

LUA-WIDOW-CONTROL

Max Chernoff

v 2.1.2

ctan.org/pkg/luawidow-control

github.com/gucci-on-fleek/luawidow-control

Lua-widow-control is a Plain T_EX/L^AT_EX/ConT_EXt/OpT_EX package that removes widows and orphans without any user intervention. Using the power of LuaT_EX, it does so *without* stretching any glue or shortening any pages or columns. Instead, lua-widow-control automatically lengthens a paragraph on a page or column where a widow or orphan would otherwise occur.

QUICK START

Ensure that your T_EX Live/MikT_EX distribution is up-to-date. Then, L^AT_EX users just need to place `\usepackage{lua-widow-control}` in the preamble of their document. For more details, see the [Usage sections](#).

CONTENTS

Quick Start	1
Preliminaries	2
Motivation	3
Widows and Orphans	3
<i>Widows • Orphans • Broken Hyphens</i>	
T _E X's Pagination	4
<i>Algorithm • Behaviour</i>	
Demonstration	6
<i>“Ignore” • “Shorten” • “Stretch”</i>	
<i>“lua-widow-control”</i>	
Installation	7
<i>T_EX Live • MikT_EX • Manual • Steps</i>	

Dependencies	7
<i>Plain T_EX</i> • <i>L^AT_EX</i> • <i>ConT_EXt</i> • <i>OpT_EX</i>	
Loading the Package	8
Options	8
<i>Overview</i> • <i>Disabling</i> • <i>Enabling</i>	
<i>Automatically disabling</i> • <i>\emergencystretch</i>	
<i>Penalties</i> • <i>\nobreak Behaviour</i>	
<i>Maximum Cost</i> • <i>Debug Mode</i>	
Presets	12
<i>default</i> • <i>strict</i> • <i>balanced</i>	
Compatibility	13
<i>Columns</i> • <i>Performance</i> • <i>ε-T_EX penalties</i>	
<i>Grids</i> • <i>Footnotes</i>	
Stability	15
Short last lines	15
Known Issues	16
Contributions	17
License	17
References	17
Implementation	18
<i>lua-widow-control.lua</i> • <i>lua-widow-control.tex</i>	
<i>lua-widow-control.sty</i>	
<i>lua-widow-control-2022-02-22.sty</i>	
<i>t-lua-widow-control.mkxl</i>	
<i>lua-widow-control.opm</i> • <i>Demo from Table 1</i>	

PRELIMINARIES

This manual begins with a brief introduction to widows, orphans, and lua-widow-control. For an extended introduction and discussion of these topics, please see the *TUGboat* article¹ distributed with this manual (Links: [local](#), [CTAN](#), [GitHub](#)). You can also skip ahead to the [installation instructions on page 7](#) or the [usage section starting at page 8](#).

MOTIVATION

Unmodified T_EX has only two familiar ways of dealing with widows and orphans: it can either shorten a page by one line, or it can stretch vertical whitespace. T_EX was designed for mathematical and scientific typesetting, where a typical page has multiple section headings, tables, figures, and equations. For this style of document, T_EX's default behaviour works quite well, since the slight stretching of whitespace between the various document elements is nearly imperceptible; however, for prose or other documents composed almost entirely of paragraphs, there is little vertical whitespace to stretch.

Lua-widow-control offers an alternative method of removing widows and orphans: instead of shortening a page or stretching vertical whitespace, lua-widow-control simply chooses a paragraph to lengthen by one line such that the widow or orphan is eliminated.

WIDOWS AND ORPHANS

- Widows** A “widow” occurs when the majority of a paragraph is on one page or column, but the last line is on the following page or column. It not only looks quite odd for a lone line to be at the start of the page, but it makes a paragraph harder to read since the separation of a paragraph and its last line disconnects the two, causing the reader to lose context for the widowed line.
- Orphans** An “orphan” occurs when the first line of a paragraph is at the end of the page or column preceding the remainder of the paragraph. They are not as distracting for the reader, but they are still not ideal. Visually, widows and orphans are about equally disruptive; however, orphans tend not to decrease the legibility of a text as much as widows, so some authors choose to ignore them.
- Broken Hyphens** “Broken” hyphens occur whenever a page break occurs in a hyphenated word. These are not related to widows and orphans; however, breaking a word across two pages is at least as disruptive for the reader as widows and orphans. T_EX identifies broken hyphens in the same ways as widows and orphans, so lua-widow-control treats broken hyphens in the same way.

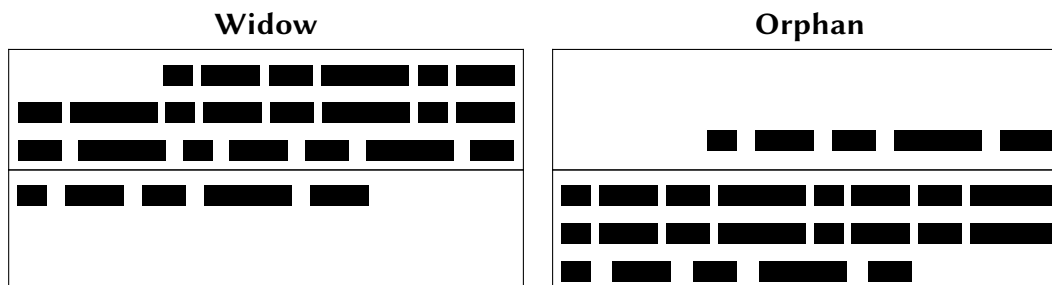


Figure 1 A visual comparison of widows and orphans.

T_EX'S PAGINATION

Algorithm It is tricky to understand how lua-widow-control works if you aren't familiar with how T_EX breaks pages and columns. For a full description, you should consult Chapter 15 of *The T_EX Book*² ("How T_EX Makes Lines into Pages"); however, this goes into much more detail than most users require, so here is a *very* simplified summary of T_EX's page breaking algorithm:

T_EX fills the page with lines and other objects until the next object will no longer fit. Once no more objects will fit, T_EX will align the bottom of the last line with the bottom of the page by stretching any available vertical spaces if (in L^AT_EX) `\flushbottom` is set; otherwise, it will break the page and leave the bottom empty.

However, some objects have "penalties" attached. Penalties encourage or discourage page breaks from occurring at specific places. For example, L^AT_EX sets a negative penalty before section headings to encourage a page break there; conversely, it sets a positive penalty after section headings to discourage breaking.

To reduce widows and orphans, T_EX sets weakly-positive penalties between the first and second lines of a paragraph to prevent orphans, and between the penultimate and final lines to prevent widows.

Behaviour Due to these "penalties" attached to widows and orphans, T_EX tries to avoid creating them. Widows and orphans with small penalties attached—like L^AT_EX's default values of 150—are only lightly coupled to the rest of the paragraph, while widows and orphans with large penalties—values of 10 000 or more—are treated as infinitely bad and are thus unbreakable. Intermediate values behave just as you would expect, discouraging page breaks proportional to their value.

However, when these lines are moved as a group, T_EX will have to make a

Ignore	Shorten	Stretch	Lua-widow-control
<p>Lua-widow-control can remove most widows and orphans from a document, <i>without</i> stretching any glue or shortening any pages.</p> <p>It does so by automatically lengthening a paragraph on a page where a widow or orphan would otherwise occur. While T_EX breaks paragraphs into their natural length, lua-widow-control is breaking the paragraph 1 line longer than its natural length. T_EX's paragraph is output to the page, but lua-widow-control's paragraph is just stored for later. When a widow or orphan occurs, lua-widow-control can take over. It selects the previously-saved paragraph with the least badness; then, it replaces T_EX's paragraph with its saved paragraph. This increases the text block height of the page by 1 line.</p> <p>Now, the last line of the current page can be pushed to the top of the next page. This removes the widow or the orphan with-</p>	<p>Lua-widow-control can remove most widows and orphans from a document, <i>without</i> stretching any glue or shortening any pages.</p> <p>It does so by automatically lengthening a paragraph on a page where a widow or orphan would otherwise occur. While T_EX breaks paragraphs into their natural length, lua-widow-control is breaking the paragraph 1 line longer than its natural length. T_EX's paragraph is output to the page, but lua-widow-control's paragraph is just stored for later. When a widow or orphan occurs, lua-widow-control can take over. It selects the previously-saved paragraph with the least badness; then, it replaces T_EX's paragraph with its saved paragraph. This increases the text block height of the page by 1 line.</p> <p>Now, the last line of the current page can be pushed to the top of the next page.</p>	<p>Lua-widow-control can remove most widows and orphans from a document, <i>without</i> stretching any glue or shortening any pages.</p> <p>It does so by automatically lengthening a paragraph on a page where a widow or orphan would otherwise occur. While T_EX breaks paragraphs into their natural length, lua-widow-control is breaking the paragraph 1 line longer than its natural length. T_EX's paragraph is output to the page, but lua-widow-control's paragraph is just stored for later. When a widow or orphan occurs, lua-widow-control can take over. It selects the previously-saved paragraph with the least badness; then, it replaces T_EX's paragraph with its saved paragraph. This increases the text block height of the page by 1 line.</p> <p>Now, the last line of the current page can be pushed to the top of the next page.</p>	<p>Lua-widow-control can remove most widows and orphans from a document, <i>without</i> stretching any glue or shortening any pages.</p> <p>It does so by automatically lengthening a paragraph on a page where a widow or orphan would otherwise occur. While T_EX breaks paragraphs into their natural length, lua-widow-control is breaking the paragraph 1 line longer than its natural length. T_EX's paragraph is output to the page, but lua-widow-control's paragraph is just stored for later. When a widow or orphan occurs, lua-widow-control can take over. It selects the previously-saved paragraph with the least badness; then, it replaces T_EX's paragraph with its saved paragraph. This increases the text block height of the page by 1 line.</p> <p>Now, the last line of the current page can be pushed to the top of the next page.</p>
<p>out creating any additional work.</p>	<p>This removes the widow or the orphan without creating any additional work.</p>	<p>This removes the widow or the orphan without creating any additional work.</p>	<p>This removes the widow or the orphan without creating any additional work.</p>
<p><code>\parskip=0pt</code></p> <p><code>\clubpenalty=0</code></p> <p><code>\widowpenalty=0</code></p>	<p><code>\parskip=0pt</code></p> <p><code>\clubpenalty=10000</code></p> <p><code>\widowpenalty=10000</code></p>	<p><code>\parskip=0pt</code> plus 1fill</p> <p><code>\clubpenalty=10000</code></p> <p><code>\widowpenalty=10000</code></p>	<p><code>\usepackage{lua-widow-control}</code></p>

Table 1 A visual comparison of various automated widow handling techniques.

page or column with less lines. “**Demonstration**” goes into further detail about how T_EX deals with these too-short pages or columns.

DEMONSTRATION

Although T_EX’s page breaking algorithm is reasonably straightforward, it can lead to complex behaviour when widows and orphans are involved. The usual choices, when rewriting is not possible, are to ignore them, stretch some glue, or shorten the page. **Table 1** has a visual comparison of these options, which we’ll discuss in the following:

- | | |
|---------------------|---|
| “Ignore” | As you can see, the last line of the page is on a separate page from the rest of its paragraph, creating a widow. This is usually highly distracting for the reader, so it is best avoided for the reasons previously discussed. |
| “Shorten” | This page did not leave any widows, but it did shorten the previous page by one line. Sometimes this is acceptable, but usually it looks bad because pages will then have different text-block heights. This can make the pages look quite uneven, especially when typesetting with columns or in a book with facing pages. |
| “Stretch” | <p>This page also has no widows and it has a flush bottom margin. However, the space between each pair of paragraphs had to be stretched.</p> <p>If this page had many equations, headings, and other elements with natural space between them, the stretched out space would be much less noticeable. T_EX was designed for mathematical typesetting, so it makes sense that this is its default behaviour. However, in a page with mostly text, these paragraph gaps look unsightly.</p> <p>Also, this method is incompatible with grid typesetting, where all glue stretching must be quantised to the height of a line.</p> |
| “lua-widow-control” | <p>Lua-widow-control has none of these issues: it eliminates the widows in a document while keeping a flush bottom margin and constant paragraph spacing.</p> <p>To do so, lua-widow-control lengthened the second paragraph by one line. If you look closely, you can see that this stretched the interword spaces. This stretching is noticeable when typesetting in a narrow text block, but is mostly imperceptible with larger widths.</p> <p>Lua-widow-control automatically finds the “best” paragraph to stretch, so the increase in interword spaces should almost always be minimal.</p> |

INSTALLATION

Most up-to-date T_EX Live and MikT_EX systems should already have lua-widow-control installed. However, a manual installation may occasionally be required.

- | | |
|-----------------------|---|
| T _E X Live | Run <code>tlmgr install lua-widow-control</code> in a terminal, or install using the “T _E X Live Manager” GUI. |
| MikT _E X | Run <code>mpm --install=lua-widow-control</code> in a terminal, or install using the “MikT _E X Maintenance” GUI. |
| Manual | Currently, ConT _E Xt MkXL (LuaMetaT _E X) users must manually install the package. Most other users will be better served by using the lua-widow-control supplied by T _E X Live and MikT _E X; however, all users may manually install the package if desired. The procedure should be fairly similar regardless of your OS, T _E X distribution, or format. |
| Steps | <ol style="list-style-type: none">1. Download <code>lua-widow-control.tds.zip</code> from CTAN, GitHub or the ConT_EXt Garden.2. Unzip the release into your <code>TEXMFLOCAL/</code> directory. (You can find its location by running <code>kpsewhich --var-value TEXMFHOME</code> in a terminal)3. Refresh the filename database:<ul style="list-style-type: none">• ConT_EXt: <code>mtxrun --generate</code>• T_EX Live: <code>mktexlsr</code>• MikT_EX: <code>initexmf --update-fndb</code> |

DEPENDENCIES

Lua-widow-control does have a few dependencies; however, these will almost certainly be met by all but the most minimal of T_EX installations.

- | | |
|------------------------|--|
| Plain T _E X | Lua-widow-control requires LuaT _E X (≥ 0.85) and the most recent version of lua-texbase (2015/10/04). Any version of T _E X Live ≥ 2016 will meet these requirements. |
|------------------------|--|

L^AT_EX Lua-widow-control requires LuaT_EX (≥ 0.85), L^AT_EX ($\geq 2020/10/01$), and microtype (any version). Any version of T_EX Live ≥ 2021 will meet these requirements.

Lua-widow-control also supports a “legacy” mode for older L^AT_EX kernels. This uses an older version of the L^AT_EX code while still using the most recent Lua code. This mode requires LuaT_EX (≥ 0.85), L^AT_EX ($\geq 2015/01/01$), microtype (any version), and etoolbox (any version). Any version of T_EX Live ≥ 2016 will meet these requirements.

Please note that when running in legacy mode, you cannot use the key-value interface. This legacy interface is undocumented, but mostly the same as the “Plain T_EX” interface.

ConT_EXt Lua-widow-control supports both ConT_EXt MkXL (LuaMetaT_EX) and ConT_EXt MkIV (LuaT_EX).

OpT_EX Lua-widow-control works with any version of OpT_EX and has no dependencies.

LOADING THE PACKAGE

Plain T _E X	<code>\input lua-widow-control</code>
L ^A T _E X	<code>\usepackage{lua-widow-control}</code>
ConT _E Xt	<code>\usemodule[lua-widow-control]</code>
OpT _E X	<code>\load[lua-widow-control]</code>

OPTIONS

Lua-widow-control is automatically enabled with the default settings as soon as you load it. Most users should not need to configure lua-widow-control; however, the packages provides a few commands.

Overview L^AT_EX users can set the options either when loading the package (`\usepackage[options]{lua-widow-control}`) or at any point using `\lwcsetup{options}`.

ConT_EXt users should use the `\setuplwc[options]` command for setting options at any point.

Plain T_EX and OpT_EX are a little different. Some options require you to set a register (i.e., `\lwcemergencystretch = dimension`), while others use macro arguments (i.e., `\lwcnobreak{option}`).

Disabling You may want to disable lua-widow-control for certain portions of your document. You can do so with the following commands:

Plain T _E X/OpT _E X	<code>\lwcdisable</code>
L ^A T _E X	<code>\lwcsetup{disable}</code>
ConT _E Xt	<code>\setuplwc[state = stop]</code>

This prevents lua-widow-control from stretching any paragraphs that follow. If a page has earlier paragraphs where lua-widow-control was still enabled and a widow or orphan is detected, lua-widow-control will still attempt to remove the widow or orphan.

Enabling Lua-widow-control is enabled as soon as the package is loaded. If you have previously disabled it, you will need to re-enable it to save new paragraphs.

Plain T _E X/OpT _E X	<code>\lwenable</code>
L ^A T _E X	<code>\lwcsetup{enable}</code>
ConT _E Xt	<code>\setuplwc[state = start]</code>

Automatically disabling You may want to disable lua-widow-control for certain commands where stretching is undesirable such as section headings. Of course, manually disabling and then enabling lua-widow-control multiple times throughout a document would quickly become tedious, so lua-widow-control provides some options to do this automatically for you.

Lua-widow-control automatically patches the default L^AT_EX, ConT_EXt, Plain T_EX, OpT_EX, memoir, KOMA-Script, and titlesec section commands, so you don't need to patch these. Any others, though, you'll need to patch yourself.

Plain T _E X/OpT _E X	<code>\lwcdisablecmd <\macro></code>
L ^A T _E X	<code>\lwcsetup{disablecmds = {\<macronameone>, <macronametwo>}}</code>
ConT _E Xt	<code>\prependtoks\lwc@patch@pre\to\everybefore<hook></code> <code>\prependtoks\lwc@patch@pre\to\everyafter<hook></code>

The Plain T_EX, OpT_EX, and ConT_EXt commands *append* to the list of patched commands: they simply patch the provided commands while leaving the original patches in place. The L^AT_EX option *sets* the list of patched commands: it replaces the default list with the provided list.

`\emergencystretch` Lua-widow-control defaults to an `\emergencystretch` value of 3 em for stretched paragraphs, but you can configure this.

Lua-widow-control will only use the `\emergencystretch` when it cannot lengthen a paragraph in any other way, so it is fairly safe to set this to a large value. \TeX accumulates badness when `\emergencystretch` is used, so it's pretty rare that a paragraph that requires any `\emergencystretch` will actually be used on the page.

Plain \TeX /Op \TeX `\lwcemergencystretch = <dimension>`

L \TeX `\lwcsetup{emergencystretch = <dimension>}`

Con \TeX t `\setuplwc[emergencystretch = <dimension>]`

Penalties You can also manually adjust the penalties that \TeX assigns to widows and orphans. Usually, the defaults are fine, but there are a few circumstances where you may want to change them.

Plain \TeX /Op \TeX `\widowpenalty = <integer>`

`\clubpenalty = <integer>`

`\brokenpenalty = <integer>`

L \TeX `\lwcsetup{widowpenalty = <integer>}`

`\lwcsetup{orphanpenalty = <integer>}`

`\lwcsetup{brokenpenalty = <integer>}`

Con \TeX t `\setuplwc[widowpenalty = <integer>]`

`\setuplwc[orphanpenalty = <integer>]`

`\setuplwc[brokenpenalty = <integer>]`

The value of these penalties determines how much \TeX should attempt to stretch glue before passing the widow or orphan to lua-widow-control. If you set the values to 1 (default), \TeX will stretch nothing and immediately trigger lua-widow-control; if you set the values to 10 000, \TeX will stretch infinitely and lua-widow-control will never be triggered. If you set the value to some intermediate number, \TeX will first attempt to stretch some glue to remove the widow or orphan; only if it fails will lua-widow-control come in and lengthen a paragraph. As a special case, if you set the values to 0, both \TeX and lua-widow-control will completely ignore the widow or orphan.

\nobreak Behaviour When lua-widow-control encounters an orphan, it removes it by moving the orphaned line to the next page. The majority of the time, this is an appropriate solution. However, if the orphan is immediately preceded by a section heading (or \nobreak/\penalty 10000), lua-widow-control would naïvely separate a section heading from the paragraph that follows. This is almost always undesirable, so lua-widow-control provides some options to configure this.

Plain T_EX/OpT_EX `\lwc nobreak{<value>}`
L^AT_EX `\lwc setup{nobreak = <value>}`
ConT_EXt `\setuplwc[nobreak = <value>]`

The default value, `keep`, *keeps* the section heading with the orphan by moving both to the next page. The advantage to this option is that it removes the orphan and retains any \nobreaks; the disadvantage is that moving the section heading can create a large blank space at the end of the page.

The value `split` *splits* up the section heading and the orphan by moving the orphan to the next page while leaving the heading behind. This is usually a bad idea, but exists for the sake of flexibility.

The value `warn` causes lua-widow-control to give up on the page and do nothing, leaving an orphaned line. Lua-widow-control *warns* the user so that they can manually remove the orphan.

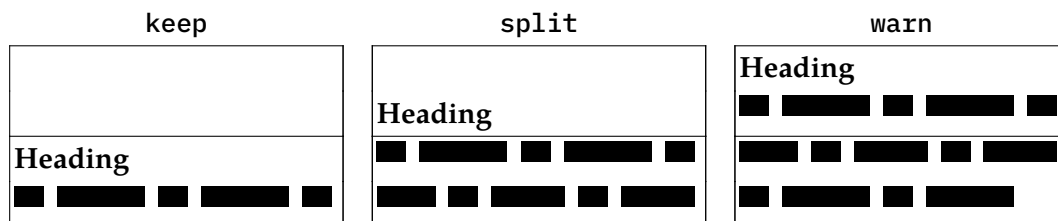


Figure 2 A visual comparison of the various nobreak options, where each box represents a different page.

Maximum Cost Lua-widow-control ranks each paragraph on the page by how much it would “cost” to lengthen that paragraph. By default, lua-widow-control selects the paragraph on the page with the lowest cost; however, you can configure it to only select paragraphs below a selected cost.

If there aren’t any paragraphs below the set threshold, then lua-widow-control won’t remove the widow or orphan and will instead issue a warning.

Plain T _E X/OpT _E X	<code>\lwcmaxcost = <integer></code>
L ^A T _E X	<code>\lwcsetup{max-cost = <integer>}</code>
ConT _E Xt	<code>\setuplwc[maxcost = <integer>]</code>

Based on my testing, max-cost values less than 1 000 cause completely imperceptible changes in interword spacing; values less than 5 000 are only noticeable if you are specifically trying to pick out the expanded paragraph on the page; values less than 15 000 are typically acceptable; and larger values may become distracting. Lua-widow-control defaults to an infinite max-cost, although the “strict” and “balanced” modes sets the values to 5 000 and 10 000 respectively.

Lua-widow-control uses a “cost function” C that is initially defined as

$$C = \frac{d}{\sqrt{l}}$$

where d is the total demerits of the paragraph, and l is the number of lines in the paragraph; however, advanced users may also set a custom cost function by redefining the `lwc.paragraph_cost(demerits, lines)` function.

Debug Mode

Lua-widow-control offers a “debug” mode that prints extra information in the log files. This may be helpful to understand how lua-widow-control is processing paragraphs and pages. If you are reporting an issue with lua-widow-control make sure to compile your document with debug mode enabled!

Plain T _E X/OpT _E X	<code>\lwcdebug 1</code> <code>\lwcdebug 0</code>
L ^A T _E X	<code>\lwcsetup{debug = true}</code> <code>\lwcsetup{debug = false}</code>
ConT _E Xt	<code>\setuplwc[debug = start]</code> <code>\setuplwc[debug = stop]</code>

PRESETS

As you can see, lua-widow-control provides quite a few options. Luckily, there are a few presets that you can use to set multiple options at once. These presets are a good starting point for most documents, and you can always manually override individual options.

Currently, these presets are L^AT_EX-only.

L^AT_EX `\lwcsetup{preset}`

default If you use lua-widow-control without any options, it defaults to this preset. In default mode, lua-widow-control takes all possible measures to remove widows and orphans and will not attempt to stretch any vertical glue. This usually removes >95% of all possible widows and orphans. The catch here is that this mode is quite aggressive, so it often leaves behind some fairly “spacey” paragraphs.

This mode is good if you want to remove (nearly) all widows and orphans from your document, without fine-tuning the results.

strict Lua-widow-control also offers a strict mode. This greatly restricts lua-widow-control’s tolerance and makes it so that it will only lengthen paragraphs where the change will be imperceptible.

The caveat with strict mode is that—depending on the document— lua-widow-control will be able to remove less than a third of the widows and orphans. For the widows and orphans that can’t be automatically removed, a warning will be printed to your terminal and log file so that a human can manually fix the situation.

This mode is good if you want the best possible typesetting and are willing to do some manual editing.

balanced Balanced mode sits somewhere between default mode and strict mode. This mode first lets T_EX stretch a little glue to remove the widow or orphan; only if that fails will it then trigger lua-widow-control. Even then, the maximum paragraph cost is capped. Here, lua-widow-control can usually remove 90% of a document’s potential widows and orphans, and it does so while making a minimal visual impact.

This mode is recommended for most users who care about their document’s typography. This mode is not the default since it doesn’t remove all widows and orphans: it still requires a little manual intervention.

COMPATIBILITY

The lua-widow-control implementation is almost entirely in Lua, with only a minimal T_EX footprint. It doesn’t modify the output routine, inserts/floating, `\everypar`, and it doesn’t insert any whatsits. This means that it should be compatible with nearly any T_EX package, class, and format. Most changes that lua-widow-control makes are not observable on the T_EX side.

Option	default	balanced	strict
max-cost	∞	10000	5000
emergencystretch	3em	1em	0pt
nobreak	keep	keep	warn
widowpenalty	1	500	1
orphanpenalty	1	500	1
brokenpenalty	1	500	1

Table 2 Lua-widow-control options set by each mode.

However, on the Lua side, lua-widow-control modifies much of a page’s internal structure. This should not affect any \TeX code; however, it may surprise Lua code that modifies or depends on the page’s low-level structure. This does not matter for Plain \TeX or \LaTeX , where even most Lua-based packages don’t depend on the node list structure; nevertheless, there are a few issues with Con \TeX t.

Simple Con \TeX t documents tend to be fine, but many advanced Con \TeX t features rely heavily on Lua and can thus be disturbed by lua-widow-control. This is not a huge issue—the lua-widow-control manual is written in Con \TeX t—but lua-widow-control is inevitably more reliable with Plain \TeX and \LaTeX than with Con \TeX t.

Finally, keep in mind that adding lua-widow-control to a document will almost certainly change its page break locations.

Columns Since \TeX and the formats implement column breaking and page breaking through the same internal mechanisms, lua-widow-control removes widows and orphans between columns just as it does with widows and orphans between pages.

Lua-widow-control is known to work with the \LaTeX class option `twocolumn` and the two-column output routine from Chapter 23 of *The \TeX Book*².

Performance Lua-widow-control runs entirely in a single pass, without depending on any `.aux` files or the like. Thus, it shouldn’t meaningfully increase compile times. Although lua-widow-control internally breaks each paragraph twice, modern computers break paragraphs near-instantaneously, so you are not likely to notice any slowdown.

ε -T_EX penalties Knuth’s original T_EX has three basic line penalties: `\interlinepenalty`, which is inserted between all lines; `\clubpenalty`, which is inserted after the first line; and `\widowpenalty`, which is inserted before the last line. The ε -T_EX extensions generalize these commands with a syntax similar to `\parshape`: with `\widowpenalties` you can set the penalty between the last, second last, and n th last lines of a paragraph; `\interlinepenalties` and `\clubpenalties` behave similarly.

Lua-widow-control makes no explicit attempts to support these new `-penalties` commands. Specifically, if you give a line a penalty that matches either `\widowpenalty` or `\clubpenalty`, lua-widow-control will treat the lines exactly as it would a widow or orphan. So while these commands won’t break lua-widow-control, they are likely to lead to some unexpected behaviour.

Grids Lua-widow-control is fully compatible with the grid snapping features of ConT_EXt ConT_EXt MkIV and ConT_EXt MkXL.

Footnotes If there are footnotes (or any other type of inline `\insert`) present in the moved line, lua-widow-control will move both the “footnote mark” and the “footnote text” such that both are on the same page. However, this may lead to an odd blank space at the bottom of the page since lua-widow-control needs to move both the line and its footnotes. Footnotes cause the same page-breaking issues in unmodified Plain T_EX and L^AT_EX, so this is mostly unavoidable.

STABILITY

The documented interfaces of lua-widow-control can be considered stable: I’m not planning on removing or modifying any existing options or commands in any way that would break documents.

However, lua-widow-control’s page breaking *is* subject to change. I will attempt to keep page breaks the same whenever reasonable; however, I will *rarely* make modifications to the algorithm when I can improve the output quality. Any such changes will be clearly noted in the release notes.

SHORT LAST LINES

When lengthening a paragraph with `\looseness`, it is common advice to insert ties (~) between the last few words of the paragraph to avoid overly-short last lines². Lua-widow-control does this automatically, but instead of using ties or `\hboxes`, it uses the

`\parfillskip` parameter. When lengthening a paragraph (and only when lengthening a paragraph—remember, lua-widow-control doesn’t interfere with \TeX ’s output unless it detects a widow or orphan), lua-widow-control sets `\parfillskip` to `0pt plus 0.8\hspace`. This normally makes the last line of a paragraph be at least 20% of the overall paragraph’s width, thus preventing ultra-short lines.

KNOWN ISSUES

- When a three-line paragraph is at the end of a page forming a widow, lua-widow-control will remove the widow; however, it will leave an orphan. This issue is inherent to any process that removes widows through paragraph expansion and is thus unavoidable. Orphans are considered to be better than widows³, so this is still an improvement.
- Lua-widow-control only attempts to expand paragraphs; it never attempts to shrink them. See the *TUGboat* article¹ §15.3 for further discussion. (**Issue #33**)
- Lua-widow-control can only expand paragraphs that fit completely on a page. This is unavoidable due to the one-page-at-a-time model: you can’t modify the bottom half of a paragraph since its top half has already shipped out, and you can’t expand the top half of a paragraph since that can’t remove orphans. This only causes issues if your document has paragraphs so long that a page only has two half-paragraphs and zero whole paragraphs.
- Sometimes a widow or orphan cannot be eliminated because no paragraph has enough stretch. Sometimes this can be remediated by increasing lua-widow-control’s `\emergencystretch`; however, some pages just don’t have any suitable paragraph.

Long paragraphs with short words tend to be stretchier than short paragraphs with long words since these long paragraphs have more interword glue. Narrow columns also stretch more easily than wide columns since you need to expand a paragraph by less to make a new line.

- When running under LuaMeta \TeX (Con \TeX t), the log may contain many lines like “`luatex warning > tex: left parfill skip is gone`”. These messages are completely harmless (although admittedly quite annoying). (**Issue #7**)
- Lua-widow-control only attempts to expand paragraphs on a page with a widow or orphan. A global system like in *A general framework for globally optimized pagination*⁴ would solve this; however, this is both NP-complete⁵ and impossible

to solve in a single pass. Very rarely would such a system remove widows or orphans that lua-widow-control cannot.

- Lua-widow-control does not move footnotes in Con \TeX t MkXL due to limitations with the LuaMeta \TeX engine.

CONTRIBUTIONS

If you have any issues with lua-widow-control, please create an issue at the [project's GitHub page](#). Or, if you think that you can solve any of the “[Known Issues](#)” or add any new features, [submit a PR](#). Thanks!

LICENSE

Lua-widow-control is licensed under the [Mozilla Public License, version 2.0](#) or greater. The documentation is licensed under [CC-BY-SA, version 4.0](#) or greater as well as the MPL.

Please note that a compiled document is **not** considered to be an “Executable Form” as defined by the MPL. The MPL and CC-BY-SA licenses **only** apply to you if you distribute the lua-widow-control source code or documentation.

REFERENCES

1. [Chernoff, M \(2022\)](#). Automatically removing widows and orphans with lua-widow-control. *TUGboat*, 43(1), 28–39. DOI: [10.47397/tb/43-1/tb133chernoff-widows](#)
2. [Knuth, DE \(2020\)](#). *The \TeX Book*. Addison–Wesley. [ctan.org/pkg/texbook](#)
3. [Bringhurst, R \(2004\)](#). *The Elements of Typographic Style*. (3rd ed.). Hartley & Marks.
4. [Mittelbach, F \(2018\)](#). A general framework for globally optimized pagination. *Computational Intelligence*, 35(2), 242–284. DOI: [10.1111/coin.12165](#)
5. [Plass, MF \(1981\)](#). *Optimal pagination techniques for automatic typesetting systems*. (PhD thesis). Stanford University. [tug.org/docs/plass/plass-thesis.pdf](#)

IMPLEMENTATION

From here and until the end of this manual is the raw source code of lua-widow-control. This is primarily of interest to developers; most users need not read further.

This code vaguely resembles the typical L^AT_EX literate programming style, although I use extensive inline comments instead of arcane docstrip macros. Hopefully this is useful as a reference for advanced lua-widow-control users as well as anyone doing extensive node manipulation in Lua_T_EX.

If want to offer any improvements to the code below, please open an issue or a PR on [GitHub](#).

lua-widow-control.lua

```
--[[
    lua-widow-control
    https://github.com/gucci-on-fleek/lua-widow-control
    SPDX-License-Identifier: MPL-2.0+
    SPDX-FileCopyrightText: 2022 Max Chernoff
  ]]
```

```
--- Tell the linter about node attributes
--- @class node
--- @field depth integer
--- @field height integer
--- @field id integer
--- @field list node
--- @field next node
--- @field penalty integer
--- @field prev node
--- @field subtype integer

-- Initial setup
lwc = lwc or {}
lwc.name = "lua-widow-control"

-- Locals for `debug_print`
local debug_lib = debug
local string_rep = string.rep
local write_nl = texio.write_nl

local write_log
if status.luatex_engine == "luametatex" then
    write_log = "logfile"
else
    write_log = "log"
```

```

end

--- Prints debugging messages to the log, only if `debug` is set to `true`.
---
--- @param title string The "title" to use
--- @param text string? The "content" to print
--- @return nil
local function debug(title, text)
    if not lwc.debug then return end

    -- The number of spaces we need
    local filler = 15 - #title

    if text then
        write_nl(write_log, "LWC (" .. title .. string_rep(" ", filler) .. "): " .. text
        )
    else
        write_nl(write_log, "LWC: " .. string_rep(" ", 18) .. title)
    end
end

end

--[[
    \lwc/ is intended to be format-agnostic. It only runs on Lua\TeX{},
    but there are still some slight differences between formats. Here, we
    detect the format name then set some flags for later processing.
]]
local format = tex.formatname
local context, latex, plain, optex, lmtx

if format:find("cont") then -- cont-en, cont-fr, cont-nl, ...
    context = true
    if status.luatex_engine == "luametatex" then
        lmtx = true
    end
elseif format:find("latex") then -- lualatex, lualatex-dev, ...
    latex = true
elseif format == "luatex" or format == "luahbtex" then -- Plain
    plain = true
elseif format:find("optex") then -- OpTeX
    optex = true
end

--[[
    Save some local copies of the node library to reduce table lookups.
    This is probably a useless micro-optimization, but it is done in all of the

```

```

    ConTeXt and expl3 Lua code, so I should probably do it here too.
]]
-- Node ID's
-- (We need to hardcode the subid's sadly)
local id_from_name = node.id
local baselineskip_subid = 2
local glue_id = id_from_name("glue")
local glyph_id = id_from_name("glyph")
local hlist_id = id_from_name("hlist")
local insert_id = id_from_name("insert") or id_from_name("ins")
local line_subid = 1
local linebreakpenalty_subid = 1
local par_id = id_from_name("par") or id_from_name("local_par")
local penalty_id = id_from_name("penalty")

-- Local versions of globals
local abs = math.abs
local copy = node.copy
local copy_list = node.copy_list or node.copypoint
local find_attribute = node.find_attribute or node.findattribute
local free = node.free
local free_list = node.flush_list or node.flushlist
local get_attribute = node.get_attribute or node.getattribute
local insert_token = token.put_next or token.putnext
local last = node.slide
local linebreak = tex.linebreak
local new_node = node.new
local set_attribute = node.set_attribute or node.setattribute
local string_char = string.char
local tex_box = tex.box
local tex_count = tex.count
local tex_dimen = tex.dimen
local tex_lists = tex.lists
local traverse = node.traverse
local traverse_id = node.traverse_id or node.traverseid
local vpack = node.vpack

-- Misc. Constants
local iffalse = token.create("iffalse")
local iftrue = token.create("iftrue")
local INFINITY = 10000
local INSERT_CLASS_MULTIPLE = 1000 * 1000
local INSERT_FIRST_MULTIPLE = 1000
local min_col_width = tex.sp("250pt")

```

```

local PAGE_MULTIPLE = 100
local SINGLE_LINE = 50

--[[ Package/module initialization.

    Here, we replace any format/engine-specific variables/functions with some
    generic equivalents. This way, we can write the rest of the module without
    worrying about any format/engine differences.
]]
local contrib_head,
    emergencystretch,
    info,
    insert_attribute,
    max_cost,
    pagenum,
    paragraph_attribute,
    stretch_order,
    warning

if lmtx then
    -- LMTX has removed underscores from most of the Lua parts
    debug("LMTX")
    contrib_head = "contributehead"
    stretch_order = "stretchorder"
else
    contrib_head = "contrib_head"
    stretch_order = "stretch_order"
end

if context then
    debug("ConTeXt")

    warning = logs.reporter(lwc.name, "warning")
    local _info = logs.reporter(lwc.name, "info")
    --[[ We don't want the info messages on the terminal, but ConTeXt doesn't
        provide any logfile-only reporters, so we need this hack.
    ]]
    info = function (text)
        logs.pushtarget("logfile")
        _info(text)
        logs.poptarget()
    end
    paragraph_attribute = attributes.public(lwc.name .. "_paragraph")
    insert_attribute = attributes.public(lwc.name .. "_insert")

```

```

pagenum = function() return tex_count["realpageno"] end

-- Dimen names
emergencystretch = "lwc_emergencystretch"
max_cost = "lwc_max_cost"
elseif plain or latex or optex then
  pagenum = function() return tex_count[0] end

  -- Dimen names
  if tex.isdimen("g__lwc_emergencystretch_dim") then
    emergencystretch = "g__lwc_emergencystretch_dim"
    max_cost = "g__lwc_maxcost_int"
  else
    emergencystretch = "lwcemergencystretch"
    max_cost = "lwcmaxcost"
  end

  if plain or latex then
    debug("Plain/LaTeX")
    luatexbase.provides_module {
      name = lwc.name,
      date = "2022/05/26", --%%slashdate
      version = "2.1.2", --%%version
      description = [[

```

This module provides a LuaTeX-based solution to prevent widows and orphans from appearing in a document. It does so by increasing or decreasing the lengths of previous paragraphs.]],

```

    }
    warning = function(str) luatexbase.module_warning(lwc.name, str) end
    info = function(str) luatexbase.module_info(lwc.name, str) end
    paragraph_attribute = luatexbase.new_attribute(lwc.name .. "_paragraph")
    insert_attribute = luatexbase.new_attribute(lwc.name .. "_insert")
  elseif optex then
    debug("OpTeX")

    warning = function(str) write_nl(lwc.name .. " Warning: " .. str) end
    info = function(str) write_nl("log", lwc.name .. " Info: " .. str) end
    paragraph_attribute = alloc.new_attribute(lwc.name .. "_paragraph")
    insert_attribute = alloc.new_attribute(lwc.name .. "_insert")
  end
else -- This shouldn't ever happen
  error [[Unsupported format.

```

```

Please use LaTeX, Plain TeX, ConTeXt or OpTeX.]]
end

--[[ Table to hold the alternate paragraph versions.

    This is global(ish) mutable state, which isn't ideal, but any other way of
    passing this data around would be even worse.
]]
local paragraphs = {}
local inserts = {}

--[[
    Function definitions
]]

--- Gets the current paragraph and page locations
--- @return string
local function get_location()
    return "At " .. pagenum() .. "/" .. #paragraphs
end

--- Prints the starting glyphs and glue of an `hlist`
---
--- @param head node
--- @return nil
local function get_chars(head)
    if not lwc.debug then return end

    local chars = ""
    for n in traverse(head) do
        if n.id == glyph_id then
            if n.char < 127 then -- Only ASCII
                chars = chars .. string_char(n.char)
            else
                chars = chars .. "#" -- Replacement for an unknown glyph
            end
        elseif n.id == glue_id then
            chars = chars .. " " -- Any glue goes to a space
        end
        if #chars > 25 then
            break
        end
    end

    debug(get_location(), chars)
end

```

```

end

--- The "cost function" to use. Users can redefine this if they wish.
---
--- @param demerits number The demerits of the broken paragraph
--- @param lines number The number of lines in the broken paragraph
--- @return number The cost of the broken paragraph
function lwc.paragraph_cost(demerits, lines)
    return demerits / math.sqrt(lines)
end

--- Checks if the ConTeXt "grid snapping" is active
--- @return boolean
local function grid_mode_enabled()
    -- Compare the token "mode" to see if `\\ifgridsnapping` is `\\iftrue`
    return token.create("ifgridsnapping").mode == iftrue.mode
end

--- Gets the next node of a specified type/subtype in a node list
---
--- @param head node The head of the node list
--- @param id number The node type
--- @param args table?
---     subtype: number = The node subtype
---     reverse: bool = Whether we should iterate backwards
--- @return node
local function next_of_type(head, id, args)
    args = args or {}

    if lmtx or not args.reverse then
        for n, subtype in traverse_id(id, head, args.reverse) do
            if (subtype == args.subtype) or (args.subtype == nil) then
                return n
            end
        end
    else
        --[[ Only LMTX has the built-in backwards traverser, so we need to do it
        ourselves here.
        ]]
        while head do
            if head.id == id and
                (head.subtype == args.subtype or args.subtype == nil)
            then
                return head
            end
            head = head.next
        end
    end
end

```



```

        end
        head = head.prev
    end
end
end

--- Breaks a paragraph one line longer than natural
---
--- @param head node The unbroken paragraph
--- @return node long_node The broken paragraph
--- @return table long_info An info table about the broken paragraph
local function long_paragraph(head)
    -- We can't modify the original paragraph
    head = copy_list(head)

    -- Prevent ultra-short last lines (\TeX{}Book p. 104), except with narrow columns
    -- Equivalent to \parfillskip=0pt plus 0.8\hsize
    local parfillskip
    if lmtx or last(head).id ~= glue_id then
        -- LMTX does not automatically add the \parfillskip glue
        parfillskip = new_node("glue", "parfillskip")
    else
        parfillskip = last(head)
    end

    if tex.hsize > min_col_width then
        parfillskip[stretch_order] = 0
        parfillskip.stretch = 0.8 * tex.hsize -- Last line must be at least 20% long
    end

    if lmtx or last(head).id ~= glue_id then
        last(head).next = parfillskip
    end

    -- Break the paragraph 1 line longer than natural
    return linebreak(head, {
        looseness = 1,
        emergencystretch = tex_dimen[emergencystretch],
    })
end

--- Breaks a paragraph at its natural length
---
--- @param head node The unbroken paragraph
--- @return table natural_info An info table about the broken paragraph

```

```

local function natural_paragraph(head)
  -- We can't modify the original paragraph
  head = copy_list(head)

  --[[ Contrary to the documentation, LMTX does not automatically add
      the \\parfillskip glue before `pre_linebreak_filter`, so we need
      to add it here so that our \\prevgraf comparisons are correct.
  ]]
  if lmtx then
    parfillskip = new_node("glue", "parfillskip")
    parfillskip[stretch_order] = 1
    parfillskip.stretch = 1 -- 0pt plus 1fil
    last(head).next = parfillskip
  end

  -- Break the paragraph naturally to get \\prevgraf
  local natural_node, natural_info = linebreak(head)
  free_list(natural_node)

  return natural_info
end

--- Saves each paragraph, but lengthened by 1 line
---
--- Called by the `pre_linebreak_filter` callback
---
--- @param head node
--- @return node
function lwc.save_paragraphs(head)
  if (head.id ~= par_id and context) or -- Ensure that we were actually given a par
    status.output_active or -- Don't run during the output routine
    tex.nest.ptr > 1 -- Don't run inside boxes
  then
    return head
  end

  -- Prevent the "underfull hbox" warnings when we store a potential paragraph
  local renewable_box_warnings
  if (context or optex) or
    #luatexbase.callback_descriptions("hpack_quality") == 0
  then -- See #18 and michal-h21/linebreaker#3
    renewable_box_warnings = true
    lwc.callbacks.disable_box_warnings.enable()
  end
end

```

```

long_node, long_info = long_paragraph(head)

natural_info = natural_paragraph(head)

if renewable_box_warnings then
    lwc.callbacks.disable_box_warnings.disable()
end

if not grid_mode_enabled() then
    -- Offset the \prevdepth differences between natural and long
    local prevdepth = new_node("glue")
    prevdepth.width = natural_info.prevdepth - long_info.prevdepth
    last(long_node).next = prevdepth
end

local long_cost = lwc.paragraph_cost(long_info.demerits, long_info.prevgraf)

if long_info.prevgraf == natural_info.prevgraf + 1 and
    long_cost > 10 -- Any paragraph that is "free" to expand is suspicious
then
    table.insert(paragraphs, {
        cost = long_cost,
        node = next_of_type(long_node, hlist_id, { subtype = line_subid })
    })
end

-- Print some debugging information
get_chars(head)
debug(get_location(), "nat lines " .. natural_info.prevgraf)
debug(
    get_location(),
    "nat cost " ..
    lwc.paragraph_cost(natural_info.demerits, natural_info.prevgraf)
)
debug(get_location(), "long lines " .. long_info.prevgraf)
debug(
    get_location(),
    "long cost " ..
    lwc.paragraph_cost(long_info.demerits, long_info.prevgraf)
)

-- \ConTeXt{} crashes if we return `true`
return head
end

```

```

--- Tags the beginning and the end of each paragraph as it is added to the page.
---
--- We add an attribute to the first and last node of each paragraph. The ID is
--- some arbitrary number for \lwc/, and the value corresponds to the
--- paragraphs index, which is negated for the end of the paragraph.
---
--- @param head node
--- @return nil
local function mark_paragraphs(head)
    -- Tag the paragraphs
    if not status.output_active then -- Don't run during the output routine
        -- Get the start and end of the paragraph
        local top_para = next_of_type(head, hlist_id, { subtype = line_subid })
        local bottom_para = last(head)

        while bottom_para.id == insert_id do
            bottom_para = bottom_para.prev
        end

        if top_para ~= bottom_para then
            set_attribute(
                top_para,
                paragraph_attribute,
                #paragraphs + (PAGE_MULTIPLE * pagenum())
            )
            set_attribute(
                bottom_para,
                paragraph_attribute,
                -1 * (#paragraphs + (PAGE_MULTIPLE * pagenum()))
            )
        else
            -- We need a special tag for a 1-line paragraph since the node can only
            -- have a single attribute value
            set_attribute(
                top_para,
                paragraph_attribute,
                #paragraphs + (PAGE_MULTIPLE * pagenum()) + SINGLE_LINE
            )
        end
    end
end

--- Tags the each line with the indices of any corresponding inserts.
---

```

```

--- We need to tag the first element of the hlist before the any insert nodes
--- since the insert nodes are removed before `pre_output_filter` gets called.
---
--- @param head node
--- @return nil
local function mark_inserts(head)
    local insert_indices = {}
    for insert in traverse_id(insert_id, head) do
        -- Save the found insert nodes for later
        inserts[#inserts+1] = copy(insert)

        -- Tag the insert's content so that we can find it later
        set_attribute(insert.list, insert_attribute, #inserts)

        for n in traverse(insert.list.next) do
            set_attribute(n, insert_attribute, -1 * #inserts)
        end

        --[[ Each hlist/line can have multiple inserts, but so we can't just tag
            the hlist as we go. Instead, we need save up all of their indices,
            then tag the hlist with the first and last indices.
        ]]
        insert_indices[#insert_indices+1] = #inserts

        if not insert.next or
            insert.next.id ~= insert_id
        then
            local hlist_before = next_of_type(insert, hlist_id, { reverse = true} )

            --[[ We tag the first element of the hlist/line with an integer
                that holds the insert class and the first and last indices
                of the inserts contained in the line. This won't work if
                the line has multiple classes of inserts, but I don't think
                that happens in real-world documents.
            ]]
            set_attribute(
                hlist_before.list,
                insert_attribute,
                insert.subtype * INSERT_CLASS_MULTIPLE +
                insert_indices[1] * INSERT_FIRST_MULTIPLE +
                insert_indices[#insert_indices]
            )

            -- Clear the indices to prepare for the next line
            insert_indices = {}

```

```

        end
    end
end

--- Saves the inserts and tags a typeset paragraph. Called by the
--- `post_linebreak_filter` callback.
---
--- @param head node
--- @return node
function lwc.mark_paragraphs(head)
    mark_paragraphs(head)
    mark_inserts(head)

    return head
end

--- Checks to see if a penalty matches the widow/orphan/broken penalties
---
--- @param penalty number
--- @return boolean
function is_matching_penalty(penalty)
    local widowpenalty = tex.widowpenalty
    local clubpenalty = tex.clubpenalty
    local displaywidowpenalty = tex.displaywidowpenalty
    local brokenpenalty = tex.brokenpenalty

    penalty = penalty - tex.interlinepenalty

    -- https://tug.org/TUGboat/tb39-3/tb123mitt-widows-code.pdf#subsection.0.2.1
    return penalty ~= 0 and
        penalty < INFINITY and (
            penalty == widowpenalty or
            penalty == displaywidowpenalty or
            penalty == clubpenalty or
            penalty == clubpenalty + widowpenalty or
            penalty == clubpenalty + displaywidowpenalty or
            penalty == brokenpenalty or
            penalty == brokenpenalty + widowpenalty or
            penalty == brokenpenalty + displaywidowpenalty or
            penalty == brokenpenalty + clubpenalty or
            penalty == brokenpenalty + clubpenalty + widowpenalty or
            penalty == brokenpenalty + clubpenalty + displaywidowpenalty
        )
end

```

```

--- Reset any state saved between pages
---
--- @return nil
local function reset_state()
    paragraphs = {}

    for _, insert in ipairs(inserts) do
        free(insert)
    end

    inserts = {}
end

--- When we are unable to remove a widow/orphan, print a warning
---
--- @return nil
local function remove_widows_fail()
    warning("Widow/Orphan/broken hyphen NOT removed on page " .. pagenum())
    reset_state()
end

--- Finds the first and last paragraphs present on a page
---
--- @param head node The node representing the start of the page
--- @return number first_index The index of the first paragraph on the page in
---                             the 'paragraphs' table
--- @return number last_index The index of the last paragraph on the page in the
---                             'paragraphs' table
local function first_last_paragraphs(head)
    local first_index, last_index

    -- Find the last paragraph on the page, starting at the end, heading in reverse
    local n = last(head)
    while n do
        local value = get_attribute(n, paragraph_attribute)
        if value then
            last_index = value % PAGE_MULTIPLE
            break
        end

        n = n.prev
    end

    -- Find the first paragraph on the page, from the top
    local first_val, first_head = find_attribute(head, paragraph_attribute)

```

```

if first_val // PAGE_MULTIPLE == pagenum() - 1 then
    --[[ If the first complete paragraph on the page was initially broken on the
        previous page, then we can't expand it here so we need to skip it.
    ]]
    first_index = find_attribute(
        first_head.next,
        paragraph_attribute
    ) % PAGE_MULTIPLE
else
    first_index = first_val % PAGE_MULTIPLE
end

return first_index, last_index
end

--- Selects the "best" paragraph on the page to expand
---
--- @param head node The node representing the start of the page
--- @return number? best_index The index of the paragraph to expand in the
---                             `paragraphs` table
local function best_paragraph(head)
    local first_paragraph_index, last_paragraph_index = first_last_paragraphs(head)

    -- Find the paragraph on the page with the least cost.
    local best_index = 1
    local best_cost = paragraphs[best_index].cost

    -- We find the current "best" replacement, then free the unused ones
    for index, paragraph in pairs(paragraphs) do
        if paragraph.cost < best_cost and
            index < last_paragraph_index and
            index >= first_paragraph_index
        then
            -- Free the old best paragraph
            free_list(paragraphs[best_index].node)
            paragraphs[best_index].node = nil
            -- Set the new best paragraph
            best_index, best_cost = index, paragraph.cost
        elseif index > 1 then
            -- Not sure why `i > 1` is required?
            free_list(paragraph.node)
            paragraph.node = nil
        end
    end
end
end

```



```

debug(
    "selected para",
    pagenum() .. "/" .. best_index .. " (" .. best_cost .. ")"
)

if best_cost > tex_count[max_cost] or
   best_index == last_paragraph_index
then
    return nil
else
    return best_index
end
end

--- Gets any inserts present in the moved line
---
--- @param last_line node The moved last line
--- @return table<node> inserts A list of the present inserts
local function get_inserts(last_line)
    local selected_inserts = {}

    local n = last_line.list
    while n do -- Iterate through the last line
        local line_value
        line_value, n = find_attribute(n, insert_attribute)

        if not n then
            break
        end

        --[[ With LuaMetaTeX, the subtype of `insert` nodes is always zero,
            so we cannot detect their class therefore we can't fix any moved
            footnotes.
        ]]
        if lmtx then
            warning("!!!Incorrect footnotes on page " .. pagenum() .. "!!!")
            return {}
        end

        -- Demux the insert values
        local class = line_value // INSERT_CLASS_MULTIPLE
        local first_index = (line_value % INSERT_CLASS_MULTIPLE) // INSERT_FIRST_MULTIPLE

        local last_index = line_value % INSERT_FIRST_MULTIPLE

```

```

-- Get the output box containing the insert boxes
local insert_box = tex_box[class]

local m = insert_box.list
while m do -- Iterate through the insert box
    local box_value
    box_value, m = find_attribute(m, insert_attribute)

    if not m then
        break
    end

    if abs(box_value) >= first_index and
       abs(box_value) <= last_index
    then
        -- Remove the respective contents from the insert box
        insert_box.list = node.remove(insert_box.list, m)

        if box_value > 0 then
            selected_inserts[#selected_inserts + 1] = copy(inserts[box_value])
        end
    end

    m = m.next
end

if not insert_box.list then
    tex_box[class] = nil
end

n = n.next
end

if #selected_inserts ~= 0 then
    info("Moving footnotes on page " .. pagenum())
end

return selected_inserts
end

lwc.nobreak_behaviour = "keep"
--- Moves the last line of the page onto the following page.
---
--- This is the most complicated function of the module since it needs to
--- look back to see if there is a heading preceding the last line, then it does
--- some low-level node shuffling.

```

```

---
--- @param head node The node representing the start of the page
--- @return boolean success
local function move_last_line(head)
    -- Start of final paragraph
    debug("remove_widows", "moving last line")

    -- Here we check to see if the widow/orphan was preceded by a large penalty
    local big_penalty_found, last_line, hlist_head
    local n = last(head).prev
    while n do
        if n.id == glue_id then
            -- Ignore any glue nodes
        elseif n.id == penalty_id and n.penalty >= INFINITY then
            -- Infinite break penalty
            big_penalty_found = true
        elseif big_penalty_found and n.id == hlist_id then
            -- Line before the penalty
            if lwc.nobreak_behaviour == "keep" then
                hlist_head = n
                big_penalty_found = false
            elseif lwc.nobreak_behaviour == "split" then
                n = last(head)
                break
            elseif lwc.nobreak_behaviour == "warn" then
                debug("last line", "heading found")
                return false
            end
        else
            -- Not found
            if hlist_head then
                n = hlist_head
            else
                n = last(head)
            end
            break
        end
        n = n.prev
    end

    local potential_penalty = n.prev.prev

    if potential_penalty and
        potential_penalty.id == penalty_id and

```

```

        potential_penalty.subtype == linebreakpenalty_subid and
        is_matching_penalty(potential_penalty.penalty)
    then
        warning("Making a new widow/orphan/broken hyphen on page " .. pagenum())
    end

    last_line = copy_list(n)

    -- Reinsert any inserts originally present in this moved line
    local selected_inserts = get_inserts(last_line)
    for _, insert in ipairs(selected_inserts) do
        last(last_line).next = insert
    end

    -- Add back in the content from the next page
    last(last_line).next = copy_list(tex_lists[contrib_head])

    n.prev.prev.next = nil

    -- Set the content of the next page
    last(last_line)
    tex_lists[contrib_head] = last_line

    return true
end

--- Replace the chosen paragraph with its expanded version.
---
--- This is the "core function" of the module since it is what ultimately causes
--- the expansion to occur.
---
--- @param head node
--- @param paragraph_index number
local function replace_paragraph(head, paragraph_index)
    local target_node = paragraphs[paragraph_index].node
    local free_next_nodes = false

    local start_found = false
    local end_found = false

    -- Loop through all of the nodes on the page with the lwc attribute
    local n = head
    while n do
        local value
        value, n = find_attribute(n, paragraph_attribute)
    end

```

```

if not n then
    break
end

debug("remove_widows", "found " .. value)

-- Insert the start of the replacement paragraph
if value == paragraph_index + (PAGE_MULTIPLE * pagenum()) or
   value == paragraph_index + (PAGE_MULTIPLE * pagenum()) + SINGLE_LINE
then
    debug("remove_widows", "replacement start")
    start_found = true

    -- Fix the `\\baselineskip` glue between paragraphs
    height_difference = (
        next_of_type(n, hlist_id, { subtype = line_subid }).height -
        next_of_type(target_node, hlist_id, { subtype = line_subid }).height
    )

    local prev_bls = next_of_type(
        n,
        glue_id,
        { subtype = baselineskip_subid, reverse = true }
    )

    if prev_bls then
        prev_bls.width = prev_bls.width + height_difference
    end

    n.prev.next = target_node
    free_next_nodes = true
end

-- Insert the end of the replacement paragraph
if value == -1 * (paragraph_index + (PAGE_MULTIPLE * pagenum())) or
   value == paragraph_index + (PAGE_MULTIPLE * pagenum()) + SINGLE_LINE
then
    debug("remove_widows", "replacement end")
    end_found = true

    local target_node_last = last(target_node)

    if grid_mode_enabled() then
        -- Account for the difference in depth
        local after_glue = new_node("glue")
        after_glue.width = n.depth - target_node_last.depth
    end
end

```

```

        target_node_last.next = after_glue

        after_glue.next = n.next
    else
        target_node_last.next = n.next
    end

    break
end

if free_next_nodes then
    n = free(n)
else
    n = n.next
end
end

if not (start_found and end_found) then
    warning("Paragraph NOT expanded on page " .. pagenum())
end
end

--- Remove the widows and orphans from the page, just after the output routine.
---
--- This is called just after the end of the output routine, before the page is
--- shipped out. If the output penalty indicates that the page was broken at a
--- widow or an orphan, we replace one paragraph with the same paragraph, but
--- lengthened by one line. Then, we can push the bottom line of the page to the
--- next page.
---
--- @param head node
--- @return node
function lwc.remove_widows(head)
    debug("outputpenalty", tex.outputpenalty .. " " .. #paragraphs)

    -- See if there is a widow/orphan for us to remove
    if not is_matching_penalty(tex.outputpenalty) then
        reset_state()
        return head
    end

    info("Widow/orphan/broken hyphen detected. Attempting to remove")

    -- Nothing that we can do if there aren't any paragraphs available to expand
    if #paragraphs == 0 then

```

```

        remove_widows_fail()
        return head
    end

    -- Check the original height of \\box255
    local vsize = tex_dimen.vsize
    local orig_height_diff = vpack(head).height - vsize

    -- Find the paragraph to expand
    local paragraph_index = best_paragraph(head)

    if not paragraph_index then
        remove_widows_fail()
        return head
    end

    -- Move the last line of the page to the next page
    if not move_last_line(head) then
        remove_widows_fail()
        return head
    end

    -- Replace the chosen paragraph with its expanded version
    replace_paragraph(head, paragraph_index)

    --[[ The final \\box255 needs to be exactly \\vsize tall to avoid
        over/underfull box warnings, so we correct any discrepancies
        here.
    ]]
    local new_height_diff = vpack(head).height - vsize
    -- We need the original height discrepancy in case there are \\vfill's
    local net_height_diff = orig_height_diff - new_height_diff

    if abs(net_height_diff) > 0 and
        -- A difference larger than 0.25\\baselineskip is probably not from \\lwc/
        abs(net_height_diff) < tex.skip.baselineskip.width / 4
    then
        local bottom_glue = new_node("glue")
        bottom_glue.width = net_height_diff
        last(head).next = bottom_glue
    end

    info(
        "Widow/orphan/broken hyphen successfully removed at paragraph "
        .. paragraph_index
    )

```

```

        .. " on page "
        .. pagenum()
    )

    reset_state()

    return head
end

--- Create a table of functions to enable or disable a given callback
---
--- @param t table Parameters of the callback to create
---     callback: string = The \LuaTeX{} callback name
---     func: function = The function to call
---     name: string = The name/ID of the callback
---     category: string = The category for a \ConTeXt{} "Action"
---     position: string = The "position" for a \ConTeXt{} "Action"
---     lowlevel: boolean = If we should use a lowlevel \LuaTeX{} callback instead of a
---                          \ConTeXt{} "Action"
--- @return table t Enablers/Disablers for the callback
---     enable: function = Enable the callback
---     disable: function = Disable the callback
local function register_callback(t)
    if plain or latex then -- Both use \LuaTeX{}Base for callbacks
        return {
            enable = function()
                luatexbase.add_to_callback(t.callback, t.func, t.name)
            end,
            disable = function()
                luatexbase.remove_from_callback(t.callback, t.name)
            end,
        }
    elseif context and not t.lowlevel then
        return {
            --[[ Register the callback when the table is created,
               but activate it when `enable()` is called.
            ]]
            enable = nodes.tasks.appendaction(t.category, t.position, "lwc." .. t.name)
                or function()
                    nodes.tasks.enableaction(t.category, "lwc." .. t.name)
                end,
            disable = function()
                nodes.tasks.disableaction(t.category, "lwc." .. t.name)
            end,
        }
    end
end

```



```

    }
elseif context and t.lowlevel then
    --[[ Some of the callbacks in \ConTeXt{} have no associated "actions". Unlike
        with \LuaTeX{}base, \ConTeXt{} leaves some \LuaTeX{} callbacks unregistered
        and unfrozen. Because of this, we need to register some callbacks at the
        engine level. This is fragile though, because a future \ConTeXt{} update
        may decide to register one of these functions, in which case
        \lwc/ will crash with a cryptic error message.
    ]]
    return {
        enable = function() callback.register(t.callback, t.func) end,
        disable = function() callback.register(t.callback, nil) end,
    }
elseif optex then -- Op\TeX{} is very similar to luatexbase
    return {
        enable = function()
            callback.add_to_callback(t.callback, t.func, t.name)
        end,
        disable = function()
            callback.remove_from_callback(t.callback, t.name)
        end,
    }
end
end

-- Add all of the callbacks
lwc.callbacks = {
    disable_box_warnings = register_callback({
        callback = "hpack_quality",
        func      = function() end,
        name      = "disable_box_warnings",
        lowlevel  = true,
    }),
    remove_widows = register_callback({
        callback = "pre_output_filter",
        func     = lwc.remove_widows,
        name     = "remove_widows",
        lowlevel = true,
    }),
    save_paragraphs = register_callback({
        callback = "pre_linebreak_filter",
        func     = lwc.save_paragraphs,
        name     = "save_paragraphs",
    })
}

```

```

        category = "processors",
        position = "after",
    }},
    mark_paragraphs = register_callback({
        callback = "post_linebreak_filter",
        func      = lwc.mark_paragraphs,
        name      = "mark_paragraphs",
        category  = "finalizers",
        position  = "after",
    }},
}

local lwc_enabled = false
--- Enables the paragraph callbacks
function lwc.enable_callbacks()
    debug("callbacks", "enabling")
    if not lwc_enabled then
        lwc.callbacks.save_paragraphs.enable()
        lwc.callbacks.mark_paragraphs.enable()

        lwc_enabled = true
    else
        info("Already enabled")
    end
end

--- Disables the paragraph callbacks
function lwc.disable_callbacks()
    debug("callbacks", "disabling")
    if lwc_enabled then
        lwc.callbacks.save_paragraphs.disable()
        lwc.callbacks.mark_paragraphs.disable()
        --[[ We do \emph{not} disable `remove_widows` callback, since we still want
            to expand any of the previously-saved paragraphs if we hit an orphan
            or a widow.
        ]]

        lwc_enabled = false
    else
        info("Already disabled")
    end
end

function lwc.if_lwc_enabled()

```

```

    debug("iflwc")
    if lwc_enabled then
        insert_token(iftrue)
    else
        insert_token(iffalse)
    end
end

--- Mangles a macro name so that it's suitable for a specific format
---
--- @param name string The plain name
--- @param args table<string> The TeX types of the function arguments
--- @return string name The mangled name
local function mangle_name(name, args)
    if plain then
        return "lwc@" .. name:gsub("_", "@")
    elseif optex then
        return "_lwc_" .. name
    elseif context then
        return "lwc_" .. name
    elseif latex then
        return "__lwc_" .. name .. ":" .. string_rep("n", #args)
    end
end

--- Creates a TeX command that evaluates a Lua function
---
--- @param name string The name of the csname to define
--- @param func function
--- @param args table<string> The TeX types of the function arguments
--- @return nil
local function register_tex_cmd(name, func, args)
    local scanning_func
    name = mangle_name(name, args)

    if not context then
        local scanners = {}
        for _, arg in ipairs(args) do
            scanners[#scanners+1] = token['scan_' .. arg]
        end

        scanning_func = function()
            local values = {}
            for _, scanner in ipairs(scanners) do

```

```

        values[#values+1] = scanner()
    end

    func(table.unpack(values))
end
end

if optex then
    define_lua_command(name, scanning_func)
    return
elseif plain or latex then
    local index = luatexbase.new_luafunction(name)
    lua.get_functions_table()[index] = scanning_func
    token.set_lua(name, index)
elseif context then
    interfaces.implement {
        name = name,
        public = true,
        arguments = args,
        actions = func
    }
end
end

register_tex_cmd("if_enabled", lwc.if_lwc_enabled, {})
register_tex_cmd("enable", lwc.enable_callbacks, {})
register_tex_cmd("disable", lwc.disable_callbacks, {})
register_tex_cmd(
    "nobreak",
    function(str)
        lwc.nobreak_behaviour = str
    end,
    { "string" }
)
register_tex_cmd(
    "debug",
    function(str)
        lwc.debug = str ~= "0" and str ~= "false" and str ~= "stop"
    end,
    { "string" }
)

--- Silence the luatexbase "Enabling/Removing <callback>" info messages
---
```

```

--- Every time that a paragraph is typeset, \lwc/ hooks in
--- and typesets the paragraph 1 line longer. Some of these longer paragraphs
--- will have pretty bad badness values, so TeX will issue an over/underfull
--- hbox warning. To block these warnings, we hook into the `hpack_quality`
--- callback and disable it so that no warning is generated.
---
--- However, each time that we enable/disable the null `hpack_quality` callback,
--- luatexbase puts an info message in the log. This completely fills the log file
--- with useless error messages, so we disable it here.
---
--- This uses the Lua `debug` library to internally modify the log upvalue in the
--- `add_to_callback` function. This is almost certainly a terrible idea, but I don't
--- know of a better way.
---
--- @return nil
local function silence_luatexbase()
    local nups = debug_lib.getinfo(luatexbase.add_to_callback).nups

    for i = 1, nups do
        local name, func = debug_lib.getupvalue(luatexbase.add_to_callback, i)
        if name == "luatexbase_log" then
            debug_lib.setupvalue(
                luatexbase.add_to_callback,
                i,
                function(text)
                    if text:match("^Inserting") or text:match("^Removing") then
                        return
                    else
                        func(text)
                    end
                end
            )
            return
        end
    end
end
end

--[[ Call `silence_luatexbase` in Plain and LaTeX, unless the undocumented global
`LWC_NO_DEBUG` is set. We provide this opt-out in case something goes awry
with the `debug` library calls.
]]
if (plain or latex) and
    not LWC_NO_DEBUG --- @diagnostic disable-line
then

```

```
        silence luatexbase()
end

-- Activate \lwc/
lwc.callbacks.remove_widows.enable()

return lwc
```

lua-widow-control.tex

```
% lua-widow-control
% https://github.com/gucci-on-fleek/lua-widow-control
% SPDX-License-Identifier: MPL-2.0+
% SPDX-FileCopyrightText: 2022 Max Chernoff

\wlog{lua-widow-control v2.1.2} %%version

\ifx\directlua\undefined
  \errmessage{%
    LuaTeX is required for this package.
    Make sure to compile with `luatex'%
  }
\fi

\catcode`\@=11

\input ltluatex % \LuaTeX{}Base

\clubpenalty=1
\widowpenalty=1
\displaywidowpenalty=1
\brokenpenalty=1

\newdimen\lwcemergencystretch
\lwcemergencystretch=3em

\newcount\lwcmaxcost
\lwcmaxcost=2147483647

\directlua{require "lua-widow-control"}

% Here, we enable font expansion/contraction. It isn't strictly necessary for
% \lwc/'s functionality; however, it is required for the
% lengthened paragraphs to not have terrible spacing.
\expandglyphsinfont\the\font 20 20 5
\adjustspacing=2

% Enable \lwc/ by default when the package is loaded.
\lwc@enable

% Expansion of some parts of the document, such as section headings, is quite
% undesirable, so we'll disable \lwc/ for certain commands.

% We should only reenable \lwc/ at the end if it was already enabled.
\newcount\lwc@disable@count
```

```

\def\lwc@patch@pre{%
  \lwc@if@enabled%
    \advance\lwc@disable@count by 1%
    \lwc@disable%
  \fi%
}

\def\lwc@patch@post{
  \ifnum\lwc@disable@count>0%
    \lwc@enable%
    \advance\lwc@disable@count by -1%
  \fi
}

\def\lwc@extractcomponents #1:#2->#3\STOP{%
  \def\lwc@params{#2}%
  \def\lwc@body{#3}%
}

\def\lwcdisablecmd#1{%
  \ifdefined#1%
    \expandafter\lwc@extractcomponents\meaning#1\STOP%
    \begingroup%
      \catcode`\@=11%
      \expanded{%
        \noexpand\scantokens{%
          \gdef\noexpand#1\lwc@params{%
            \noexpand\lwc@patch@pre\lwc@body\noexpand\lwc@patch@post%
          }%
        }%
      }%
    \endgroup%
  \fi%
}

\begin{group}
  \suppressoutererror=1
  \lwcdisablecmd{\beginsection} % Sectioning
\end{group}

% Make the commands public
\let\lwcenable=\lwc@enable
\let\lwcdisable=\lwc@disable
\let\lwcdebug=\lwc@debug

```



```
\let\iflwc=\lwc@if@enabled
\let\lwcnobreak=\lwc@nobreak

\catcode`\@=12
\endinput
```

lua-widow-control.sty

```
% lua-widow-control
% https://github.com/gucci-on-fleek/lua-widow-control
% SPDX-License-Identifier: MPL-2.0+
% SPDX-FileCopyrightText: 2022 Max Chernoff

% Formats built after 2015 include \LuaTeX{}Base, so this is the absolute
% minimum version that we will run under.
\NeedsTeXFormat{LaTeX2e}[2015/01/01]

% For _really_ old formats
\providecommand\DeclareRelease[3]{}
\providecommand\DeclareCurrentRelease[2]{}

\DeclareRelease{}{0000-00-00}{lua-widow-control-2022-02-22.sty}
\DeclareRelease{v1.1.6}{2022-02-22}{lua-widow-control-2022-02-22.sty}
\DeclareCurrentRelease{v2.1.2}{2022-05-26} %%version %%dashdate

% If this version of LaTeX doesn't support command hooks, then we load
% the last v1.1.X version of the package.
\providecommand\IfFormatAtLeastTF{\@ifl@t@r\fmtversion}
\IfFormatAtLeastTF{2020/10/01}{\input{lua-widow-control-2022-02-22.sty}}
\IfFormatAtLeastTF{2020/10/01}{\endinput}

\ProvidesExplPackage
  {lua-widow-control}
  {2022/05/26} %%slashdate
  {v2.1.2} %%version
  {Use Lua to remove widows and orphans}

% Unconditional Package Loads
\RequirePackage { l3keys2e }

% Message and String Constants
\str_const:Nn \c__lwc_name_str { lua-widow-control }

\msg_new:nnn
  { \c__lwc_name_str }
  { no-luatex }
  {
    LuaTeX~ is~ REQUIRED! \\\
    Make~ sure~ to~ compile~ your~ document~ with~ `lualatex'.
  }

\msg_new:nnn
```

```

{ \c__lwc_name_str }
{ patch-failed }
{
  Patching~ \c_backslash_str #1~ failed. \\
  Please~ ensure~ that~ \c_backslash_str #1~ exists.
}

\msg_new:nnn
{ \c__lwc_name_str }
{ old-format-patch }
{
  Patching~ not~ supported~ with~ old~ LaTeX. \\
  Please~ use~ a~ LaTeX~ format~ >= 2021/06/01.
}

\msg_new:nnn
{ \c__lwc_name_str }
{ old-command }
{
  \c_backslash_str #1~ has~ been~ REMOVED! \\
  Please~ use~ \c_backslash_str setuplwc \c_left_brace_str #2
  \c_right_brace_str\ instead.
}

% Don't let the user proceed unless they are using \LuaTeX{}.
\sys_if_engine luatex:F {
  \msg_critical:nn { \c__lwc_name_str } { no-luatex }
}

% Define (most of) the keys
\cs_generate_variant:Nn \keys_define:nn { Vn }

\keys_define:Vn { \c__lwc_name_str } {
  emergencystretch .dim_gset:N      = \g__lwc_emergencystretch_dim,
  emergencystretch .value_required:n = true,
  emergencystretch .initial:x       = \dim_max:nn { 3em } { 30pt },

  max-cost .int_gset:N              = \g__lwc_maxcost_int,
  max-cost .value_required:n        = true,
  max-cost .initial:x               = \c_max_int,

  widowpenalty .code:n = \int_gset:Nn \tex_widowpenalty:D { #1 }
                      \int_gset:Nn \tex_displaywidowpenalty:D { #1 },
  widowpenalty .value_required:n = true,
  widowpenalty .initial:n        = 1,

```

```

orphanpenalty .code:n = \int_gset:Nn \tex_clubpenalty:D { #1 }
                        \int_gset:Nn \@clubpenalty      { #1 },
orphanpenalty .value_required:n = true,
orphanpenalty .initial:n        = 1,

brokenpenalty .int_gset:N        = \tex_brokenpenalty:D,
brokenpenalty .value_required:n = true,
brokenpenalty .initial:n        = 1,

microtype .bool_gset:N          = \g__lwc_use_microtype_bool,
microtype .value_required:n     = true,
microtype .initial:n            = true,
microtype .usage:n              = preamble,

disablecmds .clist_gset:N       = \g__lwc_disablecmds_cl,
disablecmds .value_required:n   = false,
disablecmds .initial:n          = { \@sect,           % LaTeX default
                                   \@ssect,           % LaTeX starred
                                   \@Msect,           % Memoir
                                   \@mem@old@ssect,    % Memoir Starred
                                   \ttl@straight@ii,   % titlesec normal
                                   \ttl@top@ii,        % titlesec top
                                   \ttl@part@ii,       % titlesec part
                                   },
disablecmds .usage:n            = preamble,
}

% Load the Lua code
\lua_now:n { require "lua-widow-control" }

% Here, we enable font expansion/contraction. It isn't strictly necessary for
% \lwc/'s functionality; however, it is required for the
% lengthened paragraphs to not have terrible spacing.
\hook_gput_code:nnn { begindocument / before } { \c__lwc_name_str } {
  \bool_if:NT \g__lwc_use_microtype_bool {
    \@ifpackageloaded { microtype } {} {
      \RequirePackage[
        final,
        activate = { true, nocompatibility }
      ]
      { microtype }
    }
  }
}

```

```

% Core Function Definitions
\cs_new_eq:NN \iflwc \__lwc_iflwc:

\prg_new_conditional:Nnn \__lwc_if_enabled: { T, F, TF } {
  \__lwc_if_enabled:
    \prg_return_true:
  \else
    \prg_return_false:
  \fi
}

% Expansion of some parts of the document, such as section headings, is quite
% undesirable, so we'll disable \lwc/ for certain commands.
\int_new:N \g__lwc_disable_int

\cs_new:Npn \__lwc_patch_pre: {
  % We should only reenable \lwc/ at the end if it was already enabled.
  \__lwc_if_enabled:T {
    \int_gincr:N \g__lwc_disable_int
    \__lwc_disable:
  }
}

\cs_new:Npn \__lwc_patch_post: {
  \int_compare:nT { \g__lwc_disable_int > 0 } {
    \__lwc_enable:
    \int_gdecr:N \g__lwc_disable_int
  }
}

\cs_new:Npn \__lwc_patch_cmd:c #1 {
  \IfFormatAtLeastTF { 2021/06/01 } {
    \hook_gput_code:nnn { cmd / #1 / before } { \c__lwc_name_str } {
      \__lwc_patch_pre:
    }
    \hook_gput_code:nnn { cmd / #1 / after } { \c__lwc_name_str } {
      \__lwc_patch_post:
    }
  } {
    \msg_warning:nn
      { \c__lwc_name_str }
      { old-format-patch }
  }
}

```

```

\cs_new:Npn \__lwc_patch_cmd:N #1 {
  \__lwc_patch_cmd:c { \cs_to_str:N #1 }
}

\cs_new:Npn \__lwc_patch_cmd:n #1 {
  % If the item provided is a single token, we'll assume that it's a \macro.
  % If it is multiple tokens, we'll assume that it's a 'csname'.
  \tl_if_single:nTF { #1 } {
    \__lwc_patch_cmd:c { \cs_to_str:N #1 }
  } {
    \__lwc_patch_cmd:c { #1 }
  }
}

\hook_gput_code:nnn { begindocument / before } { \c__lwc_name_str } {
  \clist_map_function:NN \g__lwc_disablecmds_cl \__lwc_patch_cmd:n
}

%%% Class and package-specific patches

% KOMA-Script
\cs_if_exist:NT \AddtoDoHook {
  \AddtoDoHook { heading / begingroup } { \__lwc_patch_pre: \use_none:n }
  \AddtoDoHook { heading / endgroup } { \__lwc_patch_post: \use_none:n }
}

% Memoir
\cs_gset_nopar:Npn \pen@ltyabovetopbreak { 23 } % Issue #32

% Define some final keys
\keys_define:Vn { \c__lwc_name_str } {
  enable .choice:,
  enable / true .code:n = \__lwc_enable:,
  enable / false .code:n = \__lwc_disable:,
  enable .initial:n = true,
  enable .default:n = true,
  enable .value_required:n = false,

  disable .code:n = \__lwc_disable:,
  disable .value_forbidden:n = true,

  debug .choice:,
  debug / true .code:n = \__lwc_debug:n { true },
  debug / false .code:n = \__lwc_debug:n { false },

  nobreak .code:n = \__lwc_nobreak:n { #1 },

```

```

nobreak .value_required:n = true,
nobreak .initial:n         = keep,

strict .meta:n = { emergencystretch = 0pt,
                  max-cost          = 5000,
                  nobreak           = warn,
                  widowpenalty      = 1,
                  orphanpenalty     = 1,
                  brokenpenalty     = 1,
                  },
strict .value_forbidden:n = true,

default .meta:n = { emergencystretch = 3em,
                  max-cost          = \c_max_int,
                  nobreak           = keep,
                  widowpenalty      = 1,
                  orphanpenalty     = 1,
                  brokenpenalty     = 1,
                  },
default .value_forbidden:n = true,

balanced .meta:n = { emergencystretch = 1em,
                  max-cost          = 10000,
                  nobreak           = keep,
                  widowpenalty      = 500,
                  orphanpenalty     = 500,
                  brokenpenalty     = 500,
                  },
balanced .value_forbidden:n = true,
}

% Add the user interface for the keys
\exp_args:NV \ProcessKeysPackageOptions { \c__lwc_name_str }

\cs_generate_variant:Nn \keys_set:nn { Vn }
\NewDocumentCommand \lwcsetup {m} {
  \keys_set:Vn { \c__lwc_name_str }{ #1 }
}

% Legacy Commands
\NewDocumentCommand \lwcemergencystretch { } {
  \msg_error:nnnnn
    { \c__lwc_name_str }
    { old-command }
    { lwcemergencystretch }
}

```

```

        { emergencystretch=XXXpt }
    }

\NewDocumentCommand \lwcdisablecmd { m } {
    \msg_error:nnxx
    { \c__lwc_name_str }
    { old-command }
    { lwcdisablecmd }
    { disablecmds={\c_backslash_str aaa,~ \c_backslash_str bbb} }
}

\cs_new_eq:NN \lwccenable  \__lwc_enable:
\cs_new_eq:NN \lwcdisable \__lwc_disable:

\endinput

```


lua-widow-control-2022-02-22.sty

```
% lua-widow-control
% https://github.com/gucci-on-fleek/lua-widow-control
% SPDX-License-Identifier: MPL-2.0+
% SPDX-FileCopyrightText: 2022 Max Chernoff

\NeedsTeXFormat{LaTeX2e}[2015/01/01] % Formats built after 2015 include \LuaTeX{}Base
\ProvidesPackage{lua-widow-control}%
    [2022/02/22 v1.1.6]

% The version number above is somewhat-misleading: I will make bugfixes to this file
% from time to time, but the core of the file will not change. Therefore, we should
% report a real version number here for debugging.
\PackageInfo{lua-widow-control}{%
    Real version:
    2022/05/26 %%slashdate
    v2.1.2 %%version
}

\PackageWarning{lua-widow-control}{%
    Old LaTeX format detected!\MessageBreak\MessageBreak
    Lua-widow-control prefers a LaTeX format\MessageBreak
    newer than November 2020. I'll still run\MessageBreak
    the latest Lua code, but I'm using an older\MessageBreak
    version of the LaTeX code. This means that\MessageBreak
    the key-value interface is *UNSUPPORTED*.\MessageBreak
}

\ifdefined\directlua\else
    \PackageError{lua-widow-control}{%
        LuaTeX is required for this package.\MessageBreak
        Make sure to compile with `lualatex'%
    }{}
\fi

\clubpenalty=1
\widowpenalty=1
\displaywidowpenalty=1

% We can't use \newlength since that makes a \TeX{} "skip", not a "dimen"
\newdimen\lwcemergencystretch
\lwcemergencystretch=3em

\newcount\lwcmaxcost
```

```

\lwcmaxcost=2147483647

\directlua{require "lua-widow-control"}

% Here, we enable font expansion/contraction. It isn't strictly necessary for
% \lwc/'s functionality; however, it is required for the
% lengthened paragraphs to not have terrible spacing.
\RequirePackage{etoolbox}
\AtEndPreamble{
  \@ifpackageloaded{microtype}{}{} % Only load if not already loaded
  \RequirePackage[
    final,
    activate={true,nocompatibility}
  ]{microtype}
}

% Define \TeX{} wrappers for Lua functions
\newcommand{\lwcenable}{}\directlua{lwc.enable_callbacks()}
\newcommand{\lwcdisable}{}\directlua{lwc.disable_callbacks()}
\newcommand{\iflwc}{}\directlua{lwc.if_lwc_enabled()}

% Enable \lwc/ by default when the package is loaded.
\lwcenable

% Expansion of some parts of the document, such as section headings, is quite
% undesirable, so we'll disable \lwc/ for certain commands.
\newcommand{\lwc@patch@warning}[1]{\PackageWarning{lua-widow-control}{%
  Patching the \protect#1 command failed%
}}

% We should only reenale \lwc/ at the end if it was already enabled.
\newif\iflwc@should@reenable

\newcommand{\lwc@patch@pre}{}%
  \iflwc%
    \lwc@should@reenabletrue%
    \lwcdisable%
  \else%
    \lwc@should@reenablefalse%
  \fi%
}

\newcommand{\lwc@patch@post}{}%
  \iflwc@should@reenable%

```

```

        \lwcenable%
    \fi%
}

\newcommand{\lwcdisablecmd}[1]{%
    \ifdefined#1
        \pretocmd{#1}{\lwc@patch@pre}{1}{\lwc@patch@warning{#1}}%
        \apptocmd{#1}{\lwc@patch@post}{1}{\lwc@patch@warning{#1}}%
    \fi
}

\lwcdisablecmd{\@sect} % Sectioning

\endinput

```

t-lua-widow-control.mkx

```
%D \module
%D   [      file=t-lua-widow-control,
%D     version=2.1.2, %%version
%D     title=lua-widow-control,
%D     subtitle=\ConTeXt module for lua-widow-control,
%D     author=Max Chernoff,
%D     date=2022-05-26, %%dashdate
%D     copyright=Max Chernoff,
%D     license=MPL-2.0+,
%D     url=https://github.com/gucci-on-fleek/lua-widow-control]
\startmodule[lua-widow-control]
\unprotect

\installnamespace{lwc}

\installcommandhandler \????lwc {lwc} \????lwc

\newdimen\lwc_emergency_stretch
\newcount\lwc_max_cost
\appendtoks
  \lwc_emergency_stretch=\lwcparameter{emergencystretch}

  \doifelse{\lwcparameter{c!state}}{\v!start{
    \lwc_enable
  }}{
    \lwc_disable
  }

  \lwc_debug{\lwcparameter{debug}}

  \lwc_nobreak{\lwcparameter{nobreak}}

  \lwc_max_cost=\lwcparameter{maxcost}

  % We can't just set the penalties because they will be reset automatically
  % at \starttext.
  \startsetups[*default]
    \directsetup{*reset}

    \clubpenalty=\lwcparameter{orphanpenalty}
    \widowpenalty=\lwcparameter{widowpenalty}
    \displaywidowpenalty=\lwcparameter{widowpenalty}
    \brokenpenalty=\lwcparameter{brokenpenalty}
  \stopsetups
```

```

\startsetups[grid][*default]
  \directsetup{*reset}

  \clubpenalty=\lwcparameter{orphanpenalty}
  \widowpenalty=\lwcparameter{widowpenalty}
  \displaywidowpenalty=\lwcparameter{widowpenalty}
  \brokenpenalty=\lwcparameter{brokenpenalty}
\stopsetups

\setups[*default]
\to\everysetuplwc

\ctxloadluafile{lua-widow-control}

\setuplwc[
  emergencystretch=3em,
  \c!state=\v!start,
  debug=\v!stop,
  orphanpenalty=1,
  widowpenalty=1,
  brokenpenalty=1,
  nobreak=keep,
  maxcost=2147483647,
]

% Here, we enable font expansion/contraction. It isn't strictly necessary for
% \lwc/'s functionality; however, it is required for the
% lengthened paragraphs to not have terrible spacing.
\definefontfeature[default][default][expansion=quality]
\setupalign[hz]

% Expansion of some parts of the document, such as section headings, is quite
% undesirable, so we'll disable \lwc/ for certain commands.
% We should only reenable \lwc/ at the end if it was already enabled.
\newcount\lwc_disable_count

\define\lwc_patch_pre{%
  \lwc_if_enabled%
    \advance\lwc_disable_count by 1%
    \setuplwc[\c!state=\v!stop]%
  \fi%
}

\define\lwc_patch_post{
  \ifnum\lwc_disable_count>0\relax%

```

```

        \setuplwc[\c!state=\v!start]%
        \advance\lwc_disable_count by -1%
    \fi%
}

\prependtoks\lwc_patch_pre\to\everybeforesectionheadhandle % Sectioning
\prependtoks\lwc_patch_post\to\everyaftersectionheadhandle

% Make the commands public
\let\iflwc=\lwc_if_enabled

\protect
\stopmodule

```

lua-widow-control.opm

```
% lua-widow-control
% https://github.com/gucci-on-fleek/lua-widow-control
% SPDX-License-Identifier: MPL-2.0+
% SPDX-FileCopyrightText: 2022 Max Chernoff

\codedecl\lwcenable{lua-widow-control <v2.1.2>} %%version
\namespace{lwc}

\clubpenalty=1
\widowpenalty=1
\displaywidowpenalty=1
\brokenpenalty=1

\newdimen\lwcemergencystretch
\lwcemergencystretch=3em

\newcount\lwcmaxcost
\lwcmaxcost=2147483647

\directlua{require "lua-widow-control"}

% Enable \lwc/ by default when the package is loaded.
\enable

% Expansion of some parts of the document, such as section headings, is quite
% undesirable, so we'll disable \lwc/ for certain commands.

% We should only reenable \lwc/ at the end if it was already enabled.
\newcount\disable_count

\def\patch_pre{%
  \if_enabled%
    \advance\disable_count by 1%
    \disable%
  \fi%
}

\def\patch_post{
  \ifnum\disable_count>0%
    \enable%
    \advance\disable_count by -1%
  \fi
}
```

```

\def\extractcomponents #1:#2->#3\STOP{%
  \def\params{#2}%
  \def\body{#3}%
}

\def\disable_cmd#1{%
  \ifdefined#1%
    \ea\extractcomponents\_meaning#1\STOP%
    \begingroup%
      \catcode\_ =11%
      \expanded{%
        \noexpand\_scantokens{%
          \gdef\noexpand#1\params{%
            \noexpand\patch_pre\body\noexpand\patch_post%
          }%
        }%
      }%
    \endgroup%
  \fi%
}

\disable_cmd{\_printchap}
\disable_cmd{\_printsec}
\disable_cmd{\_printsecc}

% Make the commands public
\_let\lwenable=\.enable
\_let\lwcdisable=\.disable
\_let\lwcdisablecmd=\.disable_cmd
\_let\lwcddebug=\.debug
\_let\iflwc=\.if_enabled
\_let\lwcnobreak=\.nobreak

\_endnamespace
\_endcode

```


Demo from Table 1

```
\definepapersize[smallpaper][
    width=6cm,
    height=8.3cm
]\setuppapersize[smallpaper]

\setuplayout[
    topspace=0.1cm,
    backspace=0.1cm,
    width=middle,
    height=middle,
    header=0pt,
    footer=0pt,
]

\def\lwc/{\sans{lua-\allowbreak widow-\allowbreak control}}
\def\Lwc/{\sans{Lua-\allowbreak widow-\allowbreak control}}

\setupbodyfont[9pt]
\setupindenting[yes, 2em]

\definepalet[layout][grid=middlegray]
\showgrid[nonumber, none, lines]

\definefontfeature[default][default][expansion=quality,protrusion=quality]

\usetypescript[modern-base]
\setupbodyfont[reset,modern]

\setupalign[hz,hanging,tolerant]

\setuplanguage[en][spacing=packed]

\starttext
    \Lwc/ can remove most widows and orphans from a document, \emph{without} stretching
    any glue or shortening any pages.
```

It does so by automatically lengthening a paragraph on a page where a widow or orphan would otherwise occur. While `\TeX{}{}` breaks paragraphs into their natural length, `\lwc/` is breaking the paragraph 1~line longer than its natural length. `\TeX{}{}`'s paragraph is output to the page, but `\lwc/'`s paragraph is just stored for later. When a widow or orphan occurs, `\lwc/` can take over. It selects the previously-saved paragraph with the least badness; then, it replaces `\TeX{}{}`'s paragraph with its saved paragraph. This increases the text block height of the page by 1~line.

Now, the last line of the current page can be pushed to the top of the next page.

This removes the widow or the orphan without creating any additional work.

`\stoptext`