

LUA-WIDOW-CONTROL

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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 your document. For more details, see the [Usage sections](#).

CONTENTS

Quick Start	1
Motivation	2
Widows and Orphans	3
<i>Widows • Orphans</i>	
T _E X's Pagination	3
<i>Algorithm • Behavior</i>	
Other Solutions	4
Demonstration	6
<i>Ignore • Shorten • Stretch • lua-widow-control</i>	
Installation	7
<i>T_EX Live • MikT_EX • ConT_EXt M_KIV Standalone</i>	
<i>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>Enabling</i> • <i>Disabling</i> • <i>Strict Mode</i>	
<i>\emergencystretch</i> • <i>Selectively Disabling</i>	
<i>Widow and Orphan Penalties</i>	
<i>\nobreak Behaviour</i> • <i>Maximum Cost</i>	
<i>Debug Mode</i>	
Columns	12
Known Issues	12
The Algorithm	13
<i>Paragraph Breaking</i> • <i>Page Breaking</i>	
Contributions	14
License	14
References	14
Implementation	15
<i>lua-widow-control.lua</i> • <i>lua-widow-control.tex</i>	
<i>lua-widow-control.sty</i>	
<i>t-lua-widow-control.mkxl/mkiv</i>	
<i>lua-widow-control.opm</i> • <i>Demo from Table 1</i>	

MOTIVATION

T_EX provides top-notch typesetting: even 40 years after its first release, no other program produces higher quality mathematical typesetting, and its paragraph-breaking algorithm is still state-of-the-art. However, its page breaking is not quite as sophisticated as its paragraph breaking and thus suffers from some minor issues.

Unmodified T_EX typically has only 2 ways of dealing with widows and orphans: it can either shorten a page by 1 line, or it can stretch out some 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 behavior works quite well; however, for prose or

any other document composed almost entirely of text, there is no vertical whitespace to stretch.

Since there were no ready-made and fully-automated solutions to remove widows and orphans from all types of documents, I decided to create lua-widow-control.

WIDOWS AND ORPHANS

Widows Widows occur when the majority of a paragraph is on one page or column, but the last line is on the following page or column. Widows are undesirable for both aesthetics and readability. Aesthetically, it looks quite odd for a lone line to be at the start of the page. Functionally, the separation of a paragraph and its last line disconnects the two, causing the reader to lose context for the widowed line.

Orphans Orphans are when the first line of a paragraph occurs on the page or column before the remainder of the paragraph. They are not nearly 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 do, so they tend to be ignored more often.

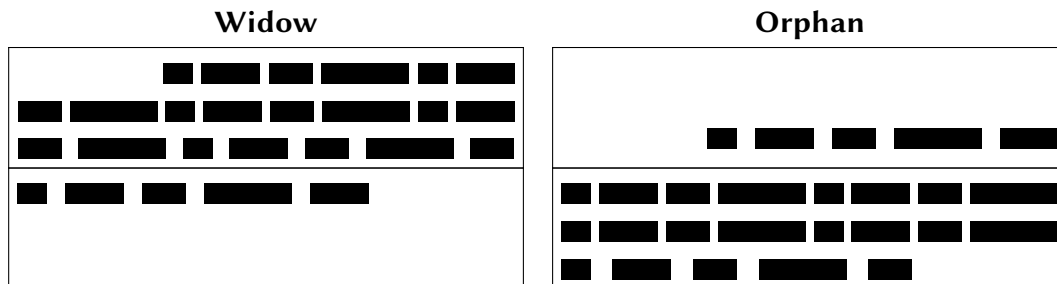


Figure 1 A visual comparison of widows and orphans.

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. Chapter 15 of *The T_EXBook*¹ ("How T_EX Makes Lines into Pages") is the best reference for this; however, it goes into much more detail than most users require. As a supplemental resource, I can also recommend Section 27 of *T_EXby Topic*², [available online](#) for free. Below follows a *very* simplified (and likely error-ridden) 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 vertical spaces.

However, some objects have penalties attached. These penalties make T_EX treat the object as if it is longer or shorter for the sake of page breaking. By default, T_EX assigns a penalties to the first and last lines of a paragraph (widows and orphans). This makes T_EX treat them as if they are larger or smaller than their actual size such that T_EX tends not to break them up.

One important note: once T_EX begins breaking a page, it never goes back and modifies any content on the page. Page breaking is a localized algorithm, without any backtracking.

Behavior Of course, this algorithm doesn't allow us to intuitively understand how T_EX deals with widows and orphans.

Due to the penalties attached to widows and orphans, T_EX treats them as if they are longer than they actually are. Widows and orphans with small penalties attached—like L^AT_EX's default values of 150—are only treated as slightly taller than 1 line, while widows and orphans with large penalties—values near 10 000—are treated as if they are 2 lines tall. Because potential widow and orphan lines are broken as if they are taller than they actually are, T_EX will tend to group them together on the same pages.

However, when these lines are moved as a group, T_EX will have to make a page or column with less lines. “**Demonstration**” goes into further detail about how T_EX deals with these too-short pages or columns. The main takeaway is that for a page exclusively filled with text, all of T_EX's builtin solutions come with compromises.

OTHER SOLUTIONS

There have been a few previous attempts to improve upon T_EX's previously-discussed widow and orphan-handling abilities; however, none of these have been able to automatically remove widows and orphans without stretching any glue or shortening any pages.

*Strategies against widows*³ and *Managing forlorn paragraph lines in L^AT_EX*⁴ both begin with comprehensive discussions of the methods of preventing widows and orphans. They both agree that widows and orphans are bad and ought to be avoided; however, they each differ in solutions. *Strategies*³ proposes an output routine that reduces the length of facing pages by 1 line when necessary to remove widows and

orphans while *Managing*⁴ proposes that the author manually rewrites or adjusts the `\looseness` when needed.

*Paragraph callback to help with widows/orphans hand tuning*⁵ contains a file `widow-assist.lua` that automatically detects which paragraphs can be safely shortened or lengthened by 1 line. *The widows-and-orphans package*⁶ alerts the author to the pages that contain widows or orphans. Combined, these packages make it very simple for the author to quickly remove widows and orphans by adjusting the `\looseness` values; however, it still requires the author to make manual source changes after each revision.

`Lua-widow-control` is essentially just a combination of `widow-assist.lua`⁵ and `widows-and-orphans`.⁶ when the `\outputpenalty` shows that a widow or orphan occurred, Lua is used to find a stretchable paragraph. What `lua-widow-control` adds on top of these packages is automation: `lua-widow-control` eliminates the requirement for any manual adjustments.

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.

DEMONSTRATION

Although \TeX 's page breaking algorithm is quite simple, it can lead to some fairly complex behaviors when widows and orphans are involved. The usual choices are to either ignore them, stretch some glue, or shorten the page. **Table 1** has a visual demonstration of some of these behaviors and how `lua-widow-control` differs from the defaults.

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 pretty distracting for the reader, so it is best avoided wherever possible.
Shorten	This page did not leave any widows, but it did shorten the previous page by 1 line. Sometimes this is acceptable, but usually it looks bad because each page will 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 flushed bottom margin. However, the space between each paragraph 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. \TeX was designed for mathematical typesetting, so it makes sense that this is its default behavior. However, in a page with mostly text, these paragraph gaps can look unsightly.</p> <p>In addition, this method is incompatible with typesetting on a grid since all glue stretch must be quantized 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 flushed bottom margin and constant paragraph spacing.</p> <p>To do so, <code>lua-widow-control</code> 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 it becomes nearly 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_EX Live Run `tlmgr install lua-widow-control` in a terminal, or install using the “T_EX Live Manager” GUI.

MikT_EX Run `mpm --install=lua-widow-control` in a terminal, or install using the “MikT_EX Maintenance” GUI.

ConT_EXt MKIV Standalone Run `first-setup.sh --modules="lua-widow-control"` in a terminal or install manually.

Manual Currently, ConT_EXt MKXL (luametaT_EX) users must manually install the package. Most other users will be better served by using the lua-widow-control supplied by T_EX Live and MikT_EX; however, all users may manually install the package if desired. The procedure should be fairly similar regardless of your OS, T_EX distribution, or format.

- Steps**
1. Download `lua-widow-control.tds.zip` from [CTAN](#) or [GitHub](#).
 2. Unzip the release into your `TEXMFLOCAL/` directory. (You can find its location by running `kpsewhich --var-value TEXMFHOME` in a terminal)
 3. Refresh the filename database:
 - ConT_EXt: `mtxrun --generate`
 - T_EX Live: `mktexlsr`
 - MikT_EX: `initexmf --update-fndb`

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_EX Lua-widow-control requires LuaT_EX (≥ 0.85) and the most recent version of lua-texbase (2015/10/04). Any version of T_EX 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. Instead, you should follow 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>\inputlua-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 always use the `\setuplwc[options]` command.

Plain T_EX and OpT_EX are a little different. Some options have commands provided (i.e., `\lwcemergencystretch=<dimension>`), while others must be set manually (i.e., `\directlua{lwc.debug = true}`).

Also, please note that not all commands are provided for all formats.

Enabling	<p>Lua-widow-control is enabled by default as soon as you load it. Nevertheless, you may need to explicitly reenable it if you have previously disabled it.</p>
	<pre>Plain T_EX/OpT_EX \lwcenable L^AT_EX \lwcsetup{enable} ConT_EXt \setuplwc[state = start]</pre>
Disabling	<pre>Plain T_EX/OpT_EX \lwcdisable L^AT_EX \lwcsetup{disable} ConT_EXt \setuplwc[state = stop]</pre>
Strict Mode	<p>By default, lua-widow-control takes all possible measures to remove widows and orphans. This normally works out pretty well; however, sometimes these measures may be a little more aggressive than certain users want.</p> <p>Lua-widow-control offers a “strict” mode that will only make modification to the page that are near-imperceptible to remove widows and orphans.</p> <pre>L^AT_EX \lwcsetup{strict}</pre>
	<p>Internally, this sets <code>emergencystretch = 0pt</code>, <code>max-cost = 2500</code>, and <code>no-break = warn</code>.</p>
\emergencystretch	<p>You can configure the <code>\emergencystretch</code> used when stretching a paragraph. The default value is 3 em.</p> <p>Lua-widow-control will only use the <code>\emergencystretch</code> when it cannot lengthen a paragraph in any other way, so it is fairly safe to set this to a large value. T_EX still accumulates badness when <code>\emergencystretch</code> is used, so it’s pretty rare that a paragraph that requires any <code>\emergencystretch</code> will actually be used on the page.</p> <pre>Plain T_EX/OpT_EX \lwcemergencystretch=<dimension> L^AT_EX \lwcsetup{emergencystretch = <dimension>} ConT_EXt \setuplwc[emergencystretch = <dimension>]</pre>
Selectively Disabling	<p>Sometimes, you may want to disable lua-widow-control for certain commands where stretching is undesirable. For example, you typically wouldn’t want section headings to be stretched.</p> <p>You could just disable then reenable lua-widow-control every time that you</p>

use the command; however, lua-widow-control provides a convenience macro that will do this automatically for you.

Lua-widow-control automatically patches the default L^AT_EX, ConT_EXt, and Plain T_EX section commands, so you shouldn't need to patch these yourself; however, lua-widow-control does **not** patch the non-standard section commands provided by memoir, KOMA-script, titlesec, OpT_EX, and others. You'll need to add these yourself.

```
Plain TEX    \lwcdisablecmd{\macro}
LATEX      \lwcsetup{disablecmds = {\macroone}, {\macrotwo}}
ConTEXt    \prependtoks\lwc@patch@pre\to\everybefore{hook}
           \prependtoks\lwc@patch@post\to\everyafter{hook}
```

Widow and Orphan Penalties You can also manually adjust the penalties that T_EX assigns to widows and orphans. Usually, the defaults are fine, but advanced users may want to change them.

```
Plain TEX/OpTEX  \widowpenalty=<integer>
                  \clubpenalty=<integer>
LATEX          \lwcsetup{widowpenalty = <integer>}
                  \lwcsetup{orphanpenalty = <integer>}
ConTEXt        \setuplwc[widowpenalty = <integer>]
                  \setuplwc[orphanpenalty = <integer>]
```

Some suitable integers:

```
Ignore widows/orphans    0
Default                  1
Disable lua-widow-control 10 000
```

\nobreak Behaviour When lua-widow-control encounters an orphan, it removes it by removing the orphaned line to the next page. However, sometimes, an orphan is immediately preceded by a section heading or a \nobreak command. By moving the orphan to the next page, you would naïvely separate a section (or other such material) from the line that follows. This really ought to be avoided, so lua-widow-control provides some options to avoid this.

Plain T_EX/OpT_EX `\directlua{lwc.nobreak_behaviour = "<value>"}`

L^AT_EX `\lwcsetup{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 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.

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.

Maximum Cost When T_EX breaks a paragraph, it scores it by the number of “demerits”. The demerits for a paragraph is the sum of the squared badnesses for each line, plus any “additional demerits” added for any other reason. The badness for a line is proportional the cube of the glue stretch ratio, so demerits grow with the sixth power of glue stretch.

To choose the “best” paragraph on the page, lua-widow-control uses a “cost function” C that is initially defined as

$$C = \frac{d}{2\sqrt{l}}$$

where d is the total demerits of the paragraph, and l is the number of lines in the paragraph.

By default, lua-widow-control just 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_EX/OpT_EX `\lwcmaxcost=<integer>`

L^AT_EX `\lwcsetup{max-cost = <integer>}`

ConT_EXt `\setuplwc[maxcost = <integer>]`

Very 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.

Plain T _E X/OpT _E X	<code>\directlua{lwc.debug = true}</code> <code>\directlua{lwc.debug = false}</code>
L ^A T _E X	<code>\lwcsetup{debug = true}</code> <code>\lwcsetup{debug = false}</code>
ConT _E Xt	<code>\setuplwc[state = start]</code> <code>\setuplwc[state = stop]</code>

COLUMNS

Since T_EX implements column breaking and page breaking through the same internal mechanisms, lua-widow-control should remove widows and orphans between columns just as well as it does with widows and orphans between pages. This has been tested with the standard L^AT_EX class option `twocolumn` and the two-column output routine from Chapter 23 of *The T_EXBook*.¹ Lua-widow-control should presumably work with any other multi-column implementation; however, due to the diversity and complexity of output routines, this cannot be guaranteed.

KNOWN ISSUES

- Lua-widow-control will rarely fail to correctly move the last line on an expanded page to the next page in documents with *very* small paper sizes.
- When a 3-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 better than widows, so this is still an improvement.
- Sometimes a widow or orphan cannot be eliminated because no paragraph has enough “stretch”. This can *sometimes* be remediated by increasing lua-widow-control’s `\emergencystretch`; however, some pages just don’t have enough “stretchy” paragraphs. Long paragraphs with short words tend to be “stretchier” than short paragraphs with long words since these long paragraphs will have

more interword glue. Narrow columns also stretch easier than wide columns since you need to expand a paragraph by less to make a new line.

- When running under `luametaTEX`, the log may be filled with lines like “`luatex warning > tex: left parfill skip is gone`”. This is harmless and can be ignored.
- Lua-widow-control will rarely raise a “Circular node list detected!” warning. This occurs when the replacement paragraph node list loops back on itself. This is usually harmless, but can rarely cause the entire compile to completely fail.
- T_EX may warn you about over or underfull vboxes on pages where lua-widow-control removed a widow or orphan. This is a false alarm and can be ignored.

THE ALGORITHM

Lua-widow-control uses a fairly simple algorithm to eliminate widows and orphans. It is pretty basic, but there are a few subtleties. Please see “[Implementation](#)” for a full listing of the source code.

Paragraph Breaking

First, lua-widow-control hooks into the paragraph breaking process.

Before a paragraph is broken by T_EX, lua-widow-control grabs the unbroken paragraph. Lua-widow-control then breaks the paragraph 1 line longer than its natural length and stores it for later, *without* interfering with how T_EX breaks paragraphs into their natural length.

After T_EX has broken its paragraph into its natural length, lua-widow-control appears once again. Before the broken paragraph is added to the main vertical list, lua-widow-control tags the first and last nodes of the paragraph. These tags create a relationship between the previously-saved lengthened paragraph and the start/end of the naturally-typeset paragraph on the page.

Page Breaking

Lua-widow-control intercepts `\box255` immediately before the output routine.

First, lua-widow-control analyzes the `\outputpenalty` of the page or column. If the page was broken at a widow or orphan, the `\outputpenalty` will equal either `\widowpenalty` or `\orphanpenalty`. If the `\outputpenalty` is not indicative of a widow or orphan, lua-widow-control will stop and return `\box255` unmodified.

At this point, we know that we have a widow or orphan on the page, so we must lengthen the page by 1 line. We iterate through the list of saved paragraphs to find the lengthened paragraph with the least cost. Once we’ve selected a paragraph

to replace, we can now traverse through the page to find the original version of this paragraph that T_EX originally typeset. Once we find the original paragraph, we “splice” the lengthened paragraph in the place of the original.

Since the page is now 1 line longer than it was before, we pull the last line off of the page to bring it back to its original length. We place the line onto the top of the *recent contributions* list so that it is added to the start of the next page. Now, we can return the new, widow-free page to the output routine.

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.

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IMPLEMENTATION

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
]]

lwc = lwc or {}
lwc.name = "lua-widow-control"
lwc.nobreak_behaviour = "keep"

local write_nl = texio.write_nl
local string_rep = string.rep
local function debug_print(title, text)
    if not lwc.debug then return end

    local filler = 15 - #title

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

--[[
    lua-widow-control is intended to be format-agnostic. It only runs on LuaTeX,
    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' then -- Plain
    plain = true
elseif format == '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 can't hurt.
]]
local last = node.slide
local copy = node.copy_list
local par_id = node.id("par") or node.id("local_par")
local glue_id = node.id("glue")
local glyph_id = node.id("glyph")
local penalty_id = node.id("penalty")
local hlist_id = node.id("hlist")
local traverse = node.traverse
local set_attribute = node.set_attribute or node.setattribute
local find_attribute = node.find_attribute or node.findattribute
local flush_list = node.flush_list or node.flushlist
local free = node.free
local min_col_width = tex.sp("250pt")

--[[
    Package/module initialization
]]
local warning,
    info,
    attribute,
    contrib_head,
    stretch_order,
    pagenum,
    emergencystretch,
    max_cost

if lmtx then
    debug_print("LMTX")
    contrib_head = 'contributehead'
    stretch_order = "stretchorder"
else
    contrib_head = 'contrib_head'
    stretch_order = "stretch_order"

```

```

end

if context then
    debug_print("ConTeXt")
    warning = logs.reporter("module", lwc.name)
    info = logs.reporter("module", lwc.name)
    attribute = attributes.public(lwc.name)
    pagenum = function() return tex.count["realpageno"] end
    emergencystretch = "lwc_emergencystretch"
    max_cost = "lwc_max_cost"
elseif plain or latex or optex then
    pagenum = function() return tex.count[0] end

    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_print("Plain/LaTeX")
        luatexbase.provides_module {
            name = lwc.name,
            date = "2022/03/07", --%%slashdate
            version = "2.0.0", --%%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
        attribute = luatexbase.new_attribute(lwc.name)
    elseif optex then
        debug_print("OpTeX")
        warning = function(str) write_nl(lwc.name .. " Warning: " .. str) end
        info = function(str) write_nl("log", lwc.name .. " Info: " .. str) end
        attribute = alloc.new_attribute(lwc.name)
    end
else -- uh oh

```

```

    error [[Unsupported format.

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

local paragraphs = {} -- List to hold the alternate paragraph versions

local function get_location()
    return "At " .. pagenum() .. "/" .. #paragraphs
end

--[[
    Function definitions
]]

--- Create a table of functions to enable or disable a given callback
--- @param t table Parameters of the callback to create
---     callback: str = The LuaTeX callback name
---     func: function = The function to call
---     name: str = The name/ID of the callback
---     category: str = The category for a ConTeXt "Action"
---     position: str = The "position" for a ConTeXt "Action"
---     lowlevel: bool = 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 LuaTeXBase 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,
}
elseif context and t.lowlevel then
    --[[
        Some of the callbacks in ConTEXt have no associated "actions". Unlike
        with LuaTEXbase, 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
        lua-widow-control 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
    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
end

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
                chars = chars .. string.char(n.char)
            else
                chars = chars .. "#"
            end
        elseif n.id == glue_id then
            chars = chars .. " "
        end
    end
end

```

```

        end
        if #chars > 25 then
            break
        end
    end

    debug_print(get_location(), chars)
end

function lwc.paragraph_cost(demerits, lines)
    return demerits / (2 * math.sqrt(lines))
end

--- Saves each paragraph, but lengthened by 1 line
function lwc.save_paragraphs(head)
    -- 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

    -- Ensure that we were actually given a par (only under ConTeXt for some reason)
    if head.id ~= par_id and context then
        return head
    end

    -- We need to return the unmodified head at the end, so we make a copy here
    local new_head = copy(head)

    -- Prevent ultra-short last lines (TEXBook p. 104), except with narrow columns
    local parfillskip = last(new_head)
    if parfillskip.id == glue_id and 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

    -- Break the paragraph 1 line longer than natural
    local long_node, long_info = tex.linebreak(new_head, {
        looseness = 1,

```

```

    emergencystretch = tex.getdimen(emergencystretch),
  })

  -- Break the natural paragraph so we know how long it was
  local natural_node, natural_info = tex.linebreak(copy(head))
  flush_list(natural_node)

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

  -- Offset the accumulated \prevdepth
  local prevdepth = node.new("glue")
  prevdepth.width = natural_info.prevdepth - long_info.prevdepth
  last(long_node).next = prevdepth

  if long_info.prevgraf == natural_info.prevgraf + 1 then
    table.insert(paragraphs, {
      cost = lwc.paragraph_cost(long_info.demerits, long_info.prevgraf),
      node = long_node
    })
  end

  get_chars(head)
  debug_print(get_location(), "nat lines " .. natural_info.prevgraf)
  debug_print(
    get_location(),
    "nat cost " ..
    lwc.paragraph_cost(natural_info.demerits, natural_info.prevgraf)
  )
  debug_print(get_location(), "long lines " .. long_info.prevgraf)
  debug_print(
    get_location(),
    "long cost " ..
    lwc.paragraph_cost(long_info.demerits, long_info.prevgraf)
  )

  -- luametaTeX 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 lua-widow-control, and the value corresponds to the
--- paragraphs index, which is negated for the end of the paragraph.
function lwc.mark_paragraphs(head)
    set_attribute(head, attribute, #paragraphs)
    set_attribute(last(head), attribute, -1 * #paragraphs)

    return head
end

--- A "safe" version of the last/slide function.
---
--- Sometimes the node list can form a loop. Since there is no last element
--- of a looped linked-list, the `last()` function will never terminate. This
--- function provides a "safe" version of the `last()` function that will break
--- the loop at the end if the list is circular.
local function safe_last(head)
    local ids = {}
    local prev

    while head.next do
        local id = node.is_node(head) -- Returns the internal node id

        if ids[id] then
            warning [[Circular node list detected!
This should never happen. I'll try and
recover, but your output may be corrupted.
(Internal Error)]]
            prev.next = nil
            debug_print("safe_last", node.type(head.id) .. " " .. node.type(prev.id))

            return prev
        end

        ids[id] = true
        head.prev = prev
        prev = head
        head = head.next
    end

    return head
end

--- Remove the widows and orphans from the page, just after the output routine.
---
```

```

--- This function holds the "meat" of the module. It 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.
function lwc.remove_widows(head)
    local head_save = head -- Save the start of the `head` linked-list

    local penalty = tex.outputpenalty - tex.interlinepenalty
    local widowpenalty = tex.widowpenalty
    local clubpenalty = tex.clubpenalty
    local displaywidowpenalty = tex.displaywidowpenalty
    local brokenpenalty = tex.brokenpenalty

    debug_print("outputpenalty", tex.outputpenalty .. " " .. #paragraphs)

    --[[
        We only need to process pages that have orphans or widows. If `paragraphs`
        is empty, then there is nothing that we can do.

        The list of penalties is from:
        https://tug.org/TUGboat/tb39-3/tb123mitt-widows-code.pdf#subsection.0.2.1
    ]]
    if penalty ~= 0 and
        penalty < 10000 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) and
        #paragraphs >= 1 then
    else
        paragraphs = {}
        return head
    end

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

```



```

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

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

debug_print(
    "selected para",
    pagenum() ..
    "/" ..
    paragraph_index ..
    " (" ..
    best_cost ..
    ")"
)

if best_cost > tex.getcount(max_cost) then
    -- If the best replacement is too bad, we can't do anything
    warning("Widow/Orphan NOT removed on page " .. pagenum())
    paragraphs = {}
    return head_save
end

local target_node = paragraphs[paragraph_index].node

-- Start of final paragraph
debug_print("remove_widows", "moving last line")

head = last(head_save).prev

```

```

local big_penalty_found, last_line, hlist_head
while head do
  if head.id == glue_id then
    -- Ignore any glue nodes
  elseif head.id == penalty_id and head.penalty >= 10000 then
    -- Infinite break penalty
    big_penalty_found = true
  elseif big_penalty_found and head.id == hlist_id then
    -- Line before the penalty
    if lwc.nobreak_behaviour == "keep" then
      hlist_head = head
      big_penalty_found = false
    elseif lwc.nobreak_behaviour == "split" then
      head = last(head_save)
      break
    elseif lwc.nobreak_behaviour == "warn" then
      warning("Widow/Orphan NOT removed on page " .. pagenum())
      paragraphs = {}
      return head_save
    end
  else
    -- Not found
    if hlist_head then
      head = hlist_head
    else
      head = last(head_save)
    end
    break
  end
  head = head.prev
end

last_line = copy(head)
last(last_line).next = copy(tex.lists[contrib_head])

head.prev.prev.next = nil
-- Move the last line to the next page
tex.lists[contrib_head] = last_line

local free_next_nodes = false

-- Loop through all of the nodes on the page with the lwc attribute
head = head_save
while head do

```

```

local value
value, head = find_attribute(head, attribute)

if not head then
    break
end

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

-- Insert the start of the replacement paragraph
if value == paragraph_index then
    debug_print("remove_widows", "replacement start")
    safe_last(target_node) -- Remove any loops

    head.prev.next = target_node
    free_next_nodes = true
end

-- Insert the end of the replacement paragraph
if value == -1 * paragraph_index then
    debug_print("remove_widows", "replacement end")
    safe_last(target_node).next = head.next
    break
end

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

end

info(
"Widow/orphan successfully removed at paragraph "
.. paragraph_index
.. " on page "
.. pagenum()
.. "."
)

paragraphs = {} -- Clear paragraphs array at the end of the page

return head_save
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 enabled = false
function lwc.enable_callbacks()
  debug_print("callbacks", "enabling")
  if not enabled then
    lwc.callbacks.save_paragraphs.enable()
    lwc.callbacks.mark_paragraphs.enable()

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

```

```

function lwc.disable_callbacks()
  debug_print("callbacks", "disabling")
  if enabled then
    lwc.callbacks.save_paragraphs.disable()
    lwc.callbacks.mark_paragraphs.disable()
    --[[
      We do 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.
    ]]

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

function lwc.if_lwc_enabled()
  debug_print("iflwc")
  if enabled then
    tex.sprint("\\iftrue")
  else
    tex.sprint("\\iffalse")
  end
end

--- Silence the luatexbase "Enabling/Removing <callback>" info messages
---
--- Every time that a paragraph is typeset, lua-widow-control 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.
local function silence_luatexbase()
  local nups = debug.getinfo(luatexbase.add_to_callback).nups

```

```

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

-- Activate lua-widow-control
if plain or latex then
  silence_luatexbase()
end

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 v2.0.0} %%version

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

```

```

\input ltluatex % LuaTeXBase

\clubpenalty=1
\widowpenalty=1
\displaywidowpenalty=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
% lua-widow-control's functionality; however, it is required for the
% lengthened paragraphs to not have terrible spacing.
\expandglyphsinfont\the\font 20 20 5
\adjustspacing=2

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

% Enable lua-widow-control 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 lua-widow-control for certain commands.
\catcode`@=11

% We should only reen able lua-widow-control at the end if it was already enabled.
\newif\iflwc@should@reenable

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

```

```

\def\lwc@patch@post{\iflwc@should@reenable%
  \lwcenable%
\fi}

\def\lwcdisablecmd#1{%
  \ifdefined#1
    \expandafter\def\expandafter#1\expandafter{\lwc@patch@pre #1\lwc@patch@post}
  \fi
}
\catcode`\@=12

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

\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 LuaTeXBase, 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{v2.0.0}{2022-03-07} %%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}
{2022/03/07} %%slashdate
{v2.0.0} %%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
\keys_define:nn { \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,

  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 },
  disablecmds .usage:n         = preamble,

  nobreak .choice:,
  nobreak / keep .code:n = \lua_now:n { lwc.nobreak_behaviour = "keep" },
  nobreak / split .code:n = \lua_now:n { lwc.nobreak_behaviour = "split" },
  nobreak / warn .code:n = \lua_now:n { lwc.nobreak_behaviour = "warn" },
}

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

```

```

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

% Core Function Definitions
\cs_new:Npn \__lwc_enable: {
  \lua_now:n { lwc.enable_callbacks() }
}

\cs_new:Npn \__lwc_disable: {
  \lua_now:n { lwc.disable_callbacks() }
}

\prg_set_conditional:Nnn \__lwc_if_enabled: { T, F, TF } {
  \lua_now:n { lwc.if_lwc_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 lua-widow-control for certain commands.
\bool_new:N \g__lwc_should_reenable_bool

\cs_new:Npn \__lwc_patch_cmd:c #1 {
  \IfFormatAtLeastTF {2021/06/01} {
    \hook_gput_code:nnn { cmd / #1 / before } { \c__lwc_name_str } {
      % We should only reenale lua-widow-control at the end if it was already
      enabled.
      \__lwc_if_enabled:TF {
        \bool_gset_true:N \g__lwc_should_reenable_bool
        \__lwc_disable:
      }
    }
  }
}

```

```

    } {
        \bool_gset_false:N \g__lwc_should_reenable_bool
    }
}
\hook_gput_code:nnn { cmd / #1 / after } { \c__lwc_name_str } {
    \bool_if:NT { \g__lwc_should_reenable_bool } {
        \__lwc_enable:
    }
}
} {
    \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 }
}

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

% Define some final keys
\keys_define:nn { \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 = \lua_now:n { lwc.debug = true },
    debug / false .code:n = \lua_now:n { lwc.debug = false },

    strict .meta:n = { emergencystretch = 0pt,
        max-cost      = 2500,
        nobreak       = warn,
    },
}

```

```

strict .value_forbidden:n = true,

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

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

\NewDocumentCommand \lwcsetup {m} { \keys_set:nn{\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 \lwcenable \__lwc_enable:
\cs_new_eq:NN \lwcdisable \__lwc_disable:

\endinput

```

t-lua-widow-control.mkxl/mkiv

```

%D \module
%D   [      file=t-lua-widow-control,
%D       version=2.0.0, %%version
%D       title=lua-widow-control,
%D       subtitle=ConTeXt module for lua-widow-control,
%D       author=Max Chernoff,
%D       date=2022-03-07, %%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
\appendtoks
    \lwc_emergency_stretch=\lwcparameter{emergencystretch}
\to\everysetuplwc

\appendtoks
    \doifelse{\lwcparameter{c!state}}{\v!start{
        \ctxlua{lwc.enable_callbacks()}
    }}{
        \ctxlua{lwc.disable_callbacks()}
    }
\to\everysetuplwc

\appendtoks
    \doifelse{\lwcparameter{debug}}{\v!start{
        \ctxlua{lwc.debug = true}
    }}{
        \ctxlua{lwc.debug = false}
    }
\to\everysetuplwc

\appendtoks
    \ctxlua{lwc.nobreak_behaviour = "\lwcparameter{nobreak}}"}
\to\everysetuplwc

\newcount\lwc_max_cost
\appendtoks
    \lwc_max_cost=\lwcparameter{maxcost}
\to\everysetuplwc

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

```

```

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

\setups[*default]
\to\everysetuplwc

\define\iflwc{\ctxlua{lwc.if_lwc_enabled()}}

\ctxloadluafile{lua-widow-control}

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

% Here, we enable font expansion/contraction. It isn't strictly necessary for
% lua-widow-control'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 lua-widow-control for certain commands.
% We should only reenable lua-widow-control at the end if it was already enabled.
\newif\iflwc_should_reenable

\define\lwc_patch_pre{%
  \iflwc%
    \lwc_should_reenabletrue%
    \setuplwc[state=stop]%
  \else%
    \lwc_should_reenablefalse
  \fi%
}

\define\lwc_patch_post{\iflwc_should_reenable%

```

```

\setuplwc[state=start]%
\fi}

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

\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 <v2.0.0>} %%version

\_clubpenalty=1
\_widowpenalty=1
\_displaywidowpenalty=1

\_newdimen\lwcemergencystretch
\lwcemergencystretch=3em

\_newcount\lwcmaxcost
\lwcmaxcost=2147483647

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

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

% Enable lua-widow-control by default when the package is loaded.
\lwcenable

\_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`