\columnwidth}$ is used only by floats (which aren’t allowed in their current implementation) and by the $\text{\footnote}$ macro. Since we want page-wide footnotes, this simple trick saved us from rewriting the $\text{\footnote}$ macros. However, some applications referred to $\text{\columnwidth}$ as the “width of the current column” to typeset displays (the amsmath package, for example) and to allow the use of such applications together with multicol this is now changed.

Before we change $\text{\linewidth}$ to the new value we record its old value in some register called $\full@width$. This value is used later on when we package all columns together.

\full@width\linewidth
\linewidth\hspace
\columnwidth\hspace

This macro is used to set the parameters associated with footnote floats. It can be redefined by applications that require different amount of spaces when typesetting footnotes.

\def\init@mult@footins{%
\multiply\count@footins\col@number
\multiply\skip@footins \col@number
}

Since we have to set $\col@number$ columns on one page, each with a height of $\@colroom$, we have to assign $\vsize = \col@number \times \@colroom$ in order to collect enough material before entering the $\output$ routine again. In fact we have to add another $(\col@number - 1) \times (\baselineskip - \topskip)$ if you think about it.

\def\set@mult@vsize{%
\set@mult@vsize@\vsize
\init@mult@footins
\vsize@\vsize
\set@mult@vsize

9I'm not sure that I really want page-wide footnotes. But balancing of the last page can only be achieved with this approach or with a multi-path algorithm which is complicated and slow. But it’s a challenge to everybody to prove me wrong! Another possibility is to reimplement a small part of the fire_up procedure in \TeX (the program). I think that this is the best solution if you are interested in complex page makeup, but it has the disadvantage that the resulting program cannot be called \TeX thereafter.
But this might not be enough since we use \vsplit later to extract the columns from the gathered material. Therefore we add some 'extra lines,' one for each column plus a corrective action depending on the value of the 'collectmore' counter. The final value is assigned globally if #1 is \global because we want to use this macro later inside the output routine too.

\begin{multicols}{#1}
\@totalleftmargin Here is the dimen register we need for saving away the outer value of \@totalleftmargin.

\newdimen\multicol@leftmargin
\@Mvi In versions prior to 1.8r the balancing at the end of the environment was done by changing the output routine from \multicol@out to \balance@column@out. As it turned out that this has a couple of issues when the last columns should not be balanced after all (for example because they contained several \columnbreak commands we now stay with one output routine for the environment and only signal that we reached the end of the environment by marking it with a special penalty that we can check for later.

\mathchardef\@Mvi=10006 % 10005 is \% \columnbreak
\endmulticols

When the boxed multicol is returned to the page it can happen that it doesn't fit onto it and \LaTeX therefore breaks earlier. The problem in that case is that during the generation \hsize, etc. got changed and this setting is still in effect right now, and if this boxed multicol is within, say, \multicols* then its output routine gets very upset. We therefore delay returning the result by saving it in box for now until we have left the group below.

\global\setbox\mc@boxedresult\vbox{%
\page@sofar
\global\let\kept@firstmark\l@kept@firstmark
\global\let\kept@botmark\l@kept@botmark
}%
\langle∗ marktrace \rangle
\mult@info\@ne{Restore kept marks to first: \meaning\kept@firstmark
bot: \meaning\kept@botmark }%
\langle /marktrace \rangle
This finishes the code for the “boxed” case.

\else If there was a \columnbreak on the very last line all material will have been moved to the \colbreak@box. Thus the galley will be empty and no output routine gets called so that the text is lost. To avoid this problem (though unlikely) we check if the current galley is empty and the \colbreak@box contains text and if so return that to the galley. If the galley is non-empty any material in \colbreak@box is added in the output routine since it needs to be put in front.

\ifdim\pagegoal=\maxdimen
\ifvoid\colbreak@box\else
\mult@info\@ne{Re-adding forced break(s) for splitting}%
\unvbox\colbreak@box\fi
\fi
\fi

If we are in an unrestricted \multicols environment we end the current paragraph above with \par but this isn’t sufficient since \TeXs page\_builder will not
totally empty the contribution list.\footnote{This once caused a puzzling bug where some of the material was balanced twice, resulting in some overprints. The reason was the \texttt{\textbackslash eject} which was placed at the end of the contribution list. Then the page\_builder was called (an explicit \texttt{\textbackslash penalty} would empty the contribution list), but the line with the \texttt{\textbackslash eject} didn’t fit onto the current page. It was then reconsidered after the output routine had ended, causing a second break after one line.} Therefore we must also add an explicit \texttt{\textbackslash penalty}. Now the contribution list will be emptied and, if its material doesn’t all fit onto the current page then the output routine will be called before we change it. At this point we need to use \texttt{\textbackslash penalty} not \texttt{\textbackslash addpenalty} to ensure that a) the recent contributions are emptied and b) that the very last item on the main vertical list is a valid break point so that \TeX breaks the page in case it is overfull.

$$\texttt{\textbackslash penalty}\z@$$

Now it’s safe to call the output routine in order to balance the columns. We do this by calling it with a special penalty.

$$\texttt{\textbackslash penalty}\texttt{-@Mvi}$$

If the \texttt{multicols} environment body was completely empty or if a multi-page \texttt{multicols} just ends at a page boundary we have the unusual case that the \texttt{\textbackslash eject} will have no effect (since the main vertical list is empty)—thus no output routine is called at all. As a result the material preceding the \texttt{multicols} (stored in \texttt{\textbackslash partial@page} will get lost if we don’t put this back by hand.

$$\texttt{\textbackslash if\textbackslash box\textbackslash partial@page}\texttt{\textbackslash un\textbackslash box\textbackslash partial@page}\texttt{\textbackslash fi}$$

After the output routine has acted we restore the kept marks to their initial value.

$$\texttt{\textbackslash global}\texttt{\textbackslash let\textbackslash kept\textbackslash \textbackslash firstmark}@\texttt{\textbackslash empty}\texttt{\textbackslash global}\texttt{\textbackslash let\textbackslash kept\textbackslash \textbackslash botmark}@\texttt{\textbackslash empty}\texttt{\textbackslash (marktrace)}\texttt{\textbackslash mult\textbackslash info}\texttt{\textbackslash tw@}\texttt{\{Make kept marks empty\}}\%\texttt{\textbackslash fi\textbackslash trace}$$

The output routine above will take care of the \texttt{\textbackslash vsize} and reinsert the balanced columns, etc. But it can’t reinsert the \texttt{\textbackslash footnotes} because we first have to restore the \texttt{\textbackslash footins} parameter since we are returning to one column mode. This will be done in the next line of code; we simply close the group started in \texttt{multicols}.

To fix an obscure bug which is the result of the current definition of the \texttt{\begin{...} \end{...}} macros, we check that we are still (logically speaking) in the \texttt{multicols} environment. If, for example, we forget to close some environment inside the \texttt{multicols} environment, the following \texttt{\endgroup} would be incorrectly considered to be the closing of this environment.

$$\texttt{\textbackslash check\textbackslash end\{multicols\}}\%\texttt{\endgroup}$$

$$\texttt{\textbackslash global}\texttt{\textbackslash c@unbalance}@\texttt{\textbackslash z@}$$

Now it’s time to return any footnotes if we are in unrestricted mode. In boxed mode footnotes are kept inside, but in that case we have to first return the saved box to the page and then write another column status into the .aux file to support \texttt{docolaction} in case we have nested environments.

$$\texttt{\textbackslash if\textbackslash ifboxedmulticols}\texttt{\textbackslash un\textbackslash box\textbackslash mc@boxedresult}\texttt{\mc@col\textbackslash status@write}\texttt{\else}\texttt{\textbackslash reinsert@footnotes}\texttt{\fi}$$

We also take a look at the amount of free space on the current page to see if it’s time for a page break. The vertical space added thereafter will vanish if \texttt{\textbackslash enough@room} starts a new page.

But there is one catch. If the \texttt{\textbackslash end{multicols}} is at the top of which can happen if there is a break point just before it (such as end ending environment) which was chosen. In that case we would do the next page using the internal \texttt{\textbackslash vsize} for multicoll collection which is a disaster. So we better catch this case. Fortunately we can detect it by looking at \texttt{\textbackslash pagegoal}.

$$\texttt{\textbackslash ifdim}\texttt{\textbackslash pagegoal}@\texttt{\textbackslash max\textbackslash dimen}\texttt{\textbackslash global}\texttt{\textbackslash vsize}@\texttt{\textbackslash col\textbackslash room}\texttt{\else}\texttt{\textbackslash en\textbackslash enough@room}@\texttt{\textbackslash col\textbackslash room}\texttt{\fi}\texttt{\fi}\texttt{\addvspace\textbackslash multicols\textbackslash sep}$$

There is one more thing to do: the balanced result of the environment is supposed to have a \texttt{\textbackslash prevdepth} of zero as we backed up by its real prevdepth within \texttt{\textbackslash page@sofar}. However if the balancing happened in the output routine then \TeX reverts to the \texttt{\textbackslash prevdepth} that was current before the OR once the OR has finished. In short \texttt{\textbackslash prevdepth} is something you can’t set globally it is always local to the current list being built. Thus we need to set it back to zero here to avoid incorrect spacing.

$$\texttt{\textbackslash prevdepth}@\texttt{\textbackslash z@}$$
If statistics are required we finally report that we have finished everything.

\begin{verbatim}
\newcount\c@unbalance
\newcount\c@collectmore
\newcount\col@number
\newcount\doublecol@number
\newcount\multicoltolerance
\newcount\multicolpretolerance
\newdimen\full@width
\newdimen\page@free
\newdimen\premulticols
\newdimen\postmulticols
\newskip\multicolsep
\newskip\multicolbaselineskip
\newbox\partial@page
\newbox\last@line
\newbox\mc@boxedresult
\end{verbatim}

Let us end this section by allocating all the registers used so far.

In the new \LaTeX{} release \col@number{} is already allocated by the kernel, so we don’t allocate it again.

\newcount\col@number
\newcount\doublecol@number
\newcount\multicoltolerance
\newcount\multicolpretolerance
\newdimen\full@width
\newdimen\page@free
\newdimen\premulticols
\newdimen\postmulticols
\newskip\multicolsep
\newskip\multicolbaselineskip
\newbox\partial@page
\newbox\last@line
\newbox\mc@boxedresult

And here are their default values:

\c@unbalance = 0
\c@collectmore = 0
\col@number = 1
\multicoltolerance = 9999
\multicolpretolerance = -1
\premulticols = 50pt
\postmulticols = 20pt
\multicolsep = 12pt plus 4pt minus 3pt
\multicolbaselineskip = 0pt

### 4.4 The output routines

We first start with some simple macros. When typesetting the page we save the columns either in the box registers 0, 2, 4, … (locally) or 1, 3, 5, … (globally). This is \textsc{plain} \TeX{} policy to avoid an overflow of the save stack.

\texttt{\textbackslash process@cols} Therefore we define a \texttt{\textbackslash process@cols} macro to help us in using these registers in the output routines below. It has two arguments: the first one is a number; the second one is the processing information. It loops starting with \texttt{\count@=#1} (\texttt{\count@} is a scratch register defined in \textsc{plain} \TeX{}), processes argument \texttt{#2}, adds two to \texttt{\count@}, processes argument \texttt{#2} again, etc. until \texttt{\count@} is higher than \texttt{\doublecol@number}. It might be easier to understand it through an example, so we define it now and explain its usage afterwards.

\begin{verbatim}
\def\process@cols#1#2{\count@#1\relax
\loop
\typeout{Looking at box \the\count@}
\#2\%\ifvoid\count@
\setbox\count@\hbox to\hsize{}\%
\else
\wd\count@\hsize\fi/%
\advance\count@\m@ne
\ifnum\count@<\doublecol@number
\repeat
\end{verbatim}

\texttt{\textbackslash page@sofar} We now define \texttt{\textbackslash page@sofar} to give an example of the \texttt{\textbackslash process@cols} macro. \texttt{\textbackslash page@sofar} should output everything prepared by the balancing routine \texttt{\textbackslash balance@columns}.\footnote{You will see the reason for this numbering when we look at the output routines \texttt{\multi@column@out} and \texttt{\balance@columns@out}.}

\begin{verbatim}
\def\page@sofar{\balance@columns
prepares its output in the even numbered scratch box registers. Now we output the columns gathered assuming that they are saved in the box registers 2 (left column), 4 (second column), … However, the last column (i.e. the rightmost) should be saved in box register 0.\footnote{You will see the reason for this numbering when we look at the output routines \texttt{\multi@column@out} and \texttt{\balance@columns@out}.}
\process@cols\mult@rightbox
We have to check if the box in question is void, because the operation \texttt{\wd\textlangle number\textrangle} on a void box will not change its dimension (sigh).
\begin{verbatim}
\ifvoid\count@
\setbox\count@\hbox to\hsize{}\%
\else
\wd\count@\hsize\fi/%
\end{verbatim}
Now we give some tracing information.
\begin{verbatim}
\ifnum\count@<\doublecol@number
\advance\count@\m@ne
\mult@info\z@\{}
\end{verbatim}
At this point we should always be in vertical mode.
\ifvmode\else\error{Multicol Error}\fi

Now we put all columns together in an \hbox of width \full@width (shifting it by \multicol@leftmargin to the right so that it will be placed correctly if we are within a list environment) and separating the columns with a rule if desired.

The box containing the columns has a large height and thus will always result in using \lineskip if the normal \baselineskip calculations are used. We therefore better cancel that process.

\nointerlineskip

As mentioned earlier we want to have the reference point of the box we put on the page being at the baseline of the last line of the columns but we also want to ensure that the box has no depth so that any following skip is automatically starting from that baseline. We achieve this by recording the depths of all columns and then finally backing up by the maximum. (perhaps a simpler method would be to assemble the box in a register and set the depth of that box to zero (not checked).)

We need a global scratch register for this; using standard TEX conventions we choose \dimen2 and initialize it with the depth of the character “p” since that is one of the depths that compete for the maximum.

\setbox\z@\hbox{\multicolmindepthstring}\global\dimen\tw@\dp\z@
\moveright\multicol@leftmargin
\hbox to\full@width{%}

The processed material might consist of a last line with a descender in which case the \prevdepth will be non-zero. However, this material is getting reformatted now so that this value is likely to be wrong. We therefore normalize the situation by pretending that the depth is zero. However, if \page@sofar is being called inside the OR then setting \prevdepth here has no long-lasting effect, we therefore have to repeat this once we return to the main vertical list. Here we set it only for those cases where the command is used within a list and then followed by something else.

\prevdepth\z@

Now after typesetting the box we back up to its baseline by using the value stored in \dimen2 (which will hold the largest depth found on any column).

\kern-\dimen\tw@

However, in case one of the columns was unusually deep \TeX may have tried some corrective actions in which case backing up by the saved value will not bring us back to the baseline. A good indication for this is a depth of \@maxdepth though it is not an absolute proof. If the option grid is used \mc@gridwarn will expand to this, otherwise to \maxdimen in which case this warning will not show up.

\ifdim\dimen\tw@ > \mc@gridwarn
\PackageWarning{multicol}{{Very deep columns!}\MessageBreak Grid alignment might be broken}%
\fi}

The default minimum depth of each column corresponds to the depth of a ‘p’ in the current font. This makes sense for Latin-based languages and was hard-wired initially, but for Asian languages it is better to use a zero depth (and alternatively one might want to use the depth of a strut or a parentheses). So we now offer a way to adjust this while maintaining backward compatibility. Use \renewcommand to alter it.

\multicolmindepthstring{p}

By default the vertical rule between columns will be in \normalcolor.

\mc@align@columns

The depths of the columns depend on their last lines. To ensure that we will always get \phantom{\multicolmindepthstring} as far as the rules are concerned we force the depth to be at least the depth of a letter ‘p’ or more exactly \multicolmindepthstring (which is what we set \dimen2 to above).

\rlap{\phantom{\multicolmindepthstring}}%
Instead of actually reinserting the footnotes we insert an empty footnote. This will trigger insertion mechanism as well and since the old footnotes are still in their box and we are on a fresh page \skip footins should be correctly taken into account.

\vfilmaxdepth

This curious definition is used as the space at the bottom of a column if we implement \raggedcolumns. Normally one only appends \vfill in that case but this is actually wrong for columns that are more or less full: by adding a glue at the bottom such a column doesn’t have any depth any more but without it the material would be allowed a depth of \@maxdepth. So we allow shrinking by that amount. This only makes a difference if the box would otherwise become overfull and shrinking never exceeds the specified value, so we should be fine.

\def\vmulticol@out{Now we can’t postpone the difficulties any longer.
The \vmulticol@out routine will be called in two situations. Either the page is full (i.e., we have collected enough material to generate all the required columns) or a float or marginpar or a \clearpage is sensed. In the latter case the \outputpenalty is less than \@M, otherwise the penalty which triggered the output routine is higher. Therefore it’s easy to distinguish both cases: we simply test this register.

\ifnum\outputpenalty < -\@M
If this was a \clearpage, a float or a marginpar we call \specials
\else
\specials else
\fi
otherwise we construct the final page. For the next block of code see comments in section 7.2.

\ifvoid\colbreak@box\else
\mult@info\one{Re-adding forced break(s) for splitting}\
\setbox\@cclv\vbox{\unvbox\colbreak@box
\penalty-\@Mv
\unvbox\@cclv}%
\fi
Let us now consider the normal case. We have to \vsplit the columns from the accumulated material in box 255. Therefore we first assign appropriate values to \splittopskip and \splitmaxdepth.

\splittopskip\topskip
\splitmaxdepth\@maxdepth
We also need to restrict \boxmaxdepth so that re-boxing is not generating boxes with arbitrary depth.

\ifvbox \@kludgeins
\advance\dimen@ -\ht\@kludgeins
\fi
The star form of \enlargethispage makes the width of the box greater than zero (sneaky isn’t it?).

\ifdim\wd\@kludgeins>\z@
\shr@nkingtrue
\fi
Now we are able to \vsplit off all but the last column. Recall that these columns should be saved in the box registers 2, 4,... (plus offset).

\process@cols\mult@firstbox{%
\setbox\count@
\vsplit\@cclv to\dimen@

\set@keptmarks
After splitting we update the kept marks.

\ifvbox\@kludgeins
\advance\dimen@ -\ht\@kludgeins
\fi
\ifvoid\colbreak@box\else
\mult@info\one{Re-adding forced break(s) for splitting}%
\setbox\@cclv\vbox{\unvbox\colbreak@box
\penalty-\@Mv
\unvbox\@cclv}%
\fi
Then we calculate the current column height (in \dimen@). Note that the height of \partial@page is already subtracted from \@colroom so we can use its value as a starter.

\ifvoid\footins\col@number
\leave\mult@footins
\fi
But we must also subtract the space occupied by footnotes on the current page. Note that we first have to reset the skip register to its normal value. Again, the actual action is carried out in a utility macro, so that other applications can modify it.

\divide\skip\footins\col@number
\ifvoid\footins\else
\leave\mult@footins
\fi
And there is one more adjustment that we have to make: if the user has issue a \enlargethispage command then the height the \@kludgeins box will be the negation of the size by which the page should be enlarged. If the star form of this command has been used then we also need to shrink the resulting column.

That local change will be reverted at the end of the output routine So for the next page the original state will be reestablished. However, in theory there is a possibility to sneak in a whole multicol environment into the running header definition. If that happens then it will also be affected by this change—too bad I think.
in certain situations, for example, if two lists follow each other and we break between them. While such space is usually zero it still has an effect because it hides depth of the last line in the column and that will result in incorrect placement.

```
\setbox\count@
\vbox to \dimen@
\unvbox \count@
\ifshrink\vfilmaxdepth\fi
\fi
```

Then the last column follows.

```
\setbox\mult@rightbox
\vsplit@cclv to \dimen@
\set@keptmarks
\setbox\mult@rightbox \vbox to \dimen@
\unvbox \mult@rightbox
\ifshrink\vfilmaxdepth\fi
\fi
```

Having done this we hope that box 255 is emptied. If not, we reinsert its contents.

```
\ifvoid\@cclv \else
\unvbox\@cclv
\ifnum\outputpenalty=\@M
\else
\penalty\outputpenalty
\fi
\fi
```

In this case a footnote that happens to fall into the leftover bit will be typeset on the wrong page. Therefore we warn the user if the current page contains footnotes. The older versions of \texttt{multicols} produced this warning regardless of whether or not footnotes were present, resulting in many unnecessary warnings.

```
\ifvoid\footins\else
\PackageWarning{multicol}{This moved some lines to the next page.\MessageBreak Footnotes on page \thepage space might be wrong}\fi
```

If the ‘\texttt{tracingmulticols}’ counter is 4 or higher we also add a rule.

```
\ifnum \c@tracingmulticols>\thr@@
\hrule allowbreak \fi
```

To get a correct marks for the current page we have to (locally) redefine \texttt{\firstmark} and \texttt{\botmark}. If \texttt{\kept@firstmark} is non-empty then \texttt{\kept@topmark} must be non-empty too so we can use their values. Otherwise we use the value of \texttt{\kept@topmark} which was first initialized when we gathered the \texttt{\partical@page} and later on was updated to the \texttt{\botmark} for the preceding page.

```
\ifx\empty\kept@firstmark
\let\firstmark\kept@topmark
\let\botmark\kept@topmark
\else
\let\firstmark\kept@firstmark
\let\botmark\kept@botmark
\fi
```

We also initialize \texttt{\topmark} with \texttt{\kept@topmark}. This will make this mark okay for all middle pages of the \texttt{multicols} environment.

```
\let\topmark\kept@topmark
\langle∗marktrace\rangle
\mult@info\tw@
\{Use kept top mark:\MessageBreak \meaning\kept@topmark\MessageBreak
Use kept first mark:\MessageBreak \meaning\kept@firstmark\MessageBreak
Use kept bot mark:\MessageBreak \meaning\kept@botmark\MessageBreak
\producemarkest\MessageBreak \meaning\botmark\MessageBreak
\@gobbletwo\rangle
\langle/\langle∗marktrace\rangle
```

With a little more effort we could have done better. If we had, for example, recorded the shrinkage of the material in \texttt{\partical@page} it would be now possible to try higher values for \texttt{\dimen@} (i.e. the column height) to overcome the problem with the nonempty box 255. But this would make the code even more complex so I skipped it in the current implementation.

Now we use \LaTeX{}’s standard output mechanism.\footnote{This will produce a lot of overhead since both output routines are held in memory. The correct solution would be to redesign the whole output routine used in \LaTeX.} Admittedly this is a funny way to do it.

Within the OR \texttt{\boxmaxdepth} needs to be unrestricted so we set it back now as it was changed above.

```
\boxmaxdepth\maxdimen
\setbox\@cclv
\vbox{\unvbox\partial@page
\page@sofar}\
```

The macro \texttt{\makel@} adds all floats assigned for the current page to this page. \texttt{\outputpage} ships out the resulting box. Note that it is just possible that such floats are present even if we do not allow any inside a \texttt{multicols} environment.

```
\makel@\outputpage
```
After the page is shipped out we have to prepare the kept marks for the following page. \texttt{\kept@firstmark} and \texttt{\kept@botmark} reinitialized by setting them to \texttt{@empty}. The value of \texttt{\botmark} is then assigned to \texttt{\kept@topmark}.  

\begin{verbatim}
464 \global\let\kept@topmark\botmark
465 \global\let\kept@firstmark\@empty
466 \global\let\kept@botmark\@empty
467 \langle\texttt{\marktrace}\rangle
468 \mult@info\tw@
469 \{\texttt{(Re)Init top mark: MessageBreak}
470 \meaning\kept@topmark
471 \@gobbletwo\%
472 \langle/\texttt{\marktrace}\rangle
\end{verbatim}

Now we reset \texttt{\@colroom} to \texttt{\@colht} which is \LaTeX's saved value of \texttt{\textheight}. We also have to reset the recorded position of the last \texttt{\marginpar} as well as the recorded size of in-text floats as we are now on a new page.

\begin{verbatim}
473 \global\@colroom\@colht
474 \global \@mparbottom \z@
475 \global@textfloatsheight \z@
\end{verbatim}

Then we process deferred floats waiting for their chance to be placed on the next page.

\begin{verbatim}
476 \process@deferreds
477 \@whilesw\if@fcolmade\fi{\@outputpage
478 \global\@colroom\@colht
479 \process@deferreds}
\end{verbatim}

If the user is interested in statistics we inform him about the amount of space reserved for floats.

\begin{verbatim}
480 \mult@info\@ne
481 \{\texttt{Colroom: MessageBreak}
482 \the\colht\texttt{space}
483 \texttt{after float space removed}
484 \texttt{= the\colht \& \gobble}\%
\end{verbatim}

Having done all this we must prepare to tackle the next page. Therefore we assign a new value to \texttt{\vsize}. New, because \texttt{\partial@page} is now empty and \texttt{\@colroom} might be reduced by the space reserved for floats.

\begin{verbatim}
485 \set@mult@vsize \global
\end{verbatim}

The \texttt{\footins} skip register will be adjusted when the output group is closed.

\begin{verbatim}
486 \fi
\end{verbatim}

This macro is used to subtract the amount of space occupied by footnotes for the current space from the space available for the current column. The space current column is stored in \texttt{\dimen@}. See above for the description of the default action.

\begin{verbatim}
487 \def\leave@mult@footins{%
488 \advance\dimen@-\skip\footins
489 \advance\dimen@-\ht\footins
490 }
\end{verbatim}

We left out two macros: \texttt{\process@deferreds} and \texttt{\speci@ls}.

\begin{verbatim}
491 \def\speci@ls{%
492 \ifnum\outputpenalty<\@MM
493 \PackageError{multicol}{Document end inside multicols environment}\@ehd
494 \@specialoutput
495 \else
496 \fi}
\end{verbatim}

If the document ends in the middle of a multicols environment, e.g., if the user forgot the end{multicols}, \TeX adds a very negative penalty to the end of the galley which is intended to signal the output routine that it is time to prepare for shipping out everything remaining. Since inside multicols the output routine of \LaTeX is disabled sometimes we better check for this case: if we find a very negative penalty we produce an error message and run the default output routine for this case.

\begin{verbatim}
493 \ifnum\outputpenalty<\@MM
494 \PackageError{multicol}{Document end inside multicols environment}\@ehd
495 \@specialoutput
496 \@else
497 \fi
\end{verbatim}

For the next block of code see comments in section 7.2.

\begin{verbatim}
498 \ifnum\outputpenalty = \@Mv
499 \mult@info\@ne{Forced column break seen}%
500 \global\advance\vsize-\pagetotal
501 \global\setbox\colbreak@box
502 \vbox{%
503 \ifvoid\colbreak@box
504 \else
505 \unvbox\colbreak@box
506 \penalty-\@Mv
507 \fi
508 \fi
\end{verbatim}

As this is the place of a forced break we now remove vertical white space just in front of it (or some of it at least) as it is quite likely that the break is not exactly in the right place, e.g., after a display environment (if \LaTeX would break here by its own it would break before the space following the display).

Thus we rebox box 255 once (using \texttt{\@maxdepth} and calling \texttt{\remove@discardable@items} inside).

The depth of 255 will then give us the depth the box would have had if it would have been a natural break. We then unbox 255 to get it into the \texttt{\colbreak@box} and then back up by this depth. This will position the bottom of the box at its natural baseline which is useful for balancing later on.

\begin{verbatim}
509 \boxmaxdepth@maxdepth
510 \setbox\cclv\vbox{%
511 \unvbox\cclv
512 \remove@discardable@items}%
513 \dimen@\dp@cclv
514 \unvbox\cclv
515 \kern-\dimen@%
Another special case is reaching the end of the \multicols environment which is signaled by \-\@Mvi. If we are at this point then we have to run the balancing code (which was previously its own output routine). First we pretend that we had a normal forced breakpoint and then call \balance@columns@out. The latter may be let to \multi@column@out if we are inside \multicols* in which case we would get a loop if the \outputpenalty is not changed—this could be cleaned up in a better way; basically it is like this, because of the older code was using different ORs and I simply reused most of it.

\ifnum\outputpenalty = -\@Mvi \mult@info@one{End penalty of \multicols seen} \else
  If we are at this point then we have to run the balancing code (which was previously its own output routine). First we pretend that we had a normal forced breakpoint and then call \balance@columns@out. The latter may be let to \multi@column@out if we are inside \multicols* in which case we would get a loop if the \outputpenalty is not changed—this could be cleaned up in a better way; basically it is like this, because of the older code was using different ORs and I simply reused most of it.
\fi

\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

Additionally we empty the \@currlist to avoid later error messages when the \LaTeX output routine is again in force. But first we have to place the boxes back onto the \@freelist. (\@elt default is \relax so this is possible with \xdef.)

\xdef\@freelist{\@freelist\@currlist}\xdef\@currlist{\relax}
\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
  \begingroup\let\@tempb\@deferlist
  Our next action is to (globally) empty \@deferlist and assign a new meaning to \@elt. Here \@scolelt is a macro that looks at the boxes in a list to decide whether they should be placed on the next page (i.e. on \@toplist or \@botlist) or should wait for further processing.
  \gdef\@deferlist{}\gdef\@elt{\@scolelt}

Now for the last part of the show: the column balancing output routine. Since this code is called with an explicit penalty (\eject) there is no need to check for something special (eg floats). We start by balancing the material gathered.

\def\balance@columns@out{\setbox\mult@box\vbox{\ifvoid\colbreak@box\else \unvbox\colbreak@box\fi\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

\ifvoid\colbreak@box\else \unvbox\colbreak@box\fi\fi
\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

\if shr@nking
\def\raggedcolumns{\@bsphack\shr@nkingtrue\@esphack}
\def\flushcolumns{\@bsphack\shr@nkingfalse\@esphack}
\def\balance@columns@out{\setbox\mult@box\vbox{\ifvoid\colbreak@box\else \unvbox\colbreak@box\fi\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

\if void\colbreak@box\else \unvbox\colbreak@box\fi\fi}
\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

\if shr@nking
\def\raggedcolumns{\@bsphack\shr@nkingtrue\@esphack}
\def\flushcolumns{\@bsphack\shr@nkingfalse\@esphack}
\def\balance@columns@out{\setbox\mult@box\vbox{\ifvoid\colbreak@box\else \unvbox\colbreak@box\fi\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

\if void\colbreak@box\else \unvbox\colbreak@box\fi\fi}
\ifshr@nking
\def\process@deferreds{\@floatplacement\@tryfcolumn\@deferlist\if@fcolmade\else
\PackageWarningNoLine{multicol}{Floats and marginpars not allowed inside 'multicols' environment!}
\unvbox\@cclv\reinsert@footnotes

\if void\colbreak@box\else \unvbox\colbreak@box\fi\fi
The last column again is a forced break, so here we discard white space as well as that is normally unwanted.

If during balancing the columns got too long the flag \iftoo@bad is set to true.

In that case we put the material back in box 255 so that we can cut a normal page. The curious set of \vskips we add is necessary to cancel out the \splittopskip that got added for balancing.

We also have to re-add the end of environment penalty since after this page we may want balance the remaining material.

We then call the standard multicols output routine which will produce a normal page for us (remember we are still within the OR so \multicols macro \multicolsout is actually not doing anything—perhaps this should be cleaned up at some point). This also means that if there was an \enlargethispage present it will apply to this page as \multicolsout will look at the status of \kludgeins.

Because balancing made the columns too long we are sure that there will be some material remaining which was put back onto the main vertical list by \multicolsout. This will also put the explicit \eject penalty back so the current \balance output routine will be called again (so we better do not add another penalty or else the OR will be called twice and we may get scrambled results).

If the balancing went ok, we are in the position to apply \page@sofar. But first we have to set \vsize to a value suitable for one column output.

We also have to look at \kludgeins and generate a new \insert in case there was one present due to an \enlargethispage command.

Then we \unvbox the \partial@page (which may be void if we are not processing the first page of this multicols environment.

Then we return the first and bottom mark and the gathered material to the main vertical list.

We need to add a penalty at this point which allows to break at this point since calling the output routine may have removed the only permissible break point thereby "glueing" any following skip to the balanced box. In case there are any weird settings for \multicolsep etc. this could produce funny results.

As we already know, reinserting of footnotes will be done in the macro \endmulticols.

This macro now does the actual balancing.

We start by setting the kept marks by updating them with any marks from this box. This has to be done before we add a penalty of \vsize=0 to the top of the box, otherwise only an empty box will be considered.

We then continue by resetting trying to remove any discardable stuff at the end of \multibox. This is rather experimental. We also add a forced break point at the very beginning, so that we can split the box to height zero later on, thereby adding a known \splittopskip glue at the beginning.

Then follow values assignments to get the \vsplitting right. We use the natural part of \topskip as the natural part for \splittopskip
and allow for a bit of undershoot and overshoot by adding some stretch and shrink.

We also have to set \boxmaxdepth which normally allows to build boxes with arbitrary depth, but as we are building text columns we really want to restrict the depth. This is necessary as we sometimes rebox the boxes generated by \vsplit and then the restriction posed by \splitmaxdepth gets lost.

The next step is a bit tricky: when \TeX assembles material in a box, the first line isn’t preceded by interline glue, i.e. there is no parameter like \boxtopskip in \TeX. This means that the baseline of the first line in our box is at some unpredictable point depending on the height of the largest character in this line. But of course we want all columns to align properly at the baselines of their first lines. For this reason we have opened \mult@box with a \penalty -10000. This will now allow us to split off from \mult@box a tiny bit (in fact nothing since the first possible break-point is the first item in the box). The result is that \splittopskip is inserted at the top of \mult@box which is exactly what we like to achieve.

Next we try to find a suitable starting point for the calculation of the column height. It should be less than the height finally chosen, but large enough to reach this final value in only a few iterations. The formula which is now implemented will try to start with the nearest value which is a multiple of \baselineskip. The coding is slightly tricky in \TeX and there are perhaps better ways ...

The code above sets \tempdim a to the length of a column if we simply divide the whole box into equal pieces. To get to the next lower multiple of \baselineskip we convert this dimen to a number (the number of scaled points) then divide this by \baselineskip (also in scaled points) and then multiply this result with \baselineskip assigning the result to \dimen0. This makes \dimen0 ≤ to \tempdim a.

Next step is to correct our result by taking into account the difference between \topskip and \baselineskip. We start by adding \topskip: if this makes the result too large then we have to subtract one \baselineskip.

As a further restriction we want to see a minimum number of rows in the balanced result based on the setting of the counter \minrows. If the starting value is lower we adjust.

At the user’s request we start with a higher value (or lower, but this usually only increases the number of tries).

We type out statistics if we were asked to do so.

But we don’t allow nonsense values for a start.

Now we try to find the final column height. We start by setting \vbadness to infinity (i.e. 10000) to suppress underfull box reports while we are trying to find an acceptable solution. We do not need to do it in a group since at the end of the output routine everything will be restored. The setting of the final columns will nearly always produce underfull boxes with badness 10000 so there is no point in warning the user about it.
We also allow for overfull boxes while we are trying to split the columns. They can easily happen if we have objects with unusual depth.

\fuzz \maxdimen

The variable \last@try will hold the dimension used in the previous trial splitting. We initialize it with a negative value.

\last@try \p@ \loop

In order not to clutter up TeX's valuable main memory with things that are no longer needed, we empty all globally used box registers. This is necessary if we return to this point after an unsuccessful trial. We use \process@cols for this purpose, starting with \mult@grightbox. Note the extra braces around this macro call. They are needed since Plain TeX's \loop ... \repeat mechanism cannot be nested on the same level of grouping.

\process@cols\mult@grightbox
{\global\setbox\count@ \vsplit\mult@grightbox to \dimen@}

After splitting we need to ensure that there isn't any space at the bottom, so we rebox once more.

\global\setbox\count@ \vbox to \dimen@
{\unvbox\count@}

After every split we check the badness of the resulting column, normally the amount of extra white in the column.

\badness
at this point. This was done so that the first column doesn’t run short compared to later columns but it is actually producing incorrect results (over-printing of text) in boundary cases, so since version v1.5 q \raggedcolumns means allows for all columns to run slightly short.

Then we give information about the last column. Some tracing code that we don’t compile into the production version unless asked for. It will produce huge listings of the boxes involved in balancing in the transcript file.

We check whether our trial was successful. The test used is very simple: we merely compare the first and the last column. Thus the intermediate columns may be longer than the first if \raggedcolumns is used. If the right-most column is longer than the first then we start over with a larger value for \dimen@.

If the height of the last box is too large we mark this trial as unsuccessful.

To ensure that there isn’t a forced break in the last column we try to split off a box of size \maxdimen from \mult@brightbox (or rather from a copy of it). This should result in a void box after the split, unless there was a forced break somewhere within the column in which case the material after the break would have stayed in the box.

\footnote{With \TeX{} version 3.141 it is now possible to use \LaTeX{}’s \texttt{\newlinechar} in the \texttt{\message} command, but people with older \TeX{} versions will now get \texttt{\^^J} instead of a new line on the screen.}
If the natural height of the first box is smaller than the current trial size but is larger than the previous trial size it is likely that we have missed a potentially better solution. (This could have happened if for some reason our first trial size was too high.) In that case we dismiss this trial and restart using the natural height for the next trial.

Finally the switch too@bad is tested. If it was made true either earlier on or due to a rightmost column being too large we try again with a slightly larger value for \dimen@.

If we come out of the loop with the switch forcedbreak@leftover set to true then balancing has failed and we should cut a normal page. We indicate this below with \too@bad true when any of the columns get too high, so we set this flag here too in order to get the same processing logic.

At that point \dimen@ holds the height that was determined by the balancing loop. If that height for the columns turns out to be larger than the available space (which is \@colroom) we squeeze the columns into the space assuming that they will have enough shrinkability to allow this. However, this squeezing should only be done if we are balancing columns on the main galley and not if we are building a boxed multicolumn (in the latter case the current \@colroom is irrelevant since the produced box might be moved anywhere at a later stage).

Then we move the contents of the odd-numbered box registers to the even-numbered ones, shrinking them if requested. We have to use \vbox not \vtop (as it was done in the first versions) since otherwise the resulting boxes will have no height (\TeXbook page 81). This would mean that extra \opskip is added when the boxes are returned to the page-builder via \page@sofar.

If the resulting box is overfull there was too much material to fit into the available space. The question though is how much? If it wasn’t more than \maxbalancingoverflow we accept it still to avoid getting very little material for the next page (which we would then have difficulties to balance).

Fail the balancing attempt:

---

15 Should get cleaned up as we now have two different routes to reach this part of the processing.

16 This might be wrong, since the shrinkability that accounts for the amount of material might be present only in some columns. But it is better to try then to give up directly.
\too@badtrue
\else

Otherwise report that there is a problem but within
the accepted boundary.
\mult@info\one
{Balanced column
too large, but less than
the\maxbalancingoverflow\}%
\fi
\fi
)

Finally end the \ifforcedbreak@leftover conditional.
\fi
\}

Amount that balancing is allowed to overflow the
available column space. We default to 12pt which
means about one line in most layouts.
\newdimen\maxbalancingoverflow
\maxbalancingoverflow=12pt

4.5 The box allocations

Early releases of these macros used the first box
registers 0, 2, 4,... for global boxes and 1, 3, 5,...
for the corresponding local boxes. (You might still
find some traces of this setup in the documentation,
sigh.) This produced a problem at the moment we
had more than 5 columns because then officially allo-
cated boxes were overwritten by the algorithm. The
new release now uses private box registers.

There was in fact a bug in the new implementa-
tion because at one point L\TeX{} started to use the
extended registers and so jumped from below 255 to
above 256, omitting the boxes allocated for inserts and
the output page box.

So nowadays we really have to check if we get the
full sequence of boxes allocated without holes (i.e.,
2 \times \text{max cols} + 1) and if not alter the allocation reg-
isters to start allocating after 255. This is all done
quite low-level by looking directly at the values of
the allocation counters.
\ifnum\numexpr
\count20-\count14-1<40
% this is = 2 * 20
\count14=&@cclv
\protect\count14=\@cclv
\let\@tempa\relax
\fi
\newbox\mult@rightbox
\newbox\mult@grightbox
\newbox\mult@firstbox
\newbox\mult@gfirstbox
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\newbox\@tempa
\let\@tempa\relax
\@ifundefined{emergencystretch}{
\newdimen\emergencystretch}{}

My tests showed that the following formula
worked pretty well. Nevertheless the \setemergencystretch
macro also gets \hsize as
second argument to enable the user to try different
formulae.
\def\setemergencystretch#1#2{
\emergencystretch 4pt
\multiply\emergencystretch#1}

5 New macros and hacks for version 1.2

If we don't use L\TeX{} 3.0 \texttt{emergencystretch} is
defined so in this case we simply add it as an unused
\texttt{dimen} register.
\ifdefined\emergencystretch
\{\newdimen\emergencystretch\}

My tests showed that the following formula
worked pretty well. Nevertheless the \setemergencystretch
macro also gets \hsize as
second argument to enable the user to try different
formulæ.
\def\setemergencystretch#1#2{
\emergencystretch 4pt
\multiply\emergencystretch#1}

Even if this should be used as a hook we use a \@ in
the name since it is more for experts.
\def\set@floatcmds{%
\let\@dblfloat\@dbflt
\def\end@dblfloat{\@endfloatbox
\@largefloatcheck
\outer@nobreak
\hsize}
This is cheap (deferring the floats until after the cur-
page) but any other solution would go deep into
L\TeX{}'s output routine and I don't like to work on it
until I know which parts of the output routine have
to be reimplemented anyway for L\TeX{}3.
We have to add the float to the \@deferlist because we assume that outside the \multicols environment we are in one column mode. This is not entirely correct, I already used the \multicols environment inside of \LaTeXs \twocolumn declaration but it will do for most applications.

5.1 Maintaining the mark registers

This section contains the routines that set the marks so that they will be handled correctly. They have been introduced with version 1.4.

First thing we do is to reserve three macro names to hold the replacement text for \TeXs primitives \markfirst, \markboth and \marktop. We initialize the first two to be empty and \kept@topmark to contain two empty pair of braces. This is necessary since \kept@topmark is supposed to contain the last mark from a preceding page and in \LaTeX any "real" mark must contain two parts representing left and right mark information.

\def\kept@topmark{{}{}}
\let\kept@firstmark\@empty
\let\kept@botmark\@empty

For debugging purposes we take a look at the value of the kept mark that we are about to return. This code will get stripped out for production.
\def\return@nonemptymark#1#2{\ifx#2\@empty\else\message{Returned #1 mark:\MessageBreak}\meaning#2\fi}

\begin{Verbatim}
\toks@\expandafter{#2}\mark{\the\toks@}
\end{Verbatim}

We don't want any breakpoint between such a returned mark and the following material (which is usually just the box where the mark came from).
\def\get@keptmarks#1{\typeout{Mark box #1 before:\ht\the\ht#1, dp \the\dp#1}{\noindent}{\begin{Verbatim}Now we open a new group and locally copy the box to itself. As a result any operation, i.e. \vsplit, will only have a local effect. Without this trick the box content would get lost up to the level where the last assignment to the box register was done.
\begin{Verbatim}
\begingroup
\vbadness@M
\setbox#1\copy#1
\end{Verbatim}
\end{Verbatim}

Now we split the box to the maximal possible dimension. This should split off the full contents of the box so that effectively everything is split off. As a result \splitfirstmark and \splitbotmark will contain the first and last mark in the box respectively.
\def\setbox#1\vsplit#1to\maxdimen

Therefore we can now set the kept marks which is a global operation and afterwards close the group. This will restore the original box contents.
\def\markboth{\setbox#1\vsplit#1to\maxdimen}
\]
For debugging we take again a look at the box dimension which shouldn’t have changed.

\begin{verbatim}
\typeout{Mark box #1 \space after: ht \the\ht#1, dp \the\dp#1}
\end{verbatim}

We now put the contents of \texttt{\splitfirstmark} into \texttt{\keptfirstmark}. In the case that there wasn’t any mark at all \texttt{\keptfirstmark} will not change by that operation.

\begin{verbatim}
\expandafter\gdef\expandafter\keptfirstmark\expandafter{\splitfirstmark}
\end{verbatim}

When debugging we show the assignment but only when something actually happened.

\begin{verbatim}
\@gobbletwo}
\end{verbatim}

We always try to set the bottom mark to the \texttt{\splitbotmark} but of course only when there has been a \texttt{\splitbotmark} at all. Again, we assume that an empty \texttt{\splitbotmark} means that the split off box part didn’t contain any marks at all.

\begin{verbatim}
\mult@info\tw@
\{Set kept bot mark:\MessageBreak
\meaning\keptbotmark%
\end{verbatim}

The \texttt{\prep@keptmarks} function is used to initialize the kept marks from the contents of \texttt{\partial@page}, i.e. the box that holds everything from the top of the current page prior to starting the \texttt{multicols} environment. However, such a box is only available if we are not producing a boxed \texttt{multicols}.

\begin{verbatim}
\def\prep@keptmarks{%
\if@boxedmulticols \else
\get@keptmarks\partial@page
\fi}
\end{verbatim}

There are situations when we may have some space at the end of a column and this macro here will attempt to get rid of it. The typical \texttt{\LaTeX} sequence is a series of self-canceling glues so if we remove them recursively we are usually fine.

Special care is needed with handling \texttt{\vspace*} as that corresponds to \texttt{\penalty10000, \vskip <skip>}, followed by \texttt{\vskip 0pt}. If we see this sequence going backwards in the vertical list we assume that this is a “desired” space. We therefore stop the recursion and reinsert the spaces.

As the \texttt{multicol} code sometimes add an explicit penalty at the end of a column we first attempt to remove it in case it is there.

\begin{verbatim}
\吁0=0pt
\edef\the@zero@skip{\the\skip0}
\end{verbatim}

Save a previous skip (if there) and then remove it, we can’t really tell the difference between no skip and a skip of zero but that’s life.

\begin{verbatim}
\edef\@tempa{\the\lastskip}%
\typeout{s1=\@tempa}%
\unskip
\ifx\@tempa\the@zero@skip
\edef\@tempb{\the\lastskip}%
\typeout{s2=\@tempb}%
\ifx\@tempb\the@zero@skip
\else
\unskip
\if\texttt{\nobreak}
\end{verbatim}

If it was a zero skip (or none) we save the next previous skip (if any).

\begin{verbatim}
\edef\@tempa{\the\lastskip}%
\typeout{s1=\@tempa}%
\edef\@tempb{\the\lastskip}%
\typeout{s2=\@tempb}%
\end{verbatim}

If this one again was zero (or more likely not there in the first place) we stop.

\begin{verbatim}
\if\texttt{\nobreak}
\unskip
\end{verbatim}

Otherwise we remove this “real” skip. Then we look if it was preceded by a penalty of 10000 (i.e., a \texttt{\nobreak})
If so this was a \vspace* or something equivalent to it. Therefore we reintroduce the skips and stop. Otherwise we recurse.

\vskip\@tempb\vskip\@tempa\relax
\else
\remove@discardable@items
\fi
\fi
\else
If the first skip was a non-zero skip we recurse as well.
\remove@discardable@items
\fi
\fi
\}
\newif\iftoo@bad
\def\too@badtrue{\global\let\iftoo@bad\iftrue}
\def\too@badfalse{\global\let\iftoo@bad\iffalse}
\newif\ifforcedbreak@leftover
\c@minrows
\newcount\c@minrows
\c@minrows=1
\c@columnbadness
\newcount\c@columnbadness
\c@columnbadness=10000
\newcount\c@finalcolumnbadness
\c@finalcolumnbadness=9999
\newdimen\last@try
\newdimen\multicolovershoot
\newdimen\multicolundershoot
\multicolovershoot=0pt
\multicolundershoot=2pt
\newbox\mult@nat@firstbox
\langle∗badness⟩
\mult@info
A helper for producing info messages
\def\mult@info#1#2{%\ifnum\c@tracingmulticols>#1%
\GenericWarning{(multicol)\@spaces\@spaces}{Package multicol: #2}%
\fi}
\@footnotetext If we store the current column width in \columnwidth we have to redefine the internal \@footnotetext macro to use \textwidth for the width of the footnotes rather than using the original definition.

Starting with version v1.5r this is now done in a way that the original definition is still used, except that locally \columnwidth is set to \textwidth. This solves two problems: first redefinitions of \@footnotetext done by a class will correctly survive and second if multicols is used inside a minipage environment the special definition of \@footnotetext in that environment will be picked up and not the one for the main galley (the latter would result in all footnotes getting lost in that case).

See the definition of the \multicols command further up for the exact code.

7 Further extensions

This section does contain code for extensions added to this package over time. Not all of them may be active, some might sit dormant and wait for being activated in some later release.

7.1 Not balancing the columns

This is fairly trivial to implement. we just have to disable the balancing output routine and replace it by the one that ships out the other pages.

\multicols* The code for this environment was suggested by Matthias Clasen.
\langle∗nobalance⟩
\@namedef{multicols*}{%
\@footnotetext If we are not on the main galley, i.e., inside a box of some sort, that approach will not work since we don’t have a vertical size for the box so we better warn that we balance anyway.
\ifiinner
\PackageWarning{multicol}%
\{multicols* inside a box does not make sense.\MessageBreak Going to balance anyway\}%
\else
If we aren’t balancing we change the \balance@columns@out to work like the normal output routine that cuts normal pages. However, there is a catch: In case the last page we cut (af-

30
ter seeing the end of the environment) is actually larger than a page (for example, if it contains more `\columnbreak` commands than columns) we end up with some leftover material that is returned to the main galley, but now the environment end penalty is missing. So we add another one here too. Of course that shouldn’t be done if there is really only a single final page, but fortunately in that case we have just finished a page and any penalty on the recent contributions will be discarded, thus the extra one is harmless—puh.

```
971 \def\balance@columns@out
972 {\multi@column@out \penalty-\@Mvi }%
973 \fi
974 \begin{multicols}
975 \endmulticols*
```

7.2 Manual column breaking

The problem with manual page breaks within `multicols` is the fact that during collection of material for all columns a page-forcing penalty (i.e. -10000 or higher) would stop the collecting pass which is not quite what is desired. On the other hand, using a penalty like -9999 would mean that there would be occasions where the `\vsplitting` operations within `multicols` would ignore that penalty and still choose a different break point.

For this reason the current implementation uses a completely different approach. In a nutshell it extends the \LaTeX output routine handling by introducing an additional penalty flag (i.e., a penalty which is forcing but higher than -10000 so that the output routine can look at this value and thus knows why it has been called).

Inside the output routine we test for this value and if it appears we do two things: save the galley up to this point in a special box for later use and reduce the `\vsize` by the height of the material seen. This way the forcing penalty is now hidden in that box and we can restart the collection process for the remaining columns. (This is done in `\speci@ls` above.)

In the output routines that do the `\vsplitting` either for balancing or for a full page we simply combine box 255 with the saved box thus getting a single box for splitting which now contains forcing breaks in the right positions.

`\columnbreak` is modeled after `\pagebreak` except that we generate a penalty -10005.

```
989 \mathchardef\@Mv=10005
990 \newcommand\columnbreak[1][4]{%
```

Increasingly lower penalty based on argument value. This is like `\pagebreak` but we use other penalty values are the \LaTeX defaults are rather pointless for pagination.

```
997 \edef\mc@break@pen
998 {\ifcase#1\@m\or 3333\or 6666\or 9999\else\@Mv\fi\relax}%
999 \ifvmode
1000 \penalty \mc@break@pen
1001 \else
1002 \@bsphack
1003 \vadjust{\penalty \mc@break@pen}%
1004 \@esphack
```

31
This is modeled after \newpage but for column breaks.
\newcommand\newcolumn{%
  \ifnum\col@number<\tw@
    \PackageError{multicol}{\noexpand\newcolumn outside multicols}{This command can only be used within a multicols or multicols* environment.}%
  \else
    \ifvmode
      We need to guard the \vfill from disappearing.
      \nobreak\vfill\kern\z@\penalty -\@Mv\relax
    \else
      \@bsphack
      \vadjust{\nobreak\vfill\kern\z@\penalty -\@Mv\relax}
      \@esphack
    \fi
  \fi}
\colbreak@box
Need a box to collect the galley up to the column break.
\newbox\colbreak@box
⟨/package⟩

7.3 Supporting right-to-left languages
\LR@column@boxes is called when we are assembling the columns for left to right typesetting. When we start we are inside an \hbox of full width. Left to right typesetting is fairly easy, we basically output each column box intermixed with vertical rules and proper spacing. As this happens inside a box of a defined width the rules and the columns automatically get into the right positions.
\def\LR@column@boxes{%
  \process@cols\mult@firstbox{%\hskip\hsize%
    \hss{\columnseprulecolor\vrule\@width\columnseprule}\hss%
  }%
  \hskip\hsize
}
At this point in the code our typesetting reference point is at the right end of the rightmost column (or rather where that column should appear).

As you will have noticed, we started with box register \mult@firstbox (i.e. the left column). So this time \count@ looped through 2, 4... (plus the appropriate offset). Finally we add box \mult@rightbox and we are done. Again we may have to update \dimen@tw@.
\def\RL@column@boxes{%
  First step is to put all rules in the right place (without adding the comes which are instead represented by a space of \hsize.\defRL@column@boxes{%
    \process@cols\mult@firstbox{%\hskip\hsize%
      \hss{\columnseprulecolor\vrule\@width\columnseprule}\hss%
    }%
    \hskip\hsize
}

At this point in the code our typesetting reference point is at the right end of the rightmost column (or rather where that column should appear).

We are now typesetting all columns by first backing up by their width (which is \hsize) then typesetting the box and then backing up again, but this time further, i.e., also across the column separation. That will then enable us to typeset the next column using the same approach until we are done with all but the final column.
The approach for the final column is similar only that we do not have to back up over any column gap.

However we do have to move the reference point to its right place: to make the rules appear at the expected places, we should get the typesetting position to the far right again. As we at the moment at the far left we skip to the far right like this:

\hskip\fullwidth

The generated “labels” are named \mc@col\check@num and they hold as values the numbers 1, 2, or 3 denoting the current column type.

The \docolaction scans for a star and optional argument and 3 mandatory ones, but we do this in chunks (not having xparse available).

The default is left-to-right:

\LRmulticolcolumns

Macros to switch between left-right and right-left typesetting. In LR typesetting the \LR@column@boxes is used to combine the columns. When typesetting right to left the \RL@column@boxes is used instead.

\newcommand\RLmulticolcolumns{\let\mc@align@columns\RL@column@boxes}
\newcommand\LRmulticolcolumns{\let\mc@align@columns\RL@column@boxes}

The default is left-to-right:

\LRmulticolcolumns

7.4 Supporting \docolaction

Whenever we want to do something that depends on the current column we execute \docolaction. This command takes one optional and three mandatory arguments. The mandatory ones denote what to do if this is a “left”, “middle”, or “right” column and the optional one is simply there to say what to do if we don’t know (default is to use the “left” column action in that case).

\mc@col@check@num We use one counter \mc@col@check@num to generate us unique label names. Each time we execute \docolaction we increment this counter to get a new name.

\newcommand\docolaction[3]{\if@docolactionstar \@docolaction\else \mc@set@col@status{mc@col\the\mc@col@check@num}{\mc@col@type} \fi}
\newcommand\@docolaction[4]{\if@docolactionstar \@docolactioncheck\else \@docolactioncheck\fi}
\newcommand\@docolactioncheck[2]{\ifcase \mc@col@type \or \relax \or \fi}
\newcommand\docolaction[4][]{\if@docolactionstar \@docolactioncheck\else \@docolactioncheck\fi}
\edef\docolactionstartrue \docolaction[4][]{\relax}
\edef\docolactionstarfalse \relax
\if@docolactionstar \docolaction[4][]{\relax}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\if@docolactionstar \docolaction[4][]{\relax}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\if@docolactionstar \docolaction[4][]{\relax}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\if@docolactionstar \docolaction[4][]{\relax}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
\ifcase \mc@col@type \or \relax \or \fi}
\edef\docolactionstarfalse \relax
\fi}
If column is unknown we use the default action or the action denoted by the optional argument (so that arg can take the value 1, 2, 3).

Otherwise we know (or think we know) that this is a first, middle, or last column:

- #2% 1 First col
- #3% 2 any middle col
- #4% 3 last col

else

\ERRORwrongdefaultgiven

\if@docolactionstar \else \docolactioncheck \fi

Here is the if used above:
\newif\if@docolactionstar

Because of extra data writing to the aux file the aux file will now contain something like the following after the document is processed the first time:

\relax
\mc@col@status{1}
\mc@set@col@status{lcol-1}{0}
\mc@col@status{2}
\mc@set@col@status{lcol-2}{0}
\mc@col@status{3}
\mc@set@col@status{lcol-3}{0}
\mc@col@status{1}
\mc@col@status{2}
\mc@col@status{3}
\mc@set@col@status{lcol-4}{0}

The \mc@col@status line denotes the column type and has been written out just before corresponding the column box was placed onto the page. The \mc@set@col@status lines have been written out as part of shipping the column boxes out, e.g., \mc@set@col@status{lcol-1}{0} was therefore somewhere within the first column as it appears between \mc@col@status{1} and \mc@col@status{2}. The second argument in that line is the value used in the previous run (or zero if there was no previous run). We can use this to determine if a rerun is necessary.

Thus with this knowledge we can set things up to get the labels working.

And when \mc@set@col@status is executed we can simply set up the label by associating it with the \mc@curr@col@status and ignore the second argument:
\def\mc@set@col@status#1#2{%
  \global\expandafter\let\csname #1\endcsname \mc@curr@col@status}

The above definition is being used when the .aux file is read in at the beginning. At the end we need a different definition to test if another typesetting run is needed. There we compare the value used in the current run (stored in the second argument) with the value used on the next run. If those two values differ we set \@tempswa to false which will trigger the “Label(s) may have changed” warning.
\AtEndDocument{\def\mc@set@col@status#1#2{%
  \ifnum #2=\mc@curr@col@status\else
    \@tempswatrue
  \fi}%
}

Finally, as part of determining in which column we are, we used a switch inside \mc@col@status@write to determine if we are in the first column or not.
\def\mc@col@status@write#1{\ifnum #1=1\mc@firstcoltrue %

\mc@col@status

When the aux file is read in \mc@col@status is used to set \mc@curr@col@status:
\def\mc@col@status#1{%
  \gdef\mc@curr@col@status(#1}
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