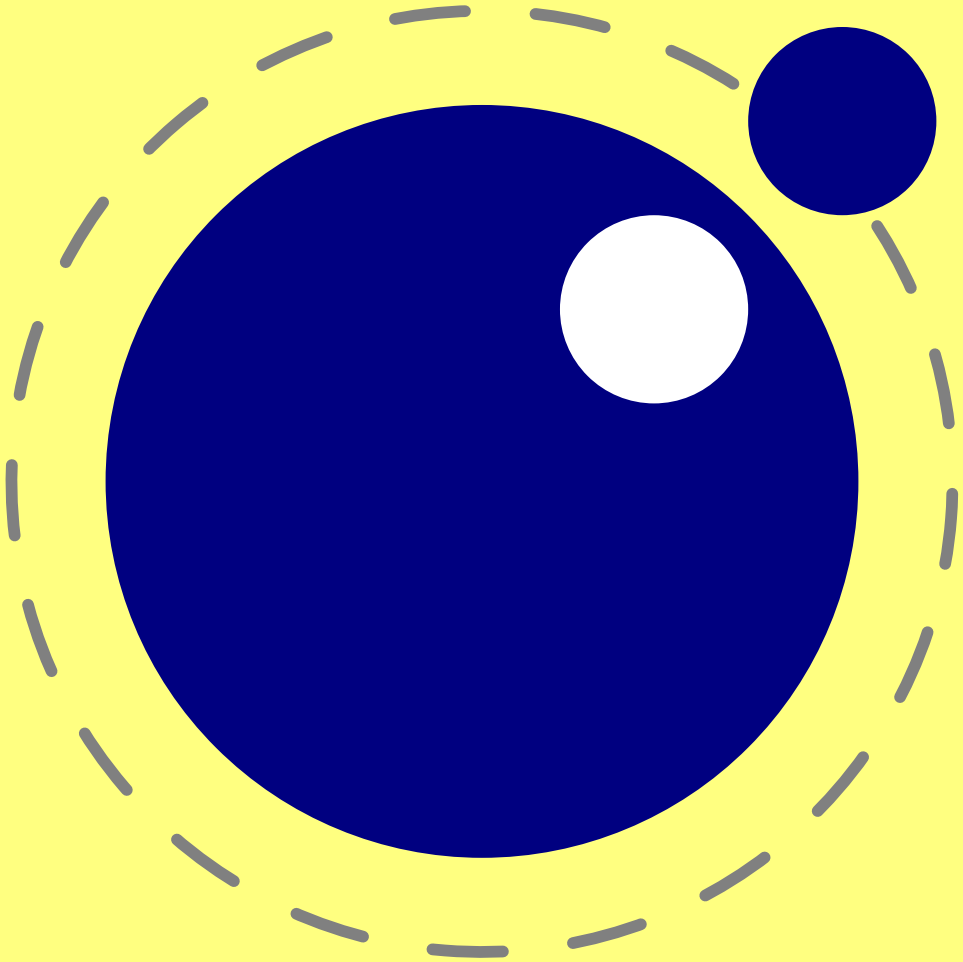
LuaTEX Reference

beta 0.20.0



LuaTEX Reference Manual

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more info: www.luatex.org
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Contents

1 Introduction

This book will eventually become the reference manual of LuaTEX. At the moment, it simply reports the behaviour of the executable matching the snapshot or beta release date in the title page.

Features may come and go. The current version of LuaTEX is not meant for production and users cannot depend on stability, nor on functionality staying the same.

Nothing is considered stable just yet. This manual therefore simply reflects the current state of the executable. ***Absolutely nothing*** on the following pages is set in stone. When the need arises, anything can (and will) be changed without prior notice.

If you are not willing to deal with this situation, you should wait for the stable version. Currently we expect the first release to be available sometime in the summer of 2008.

LuaTEX consists of a number of interrelated but (still) distinguishable parts:

- pdfTEX version 1.40.3
- Aleph RC4 (from the TEXLive repository)
- Lua 5.1.2 (+ coco)
- Dedicated Lua libraries
- Various TEX extensions
- Parts of FontForge 2007.06.07
- Newly written compiled source code to glue it all together

Neither Aleph's I/O translation processes, nor tcx files, nor encTEX can be used, these encoding-related functions are superseded by a Lua-based solution (reader callbacks). Also, some experimental pdfTEX features are removed. These can be implemented in Lua instead.

2 Basic TEX enhancements

2.1 Version information

There are three new primitives to test the version of LuaTEX:

primitive	explanation
\luatexversion	A combination of major an minor number, as in pdfTeX. Current value: **20**
\luatexrevision	The revision, as in pdfTeX. Current value: **1**
\luatexdatestamp	A combination of the local date and hour when the current executable was compiled, the syntax is identical to \luatexrevision. Value for the executable that generated this document: **2007121310**.

Note that the \luatexdatestamp depends on both the compilation time and compilation place of the current executable, it is defined in terms of the local time. The purpose of this primitive is solely to be an aid in the development process, do not use it for anything besides debugging.

2.2 UNICODE text support

Text input and output is now considered to be Unicode text, so input characters can use the full range of Unicode ($2^{20} + 2^{16} = 10FFFF = 1114111$).

Later chapters will talk of characters and glyphs. Although these are not the interchangeable, they are closely related. During typesetting, a character is always converted to a suitable graphic representation of that character in a specific font. However, while processing a list of to-be-typeset nodes, its contents may still be seen as a character. Inside LuaTEX there is not yet a clear separation between the two concepts yet. Until this is implemented, please do not be too harsh on us if we make errors in the usage of the terms.

Note: for now, it only makes sense to use values above the base plane ("0xFFFF) for \mathcode and \catcode assignments, since the hyphenation patterns are still limited to at the most 16-bit values, so the other commands will not know what to do with those high values.

A few primitives affected by this, all in a similar fashion: each of them has to accomodate for a larger range of acceptable numbers. For instance, \char now accepts values between 0 and 1114111. This should not be a problem for well-behaved input files, but it could create incompatibilities for input that would have generated an error when processed by older TEX-based engines. The maximum number of allocations is "10FFFF or $2^{20} + 2^{16}$ (21 bits). The maximum value that can be assigned are:

primitive	bits	hex	numeric
\char	21	10FFFF	$2^{20} + 2^{16}$
\chardef	21	10FFFF	$2^{20} + 2^{16}$
\lccode	21	10FFFF	$2^{20} + 2^{16}$
\uccode	21	10FFFF	$2^{20} + 2^{16}$

\sfcode	15	7FFF	2^{15}
\catcode	4	F	2^4

As far as the core engine is concerned, all input and output to text files is utf-8 encoded. Input files can be pre-processed using the reader callback. This will be explained in a later chapter.

Output in byte-sized chunks can be achieved by using characters just outside of the valid unicode range, starting at the value 1.114.112 (0x110000). When the times comes to print a character $c >= 1.114.112$, LuaTEX will actually print the single byte corresponding to $c - 1.114.112$.

Output to the terminal uses ^^ notation for the lower control range ($c < 32$), with the exception of ^^I, ^^J and ^^M. These are considered 'safe' and therefore printed as-is.

Normalization of the Unicode input can be handled by a macro package during callback processing (this will be explained in section 4.6.2).

2.3 Wide math characters

Text handling is now extended up to the full Unicode range, but math mode deals mostly with glyphs in fonts directly and fonts tend to be 16-bit at maximum. The extension from 8-bit to 16-bit was already present in Aleph by means of a set of extra primitives.

Therefore, the math primitives from TEX and Aleph are kept mostly as they are, except for the ones that convert from input to math commands like matcode and omathcode. The traditional TEX primitives are unchanged, their arguments are upscaled from 8 to 16 bits internally (as in Aleph).

primitive	max index/bits	hex			numeric
\mathchardef	15	8000			$2^3 * 2^4 * 2^8$
\mathcode	8=15	FF	=	800	$2^3 * 2^4 * 2^8$
\delcode	8=24	FF	=	FFFFF	$2^4 * 2^8 * 2^4 * 2^8$
\mathchar	15	7FFF			$2^3 * 2^4 * 2^8$
\delimiter	27	7FFFFFF			$2^3 * 2^4 * 2^8 * 2^4 * 2^8$
\omathchar	27	7FFFFFF			$2^3 * 2^8 * 2^{18}$
\odelimiter	27+24	7FFFFFF	+	FFFFFF	$2^3 * 2^8 * 2^{16} + 2^8 * 2^{16}$
\omathchardef	27	8000000			$2^3 * 2^8 * 2^{16}$
\omathcode	21=27	10FFFF	=	8000000	$2^3 * 2^8 * 2^{16}$
\odelcode	21=24+24	10FFFF	=	FFFFFF	$2^8 * 2^{16}$
			+	FFFFFF	$+2^8 * 2^{16}$

2.4 Extended tables

All traditional TEX and ε-TEX registers can be 16 bit numbers as in Aleph. The affected commands are:

\count	\marks	\skipdef	\unhbox
\dimen	\toks	\muskipdef	\unvbox
\skip	\countdef	\toksdef	\copy
\muskip	\dimendef	\box	\unhcopy

\unvcopy	\dp
\wd	\setbox
\ht	\vsplit

The same is true for the font-related pdfTEX tables like \rpcode etc.

2.5 Attribute registers

Attributes are a completely new concept in LuaTEX. Syntactically, they behave a lot like counters: attributes obey TEX's nesting stack and can be used after \the etc. just like the normal \count registers.

\attribute ⟨16-bit number⟩ ⟨optional equals⟩ ⟨31-bit number⟩
\attributedef ⟨csname⟩ ⟨optional equals⟩ ⟨16-bit number⟩

Conceptually, an attribute is either 'set' or 'unset'. Set attributes can only have values of 0 or more, otherwise they are considered unset and automatically remapped to an special negative value meaning 'unset' (currently that value is −1, but please test on negativity, not on a specific value). All attributes start out in the 'unset' state (in iniTEX).

Attributes can be used as extra counter values, but their usefulness comes mostly from the fact that the numbers and values of all 'set' attributes are attached to all nodes created in their scope. These can then be queried from any Lua code that deals with node processing. Future versions of LuaTEX will propably be using specific negative attribute ids for internal use. Further information about how to use attributes for node list processing from lua is given in chapter 7.

2.5.1 Box attributes

Nodes typically receive the list of attributes that is in effect when they are created. This moment can be quite asynchronous. For example: in paragraph building, the individual line boxes are created after the \par command has been processed, so they will receive the list of attributes that is in effect then, not the attributes that were in effect in, say, the first or third line of the paragraph.

Similar situations happen in LuaTEX regularly. A few of the more obvious problematic cases are dealt with: the attributes for nodes that are created during hyphenation and ligaturing borrow their attributes from their surrounding glyphs, and it is possible to influence box attributes directly.

But many other inserted nodes, like the nodes resulting from math mode and alignments, are processed 'out of order', and will have the attributes that are in effect at the precise moment of creation (which is often later than expected). This area needs studying, and is in fact one of the reasons for a beta at this moment.

It is possible to fine-tune the list of attributes that are applied to a hbox, vbox or vtop by the use of the keyword attr. An example:

```
\attribute2=5
\setbox0=\hbox {Hello}
\setbox2=\hbox attr1=12 attr2=-1{Hello}
```


This will set the attribute list of the box 2 to $1 = 12$, and the attributes of box 0 will be $2 = 5$. As you can see, assigning a negative value causes an attribute to be ignored.

The `attr` keyword(s) should come before a `to` or `spread`, if that is also specified.

2.6 LUA related primitives

In order to merge Lua code with TEX input, a few new primitives are needed. LuaTEX has support for 65536 separate Lua interpreter states. States are automatically created based on the integer argument to the primitives `\directlua` and `\latelua`.

2.6.1 `\directlua`

The primitive `\directlua` is used to execute Lua code immediately. The syntax is

`\directlua` ⟨16-bit number⟩ ⟨general text⟩

The ⟨general text⟩ is expanded fully, and then fed into the Lua interpreter state indicated by the ⟨16-bit number⟩. If the state does not exist yet, it will be initialized automatically. After reading and expansion has been applied to the ⟨general text⟩, the resulting token list is converted to a string as if it was displayed using `\the\toks`. On the Lua side, each `\directlua` block is treated as a separate chunk.

The conversion from and to a token list means that you normally can not use Lua line comments (starting with `--`) within the argument, as there typically will be only one 'line', so that comment will then run on until the end of the input. You will either need to use TEX-style line comments (starting with %), or change the TEX category codes locally.

The `\directlua` command is expandable: the results of the Lua code become effective immediately. As an example, the following input:

```
$\pi = \directlua0{tex.print(math.pi)}$
```

will result in $\pi = 3.1415926535898$

Because the ⟨general text⟩ is a chunk, the normal Lua error handling is triggered if there is a problem in the included code. The Lua error messages should be clear enough, but the contextual information is still pretty bad. Typically, you will only see the line number of the right brace at the end of the code.

While on the subject of errors: some of the things you can do inside Lua code can break up LuaTEX pretty bad. If you are not careful while working with the node list interface, you may even end up with assertion errors from within the TEX portion of the executable.

2.6.2 `\latelua`

`\latelua` stores Lua code in a whatsit that will be processed inside the output routine. It's intended use is very similar to `\pdfliteral`. Within the Lua code, you can print pdf statements directly to the pdf file.

\latelua ⟨16-bit number⟩ ⟨general text⟩

2.6.3 \luaescapestring

This primitive converts a TEX token sequence so that it can be safely used as the contents of a Lua string: embedded backslashes, double and single quotes, and newlines and carriage returns are escaped. This is done by prepending an extra token consisting of a backslash with category code 12, and for the line endings, converting them to `n` and `r` respectivelu. The token sequence is fully expanded.

\luaescapestring ⟨general text⟩

Most often, this command is not actually the best way to deal with the differences between the TEX and Lua. In very short bits of Lua code it is often not needed, and for longer stretches of Lua code it is easier to keep the code in a separate file and load it using Lua's `dofile`:

```
\directlua0 { dofile('mysetups.lua')}
```

2.6.4 \closelua

This primitive allows you to close a Lua state, freeing all of its used memory.

\closelua ⟨16-bit number⟩

You cannot close the initial Lua state (0), attempts to do so will be silently ignored.

States are never closed automatically except when a fatal out of memory error occurs, at which point LuaTEX will exit anyway.

Also be aware that Lua states are not closed immediately, but only when the \output routine comes into play next (because there may be pending \latelua calls).

2.7 New ε-TEX primitives

2.7.1 \clearmarks

This primitive clears a marks class completely, resetting all three connected mark texts to empty.

\clearmarks ⟨16-bit number⟩

2.7.2 \noligs and \nokerns

These primitives prohibit ligature and kerning insertion at the time when the initial node list is built by LuaTEX's main control loop. They are part of a temporary trick and will be removed in the near future. For now, you need to enable these primitives when you want to do node list processing of 'characters', where TEX's normal processing would get in the way.

\noligs ⟨integer⟩
\nokerns ⟨integer⟩

2.7.3 \formatname

\formatname's syntax is identical to \jobname.

In iniTEX, the expansion is empty. Otherwise, the expansion is the value that \jobname had during the iniTEX run that dumped the currently loaded format.

2.7.4 \scantextokens

The syntax of \scantextokens is identical to \scantokens.

This is a slightly adapted version of ε-TEX's \scantokens. The differences are:

- The last (and usually only) line does not have a \endlinechar appended
- \scantextokens never raises an EOF error, and it does not execute \everyeof tokens.
- The '.. while end of file ..' error tests are not executed, allowing the expansion to end on a different grouping level or while a conditional is still incomplete.

2.7.5 Catcode tables

Catcode tables are a new feature that allows you to switch to a predefined catcode regime in a single statement. You can have a practically unlimited number of different tables.

The subsystem is backward compatible: if you never use the following commands, your document will not notice any difference in behavior compared to traditional TEX.

The contents of each catcode table is independent of any other catcode tables, and their contents is stored and retrieved from the format file.

2.7.5.1 \catcodetable

\catcodetable ⟨28-bit number⟩

The \catcodetable switches to a different catcode table. Such a table has to be previously created using one of the two primitives below, or it has to be zero (table zero is initialized by iniTEX).

2.7.5.2 \initcatcodetable

\initcatcodetable ⟨28-bit number⟩

The \initcatcodetable creates a new table with catcodes identical to those defined by iniTEX:

```
0  \                    escape
5  ^^M          return  car_ret
```

9	^^@	null	ignore
10	<space>	space	spacer
11	a – z		letter
11	A – Z		letter
12	everything else		other
14	%		comment
15	^^?	delete	invalid_char

The new catcode table is allocated globally: it will not go away after the current group has ended. If the supplied number is identical to the currently active table, an error is raised.

2.7.5.3 \savecatcodetable

\savecatcodetable ⟨28-bit number⟩

\savecatcodetable copies the current set of catcodes to a new table with the requested number. The definitions in this new table are all treated as if they were made in the outermost level.

The new table is allocated globally: it will not go away after the current group has ended. If the supplied number is the currently active table, an error is raised.

2.7.6 \suppressfontnotfounderror

\suppressfontnotfounderror = 1

If this new integer parameter is non-zero, then LuaTEX will not complain about font metrics that are not found. Instead it will silently skip the font assignment, making the requested csname for the font \ifx equal to \nullfont, so that it can be tested against that without bothering the user.

2.7.7 Font syntax

LuaTEX will accept a braced argument as a font name:

```
\font\myfont = {cmr10}
```

This allows for embedded spaces, without the need for double quotes. Macro expansion takes place inside the argument.

2.8 Debugging

If \tracingonline is larger than 2, the node list displau will also print the node number of the nodes.

3 LUA general

3.1 Initialization

3.1.1 LUATEX as a LUA interpreter

There are some situations that make LuaTEX behave like it is a Lua interpreter only:

- If a `--luaonly` option is given on the commandline
- If the executable is named `texlua` (or `luatexlua`)
- if the only non-option argument (file) on the commandline has the extension `lua` or `luc`.

In this mode, it will set Lua's `arg[0]` to the found script name, pushing preceding options in negative values and the rest of the commandline in the positive values, just like the Lua interpreter.

LuaTEX will exit immediately after executing the specified Lua script and is, in effect, a somewhat bulky standalone Lua interpreter with a bunch of extra preloaded libraries.

3.1.2 LUATEX as a LUA byte compiler

There are two situations that make LuaTEX behaves like the Lua byte compiler:

- If a `--luaconly` option is given on the commandline
- If the executable is named `texluac`

In this mode, LuaTEX is exactly like `luac` from the standalone Lua distribution, except that it does not have the `-l` switch, and that it accepts (but ignores) the `--luaconly` switch.

3.1.3 Other commandline processing

When the LuaTEX executable starts, it looks for the `--lua` commandline option. If there is no `--lua` option, the commandline is interpreted in a similar fashion as in traditional pdfTEX and Aleph. But if the option is present, LuaTEX will enter an alternative mode of commandline parsing in comparison to the standard web2c programs.

In this mode, a small series of actions is taken in order. At first, it will only interpret a small subset of the commandline directly:

–lua=s	load and execute a Lua initialization script
–safer	disable easily exploitable Lua commands
–help	display help and exit
–version	display version and exit

Now it searches for the requested Lua initialization script. If it can not be found using the actual name given on the commandline, a second attempt is made by prepending the value of the environment variable `LUATEXDIR`, if that variable is defined.

Then it checks the `--safer` switch. You can use that to disable some Lua commands that can easily be abused by a malicious document. At the moment, this switch `nil`s the following functions:

library	functions
os	execute exec setenv rename remove tmpdir
io	popen output tmpfile
lfs	rmdir mkdir chdir lock touch

And it makes `io.open()` fail on files that are opened for anything besides reading.

Next the initialization script is loaded and executed. From within the script, the entire commandline in available in the Lua table `arg`, beginning with `arg[0]`, containing the name of the executable.

Commandline processing happens very early on. So early, in fact, that none of TEX's initializations have taken place yet. For that reason, the `tex`, `token`, `node` and `pdf` tables are off-limits during the execution of the startup file (they are nilled). Special care is taken that `texio.write` and `texio.write_nl` function properly, so that you can at least report your actions to the log file when (and if) it eventually becomes opened (note that TEX does not even know its `\jobname` yet at this point). See chapter 4 for more information about the LuaTEX-specific Lua extension tables.

The Lua initialization script is loaded into Lua state 0, and everything you do will remain visible during the rest of the run, with the exception of the aforementioned `tex`, `token`, `node` and `pdf` tables: those will be initialized to their documented state after the execution of the script. You should not store anything in variables or within tables with these four global names, as they will be overwritten completely.

We recommend you use the startup file only for your own TEX-independant initializations (if you need any), to parse the commandline, set values in the `texconfig` table, and register the callbacks you need. LuaTEX will fetch some of the other commandline options from the `texconfig` table at the end of script execution (see the description of the `texconfig` table later on in this document for more details on which ones exactly).

Unless the `texconfig` table tells it not to start kpathsea at all (set `texconfig.kpse_init` to `false` for that), LuaTEX acts on three more commandline options after the initialization script is finished:

flag	meaning
`--fmt=s`	set the format name
`--progname=s`	set the progname (only for kpathsea)
`--ini`	enable iniTEX mode

In order to initialize the built-in kpathsea library properly, LuaTEX needs to know the correct 'progname' to use, and for that it needs to check `-progname` (and `-ini` and `-fmt`, if `-progname` is missing).

3.2 LUA changes

The C coroutine (COCO) patches from luajit are applied to the Lua core, the used version is 1.1.3. See http://luajit.org/coco.html for details.

The `read("*line")` function from the io library has been adjusted so that it is line-ending neutral: any of `LF`, `CR` or `CR+LF` are acceptable line endings.

The `tostring()` printer for numbers has been changed so that it return `0` instead of something like `2e-5` (which confused TEX enormously) when the value is so small that TEX cannot distinguish it from zero.

Dynamic loading of `.so` and `.dll` files is disabled on all platforms.

`luafilesystem` has been extended with two extra boolean functions (`isdir(filename)` and `isfile(filename)`) and one extra string field in its attributes table (`permissions`).

The `string` library has an extra function: `string.explode(s[,m])`. This function returns an array containing the string argument `s` split into substrings based on the value of the string argument `m`. The second argument is a string that is either empty (this splits the string into characters), a single character (this splits on each occurrence of that character, possibly introducing empty strings), or a single character followed by the plus sign `+` (this special version does not create empty substrings). The default value for `m` is ' +' (multiple spaces).

Note: `m` is not hidden by surrounding braces (as it would be if this function was written in TEX macros).

The `string` library also has six extra iterators that return strings piecemeal:

- `string.utfvalues(s)` (returns an integer value in the Unicode range)
- `string.utfcharacters(s)` (returns a string with a single utf-8 token in it)
- `string.characters(s)` (a string containing one byte)
- `string.characterpairs(s)` (two strings each containing one byte) will produce an empty second string in the string length was odd.
- `string.bytes(s)` (a single byte value)
- `string.bytepairs(s)` (two byte values) Will produce nil instead of a number as its second return value if the string length was odd.

The `string.characterpairs()` and `string.bytepairs()` are useful especially in the conversion of UTF-16 encoded data into UTF-8.

Note: The `string` library functions `find` etc. are not Unicode-aware. In cases where this is required (i.e. because the pattern used for searching contains characters above code point 127), the corresponding functions from `unicode.utf8` should be used.

The `os` library has a few extra functions and variables:

- `os.exec('command')` is a non-returning version of `os.execute`. The advantage of this command is that it cleans out the current process before starting the new one, making it especially useful for use in TEXLua.
- `os.setenv('key','value')` This sets a variable in the environment. Passing `nil` instead of a value string will remove the variable.
- `os.env` This is a hash table containing a dump of the variables and values in the process environment at the start of the run. It is writeable, but the actual environment is *not* updated automatically.
- `os.gettimeofday()` Returns the current 'unix time', but as a float. This function is not available on the SunOS platforms, so do not use this function for portable documents.

- `os.times()` Returns the current process times cf. the unix C library 'times' call in seconds. This function is not available on the Windows and SunOS platforms, so do not use this function for portable documents.
- `os.tmpdir()` This will create a directory in the 'current directory' with the name `luatex.XXXXXX` where the X-es are replaced by a unique string. The function also returns this string, so you can `lfs.chdir()` into it, or `nil` if it failed to create the directory. The user is responsible for cleaning up at the end of the run, it does not happen automatically.

In stock Lua, many things depend on the current locale. In LuaTEX, we can't do that, because it makes documents unportable. While LuaTEX is running if forces the following locale settings:

```
LC_CTYPE=C
LC_COLLATE=C
LC_NUMERIC=C
```

3.3 LUA Modules

Some modules that are normally external to Lua are statically linked in with LuaTEX, because they offer useful functionality:

- `slnunicode`, from the Selene libraries, http://luaforge.net/projects/sln. (version 1.1)
- `luazip`, from the kepler project, http://www.keplerproject.org/luazip/. (version 1.2.1, but patched for compilation with lua 5.1)
- `luafilesystem`, also from the kepler project, http://www.keplerproject.org/luafilesystem/. (version 1.2, but patched for compilation with lua 5.1)
- `lpeg`, by Roberto Ierusalimschy, http://www.inf.puc-rio.br/~roberto/lpeg.html. (version 0.7)
  Note: `lpeg` is not Unicode-aware, but interprets strings on a byte-per-byte basis. This mainly means that `lpeg.S` cannot be used with characters above code point 127, since those characters are encoded using two bytes, and thus `lpeg.S` will look for one of those two bytes when matching, not the combination of the two.
  The same is true for `lpeg.R`, although the latter will display an error message if used with characters above code point 127: I.e. `lpeg.R('aä')` results in the message `bad argument #1 to'R' (range must have two characters)`, since to `lpeg`, `ä` is two 'characters' (bytes), so `aä` totals three.
- `lzlib`, by Tiago Dionizio, http://mega.ist.utl.pt/~tngd/lua/. (version 0.2)
- `md5`, by Roberto Ierusalimschy http://www.inf.puc-rio.br/~roberto/md5/md5-5/md5.html.

4 LUATEX LUA Libraries

The interfacing between TEX and Lua is facilitated by a set of library modules. The Lua libraries in this chapter are all defined and initialized by the LuaTEX executable. Together, they allow Lua scripts to query and change a number of TEX's internal variables, run various internal functions TEX, and set up LuaTEX's hooks to execute Lua code.

4.1 The tex library

The tex table contains a large list of virtual internal TEX parameters that are partially writable.

The designation 'virtual' means that these items are not properly defined in Lua, but are only frontends that are handled by a metatable that operates on the actual TEX values. As a result, most of the Lua table operators (like pairs and #) do not work on such items.

At the moment, it is possible to access almost every parameter that has these characteristics:

- You can use it after \the
- It is a single token.

This excludes parameters that need extra arguments, like \the\scriptfont.

The subset comprising simple integer and dimension registers are writable as well as readable (stuff like \tracingcommands and \parindent).

4.1.1 Integer parameters

The integer parameters accept and return Lua numbers.

Read-write:

tex.adjdemerits
tex.binoppenalty
tex.brokenpenalty
tex.catcodetable
tex.clubpenalty
tex.day
tex.defaulthyphenchar
tex.defaultskewchar
tex.delimiterfactor
tex.displaywidowpenalty
tex.doublehyphendemerits
tex.endlinechar
tex.errorcontextlines
tex.escapechar
tex.exhyphenpenalty
tex.fam
tex.finalhyphendemerits
tex.floatingpenalty
tex.globaldefs
tex.hangafter
tex.hbadness
tex.holdinginserts
tex.hyphenpenalty
tex.interlinepenalty
tex.language
tex.lastlinefit
tex.lefthyphenmin
tex.linepenalty
tex.localbrokenpenalty
tex.localinterlinepenalty

tex.looseness
tex.mag
tex.maxdeadcycles
tex.month
tex.newlinechar
tex.outputpenalty
tex.pausing
tex.pdfadjustinterwordglue
tex.pdfadjustspacing
tex.pdfappendkern
tex.pdfcompresslevel
tex.pdfdecimaldigits
tex.pdfgamma
tex.pdfgentounicode
tex.pdfimageapplygamma
tex.pdfimagegamma
tex.pdfimagehicolor
tex.pdfimageresolution
tex.pdfinclusionerrorlevel
tex.pdfminorversion
tex.pdfobjcompresslevel
tex.pdfoutput
tex.pdfpagebox
tex.pdfpkresolution
tex.pdfprependkern
tex.pdfprotrudechars
tex.pdftracingfonts
tex.pdfuniqueresname
tex.postdisplaypenalty
tex.predisplaydirection
tex.predisplaypenalty
tex.pretolerance
tex.relpenalty
tex.righthyphenmin
tex.savinghyphcodes
tex.savingvdiscards
tex.showboxbreadth
tex.showboxdepth
tex.time
tex.tolerance
tex.tracingassigns
tex.tracingcommands
tex.tracinggroups
tex.tracingifs
tex.tracinglostchars
tex.tracingmacros
tex.tracingnesting
tex.tracingonline
tex.tracingoutput
tex.tracingpages
tex.tracingparagraphs
tex.tracingrestores
tex.tracingscantokens
tex.tracingstats
tex.uchyph
tex.vbadness
tex.widowpenalty
tex.year

Read-only:

tex.deadcycles
tex.insertpenalties
tex.parshape
tex.prevgraf
tex.spacefactor

4.1.2 Dimension parameters

The dimension parameters accept Lua numbers (signifying scaled points) or strings (with included dimension). The result is always a string.

Read-write:

tex.boxmaxdepth
tex.delimitershortfall
tex.displayindent
tex.displaywidth
tex.emergencystretch
tex.hangindent
tex.hfuzz
tex.hoffset
tex.hsize
tex.lineskiplimit
tex.mathsurround
tex.maxdepth
tex.nulldelimiterspace
tex.overfullrule
tex.pagebottomoffset
tex.pageheight
tex.pagerightoffset
tex.pagewidth
tex.parindent
tex.pdfdestmargin
tex.pdfeachlinedepth
tex.pdfeachlineheight
tex.pdffirstlineheight
tex.pdfhorigin
tex.pdflastlinedepth
tex.pdflinkmargin
tex.pdfpageheight
tex.pdfpagewidth
tex.pdfpxdimen
tex.pdfthreadmargin
tex.pdfvorigin
tex.predisplaysize
tex.scriptspace
tex.splitmaxdepth
tex.vfuzz
tex.voffset
tex.vsize

Read-only:

tex.pagedepth
tex.pagefilllstretch
tex.pagefillstretch
tex.pagefilstretch
tex.pagegoal
tex.pageshrink
tex.pagestretch
tex.pagetotal
tex.prevdepth

4.1.3 Direction parameters

The direction parameters are read-only and return a Lua string

tex.bodydir
tex.mathdir
tex.pagedir
tex.pardir
tex.textdir

4.1.4 Glue parameters

All glue parameters are read-only and return a Lua string

tex.abovedisplayshortskip
tex.abovedisplayskip
tex.baselineskip
tex.belowdisplayshortskip
tex.belowdisplayskip
tex.leftskip
tex.lineskip
tex.parfillskip
tex.parskip
tex.rightskip
tex.spaceskip
tex.splittopskip

tex.tabskip
tex.topskip
tex.xspaceskip

4.1.5 Muglue parameters

All muglue parameters are read-only and return a Lua string

tex.medmuskip
tex.thickmuskip
tex.thinmuskip

4.1.6 Tokenlist parameters

All tokenlist parameters are read-only and return a Lua string

tex.errhelp
tex.everycr
tex.everydisplay
tex.everyeof
tex.everyhbox
tex.everyjob
tex.everymath
tex.everypar
tex.everyvbox
tex.output
tex.pdfpageattr
tex.pdfpageresources
tex.pdfpagesattr
tex.pdfpkmode

4.1.7 Convert commands

The supported commands at this moment are:

tex.AlephVersion
tex.Alephrevision
tex.OmegaVersion
tex.Omegarevision
tex.eTeXVersion
tex.eTeXrevision
tex.formatname
tex.jobname
tex.luatexrevision
tex.luatexdatestamp
tex.pdfnormaldeviate
tex.pdftexbanner
tex.pdftexrevision

All 'convert' commands are read-only and return a Lua string

If you are wondering why this list looks haphazard; these are all the cases of the 'convert' internal command that do not require an argument.

4.1.8 attribute, count, dimension and token registers

TEX's attributes (\attribute), counters (\count), dimensions (\dimen) and token (\toks) registers can be accessed and written to using four virtual sub-tables of the tex table:

tex.attribute
tex.count
tex.dimen
tex.toks

It is possible to use the names of relevant \attributedef, \countdef, \dimendef, or \toksdef control sequences as indices to these tables:

```
tex.count.scratchcounter = 0
enormous = tex.dimen['maxdimen']
```

In this case, LuaTEX looks up the value for you on the fly. You have to use a valid `\countdef` (or `\attributedef`, or `\dimendef`, or `\toksdef`), anything else will generate an error (the intent is to eventually also allow `<chardef tokens>` and even macros that expand into a number)

The attribute and count registers accept and return Lua numbers.

The dimension registers accept Lua numbers (in scaled points) or strings (with an included absolute dimension; `em` and `ex` and `px` are forbidden). The result is always a number in scaled points.

The token registers accept and return Lua strings. Lua strings are converted to and from token lists using `\the\toks` style expansion: all category codes are either space (10) or other (12).

As an alternative to array addressing, there are also accessor functions defined:

```
tex.setdimen(number n, string s)
tex.setdimen(string s, string s)
tex.setdimen(number n, number n)
tex.setdimen(string s, number n)
number n = tex.getdimen(number n)
number n = tex.getdimen(string s)

tex.setcount(number n, number n)
tex.setcount(string s, number n)
number n = tex.getcount(number n)
number n = tex.getcount(string s)

tex.settoks (number n, string s)
tex.settoks (string s, string s)
string s = tex.gettoks (number n)
string s = tex.gettoks (string s)
```

4.1.9 Box registers

The current dimensions of `\box` registers can be read and altered using three other virtual sub-tables :

```
tex.wd
tex.ht
tex.dp
```

These are indexed strictly by number.

The box size registers accept Lua numbers (in scaled points) or strings (with included dimension). The result is always a number in scaled points.

As an alternative to array addressing, there are also accessor functions defined:

```
tex.setboxwd(number n, number n)
number n = tex.getboxwd(number n)
```


```
tex.setboxht(number n, number n)
number n = tex.getboxht(number n)

tex.setboxdp(number n, number n)
number n = tex.getboxdp(number n)
```

It is also possible to set and query actual boxes, using the node interface as defined in the `node` library:

```
tex.box
```

for array access, or

```
tex.setbox(number n, <node> s)
<node> n = tex.getbox(number n)
```

for function-based access

Be warned that an assignment like

```
tex.box[0] = tex.box[2]
```

does not copy the node list, it just duplicates a node pointer. If `\box2` will be cleared by TEX commands later on, the contents of `\box0` becomes invalid as well. To prevent this from happening, always use `node.copy_list()` unless you are assigning to a temporary variable:

```
tex.box[0] = node.copy_list(tex.box[2])
```

4.1.10 Print functions

The `tex` table also contains the three print functions that are the major interface from Lua scripting to TEX.

The arguments to these three functions are all stored in an in-memory virtual file that is fed to the TEX scanner as the result of the expansion of `\directlua`.

The total amount of returnable text from a `\directlua` command is only limited by available system ram. However, each separate printed string has to fit completely in TEX's input buffer.

4.1.10.1 `tex.print`

```
tex.print(string s, ...)
tex.print(number n, string s, ...)
```

Each string argument is treated by TEX as a separate input line.

The optional parameter can be used to print the strings using the catcode regime defined by `\catcodetable n`. If `n` is not a valid catcode table, then it is ignored, and the currently active catcode regime is used instead.

The very last string of the very last `tex.print()` command in a `\directlua` will not have the `\endlinechar` appended, all others do.

4.1.10.2 tex.sprint

```
tex.sprint(string s, ...)
tex.sprint(number n, string s, ...)
```

Each string argument is treated by TEX as a special kind of input line that makes it suitable for use as a partial line input mechanism:

- TEX does not switch to the 'new line' state, so that leading spaces are not ignored.
- No `\endlinechar` is inserted.
- Trailing spaces are not removed. (Note that this does not prevent TEX itself from eating spaces as result of interpreting the line. For example, in

  ```
  before\directlua0{tex.sprint("\\relax")tex.sprint(" inbetween")}after
  ```

  the space before `inbetween` will be gobbled as a result of the 'normal' scanning of `\relax`).

4.1.10.3 tex.write

```
tex.write(string s, ...)
```

Each string argument is treated by TEX as a special kind of input line that makes is suitable for use as a quick way to dump information:

- All catcodes on that line are either 'space' (for ' ') or 'character' (for all others).
- There is no `\endlinechar` appended.

4.1.11 Helper functions

4.1.11.1 tex.round

```
number n =  tex.round(number o)
```

Rounds lua number `o`, and returns a number that is in the range of a valid TEX register value. If the number starts out of range, it generates a 'Number to big' error as well.

4.1.11.2 tex.scale

```
number n =  tex.scale(number o, number delta)
table n  =  tex.scale(table o, number delta)
```


Multiplies the lua numbers `o` and `delta`, and returns a rounded number that is in the range of a valid TEX register value. In the table version, it creates a copy of the table with all numeric top–level values scaled in that manner. If the mutiplied number(s) are of range, it generates 'Number to big' error(s) as well.

4.2 The `token` library

The `token` table contains interface functions to TEX's handling of tokens. These functions are most useful when combined with the `token_filter` callback, but they could be used standalone as well.

A token is represented in Lua as a small table. For the moment, this table consists of three numeric entries:

nr	meaning	description
1	command code	this is a value between 0 and 130 (approximately)
2	command modifier	this is a value between 0 and 2^{21}
3	control sequence id	for commands that are not te result of control sequences, like letters and characters, it is zero, otherwise, it is number pointing into the 'equivalence table'

4.2.1 `token.get_next`

```
token t = token.get_next()
```

This fetches the next input token from the current input source, without expansion.

4.2.2 `token.is_expandable`

```
boolean b = token.is_expandable(token t)
```

This tests if the token `t` could be expanded.

4.2.3 `token.expand`

```
token.expand()
```

If a token is expandable, this will expand one level of it, so that the first token of the expansion will now be the next token to be read by `tex.get_next()`.

4.2.4 `token.is_activechar`

```
boolean b = token.is_activechar(token t)
```

This is a special test that is sometimes handy. Discovering whether some token is the result of an active character turned out to be very hard otherwise.

4.2.5 token.create

```
token t = token.create(string csname)
token t = token.create(number charcode)
token t = token.create(number charcode, number catcode)
```

This is the token factory. If you feed it a string, then it is the name of a control sequence (without leading backslash), and it will be looked up in the equivalence table.

If you feed it number, then this is assumed to be an input character, and an optional second number gives its category code. This means it is possible to overrule a character's category code, with a few exceptions: the category codes 0 (escape), 9 (ignored), 13 (active), 14 (comment), and 15 (invalid) cannot occur inside a token. The values 0, 9, 14 and 15 are therefore illegal as input to `token.create()`, and active characters will be resolved immediately.

Note: unknown string sequences and never defined active characters will result in a token representing an 'undefined control sequence' with a near-random name. It is *not* possible to define brand new control sequences using `token.create`!

4.2.6 token.command_name

```
string commandname = token.command_name(token t)
```

This returns the name associated with the 'command' value of the token in LuaTEX. There is not always a direct connection between these names and primitives. For instance, all `\ifxxx` tests are grouped under `if_fest`, and the 'command modifier' defines which test is to be run.

4.2.7 token.command_id

```
number i = token.command_idtring commandname)
```

This returns a number that is the inverse operation of the previous command, to be used as the first item in a token table.

4.2.8 token.csname_name

```
string csname = token.csname_name(token t)
```

This returns the name associated with the 'equivalence table' value of the token in LuaTEX. It returns the string value of the command used to create the current token, or an empty string if there is no associated control sequence.

4.2.9 token.csname_id

```
number i = token.csname_id(string csname)
```

This returns a number that is the inverse operation of the previous command, to be used as the third item in a token table.

4.3 The node library

The node library contains functions that facilitate dealing with (lists of) nodes and their values. They allow you to alter, create, copy, delete, and insert LuaTEX node objects, the core objects within the typesetter.

LuaTEX nodes are represented in Lua as userdata with the metadata type luatex.node. The various parts within a node can be accessed using named fields.

Each node has at least the three fields next, id, and subtype:

- The next field returns the userdata object for the next node in a linked list of nodes, or nil, if there is no next node.
- The id indicates TEX's 'node type'. The field id has a numeric value for efficiency reasons, but some of the library functions also accept a string value instead of id.
- The subtype is another number. It often gives further information about a node of a particular id, but it is most important when dealing with 'whatsits', because they are differentiated solely based on their subtype.

The other available fields depend on the id (and for 'whatsits', the subtype) of the node. Further details on the various fields and their meanings are given in chapter 7.

TEX's math nodes are not yet supported: there is not yet an interface to the internals of the math list and it is not possible to create them from Lua. Support for unset (alignment) nodes is partial: they can be queried and modified from Lua code, but not created.

Nodes can be compared to each other, but: you are actually comparing indices into the node memory. This means that equality tests can only be trusted under very limited conditions. It will not work correctly in any situation where one of the two nodes has been freed and/or reallocated: in that case, there will be false positives.

At the moment, memory management of nodes should still be done explicitly by the user. Nodes are not 'seen' by the Lua garbage collector, so you have to call the node free-ing functions yourself when you are no longer in need of a node (list). Nodes form linked lists without reference counting, so you have to be careful that when control returns back to LuaTEX itself, you have not deleted nodes that are still referenced from a next pointer elsewhere, and that you did not create nodes that are referenced more than once.

4.3.1 Node handling functions

4.3.1.1 node.types

```
table t = node.types()
```

This function returns an array that maps node id numbers to node type strings, providing an overview of the possible top-level `id` types.

4.3.1.2 node.whatsits

```
table t = node.whatsits()
```

TEX's 'whatsits' all have the same `id`. The various subtypes are defined by their `subtype`. The function is much like `node.id`, except that it provides an array of `subtype` mappings.

4.3.1.3 node.id

```
number id = node.id(string type)
```

This converts a single type name to its internal numeric representation.

4.3.1.4 node.subtype

```
number subtype = node.subtype(string type)
```

This converts a single whatsit name to its internal numeric representation (`subtype`).

4.3.1.5 node.type

```
string type = node.type(number id)
```

This converts a internal numeric representation to an external string representation.

4.3.1.6 node.fields

```
table t = node.fields(number id)
table t = node.fields(number id, number subtype)
```

This function returns an array of valid field names for a particular type of node. If you want to get the valid fields for a 'whatsit', you have to supply the second argument also. In other cases, any given second argument will be silently ignored.

This function accepts string `id` and `subtype` values as well.

4.3.1.7 node.has_field

```
boolean t = node.has_field(<node> n, string field)
```

This function returns a boolean that is only true if n is actually a node, and it has the field.

4.3.1.8 node.new

```
<node> n = node.new(number id)
<node> n = node.new(number id, number subtype)
```

Creates a new node. All of the new node's fields are initialized to either zero or nil except for id and subtype (if supplied). If you want to create a new whatsit, then the second argument is required, otherwise it need not be present. As with all node functions, this function creates an node on the TEX level.

This function accepts string id and subtype values as well.

4.3.1.9 node.free

```
node.free(<node> n)
```

Removes the node n from TEX's memory. Be careful: no checks are done on whether this node is still pointed to from a register or some next field: it is up to you to make sure that the internal data structures remain correct.

4.3.1.10 node.flush_list

```
node.flush_list(<node> n)
```

Removes the node list n and the complete node list following n from TEX's memory. Be careful: no checks are done on whether any of these nodes is still pointed to from a register or some next field: it is up to you to make sure that the internal data structures remain correct.

4.3.1.11 node.copy

```
<node> m = node.copy(<node> n)
```

Creates a deep copy of node n, including all nested lists as in the case of a hlist or vlist node. Only the next field is not copied.

4.3.1.12 node.copy_list

```
<node> m = node.copy_list(<node> n)
```

Creates a deep copy of the node list that starts at n.

4.3.1.13 node.hpack

```
<node> h = node.hpack(<node> n)
<node> h = node.hpack(<node> n, number w, string info)
```

This function creates a new hlist by packaging the list that begins at node n into a horizontal box. With only a single argument, this box is created using the natural width of its components. In the three argument form, info must be either additional or exactly, and w is the additional (\hbox spread) or exact (\hbox to) width to be used.

Caveat: at this moment, there can be unexpected side-effects to this function, like updating some of the \marks and \inserts.

4.3.1.14 node.slide

```
<node> m = node.slide(<node> n)
```

Returns the last node of the node list that starts at n. As a side-effect, it also creates a reverse chain of prev pointers between nodes.

4.3.1.15 node.length

```
number i = node.length(<node> n)
number i = node.length(<node> n, <node> m)
```

Returns the number of nodes contained in the node list that starts at n. If m is also supplied it stops at m instead of at the end of the list. The node m is not counted.

4.3.1.16 node.count

```
number i = node.count(number id, <node> n)
number i = node.count(number id, <node> n, <node> m)
```

Returns the number of nodes contained in the node list that starts at n that have an matching id field. If m is also supplied, counting stops at m instead of at the end of the list. The node m is not counted.

This function also accept string id's.

4.3.1.17 node.traverse

```
<node> t = node.traverse(<node> n)
```

This is an iterator that loops over the node list that starts at n.

4.3.1.18 node.traverse_id

```
<node> t = node.traverse_id(number id, <node> n)
```

This is an iterator that loops over all the nodes in the list that starts at `n` that have a matching `id` field.

4.3.1.19 node.remove

```
<node> head, current = node.remove(<node> head, <node> current)
```

This function removes the node `current` from the list following `head`. It is your responsibility to make sure it is really part of that list. The return values are the new `head` and `current` nodes. The returned `current` is the node in the calling argument, and is only passed back as a convenience (its `next` field will be cleared). The returned `head` is more important, because if the function is called with `current` equal to `head`, it will be changed.

4.3.1.20 node.insert_before

```
<node> head, new = node.insert_before(<node> head, <node> current, <node>
new)
```

This function inserts the node `new` before `current` into the list following `head`. It is your responsibility to make sure that `current` is really part of that list. The return values are the (potentially mutated) `head` and the `new`, set up to be part of the list (with correct `next` field). If `head` is initially `nil`, it will become `new`.

4.3.1.21 node.insert_after

```
<node> head, new = node.insert_after(<node> head, <node> current, <node>
new)
```

This function inserts the node `new` after `current` into the list following `head`. It is your responsibility to make sure that `current` is really part of that list. The return values are the `head` and the `new`, set up to be part of the list (with correct `next` field). If `head` is initially `nil`, it will become `new`.

4.3.1.22 node.first_character

```
<node> n = node.first_character(<node> n)
<node> n = node.first_character(<node> n, <node> m)
```

Returns the first node that is a glyph node with a subtype indicating it is a character, or `nil`.

4.3.1.23 node.ligaturing

```
<node> h, <node> t, <boolean> success = node.ligaturing(<node> n)
<node> h, <node> t, <boolean> success = node.ligaturing(<node> n, <node> m)
```

Apply TEX-style ligaturing to the specified nodelist. The tail node `m` is optional. The two returned nodes `h` and `t` are the new head and tail (both `n` and `m` can change into a new ligature).

4.3.1.24 node.kerning

```
<node> h, <node> t, <boolean> success = node.kerning(<node> n)
<node> h, <node> t, <boolean> success = node.kerning(<node> n, <node> m)
```

Apply TEX-style kerning to the specified nodelist. The tail node `m` is optional. The two returned nodes `h` and `t` are the head and tail (either one of these can be an inserted kern node, because special kernings with word boundaries are possible).

4.3.1.25 node.unprotect_glyphs

```
node.unprotect_glyphs(<node> n)
```

Substracts 256 from all glyph node subtypes. This and the next function are helpers to convert from `characters` to `glyphs` during node processing.

4.3.1.26 node.protect_glyphs

```
node.protect_glyphs(<node> n)
```

Adds 256 to all glyph node subtypes in the node list starting at `n`, except that if the value is 1, it adds only 255. The special handling of 1 means that `characters` will become `glyphs` after substraction of 256.

4.3.2 Attribute handling

Attributes appear as linked list of userdata objects in the `attr` field of individual nodes. They can be handled individually, but it much safer and more efficient to use the dedicated functions associated with them.

4.3.2.1 node.has_attribute

```
number v = node.has_attribute(<node> n, number id)
number v = node.has_attribute(<node> n, number id, number val)
```


Tests if a node has the attribute with number `id` set. If `val` is also supplied, also tests if the value matches `val`. It returns the value, or, if no match is found, nil.

4.3.2.2 node.set_attribute

```
node.set_attribute(<node> n, number id, number val)
```

Sets the attribute with number `id` to the value `val`. Duplicate assignments are ignored.

4.3.2.3 node.unset_attribute

```
number v = node.unset_attribute(<node> n, number id, number val)
number v = node.unset_attribute(<node> n, number id)
```

Unsets the attribute with number `id`. If `val` is also supplied, it will only perform this operation if the value matches `val`. Missing attributes or attribute-value pairs are ignored.

If the attribute was actually deleted, returns its old value. Otherwise, returns nil.

4.4 The texio library

This library takes care of the low-level I/O interface.

4.4.1 Printing functions

4.4.1.1 texio.write

```
texio.write(string target, string s, ...)
texio.write(string s, ...)
```

Without the `target` argument, writes all given strings to the same location(s) TEX writes messages to at this moment. If `\batchmode` is in effect, it writes only to the log, otherwise it writes to the log and the terminal.

The optional `target` can be one of three possibilities: `term`, `log` or `term and log`.

Note: If several strings are given, and if the first of these strings is or might be one of the targets above, the `target` must be specified explicitely to prevent Lua from interpreting the first string as the target.

4.4.1.2 texio.write_nl

```
texio.write_nl(string target, string s, ...)
texio.write_nl(string s, ...)
```

Like texio.write, but make sure that the given strings will appear at the beginning of a line. You can pass a single empty string if you only want to move to the next line.

4.5 The pdf library

This table contains the current h en v values that define the location on the output page. The values can be queried and set using scaled points as units.

```
pdf.v
pdf.h
```

The associated function calls are

```
pdf.setv(number n)
number n = pdf.getv()
pdf.seth(number n)
number n = pdf.geth()
```

It also holds a print function to write stuff to the pdf document, that can be used from within a \latelua argument. This function is not to be used inside \directlua unless you know *exactly* what you are doing.

pdf.print

```
pdf.print(string s)
pdf.print(string type, string s)
```

The optional parameter can be used to mimic the behaviour of \pdfliteral: the type is direct or page.

4.6 The callback library

This library has functions that register, find and list callbacks.

The callback library is only available in Lua state zero (0).

```
id, error = callback.register(string callback_name,function callback_func)
id, error = callback.register(string callback_name,nil)
```

where the callback_name is a predefined callback name, see below. The function returns the internal id of the callback or nil, if the callback could not be registered. In the latter case, error contains an error message, otherwise it is nil.

LuaTEX internalizes the callback function in such a way that it does not matter if you redefine a function accidentally.

Callback assignments are always global. You can use the special value `nil` instead of a function for clearing the callback.

Currently, callbacks are not dumped in the format file.

```
table info = callback.list()
```

The keys in the table are the known callback names, the value is a boolean where `true` means that the callback is currently set (active).

```
function f = callback.find(callback_name)
```

If the callback is not set, `callback.find` returns `nil`.

4.6.1 File discovery callbacks

4.6.1.1 `find_read_file` and `find_write_file`

You callback function should have the following conventions:

```
string actual_name = function (number id_number, string asked_name)
```

Arguments:

id_number
: This number is zero for the log or `\input` files. For TEX's `\read` or `\write` the number is incremented by one, so `\read0` becomes 1.

asked_name
: This is the user-supplied filename, as found by `\input`, `\openin` or `\openout`.

Return value:

actual_name
: This is the filename used. For the very first file that is read in by TEX, you have to make sure you return an `actual_name` that has an extension and that is suitable for use as `jobname`. If you don't, you will have to manually fix the name of the log file and output file after LuaTEX is finished, and an eventual format filename will become mangled. That is because these file names depend on the jobname.
  You have to return `nil` if the file cannot be found.

4.6.1.2 `find_font_file`

Your callback function should have the following conventions:

```
string actual_name = function (string asked_name)
```

The `asked_name` is an otf or tfm font metrics file.

Return `nil` if the file cannot be found.

4.6.1.3 `find_output_file`

You callback function should have the following conventions:

```
string actual_name = function (string asked_name)
```

The `asked_name` is the pdf or dvi file for writing.

4.6.1.4 `find_format_file`

You callback function should have the following conventions:

```
string actual_name = function (string asked_name)
```

The `asked_name` is a format file for reading (the format file for writing is always opened in the current directory).

4.6.1.5 `find_vf_file`

Like `find_font_file`, but for virtual fonts. This applies to both Aleph's ovf files and traditional Knuthian vf files.

4.6.1.6 `find_ocp_file`

Like `find_font_file`, but for ocp files.

4.6.1.7 `find_map_file`

Like `find_font_file`, but for map files.

4.6.1.8 `find_enc_file`

Like `find_font_file`, but for enc files.

4.6.1.9 `find_sfd_file`

Like `find_font_file`, but for subfont definition files.

4.6.1.10 find_pk_file

Like find_font_file, but for pk bitmap files. The argument name is a bit special in this case. Its form is

```
<base res>dpi/<fontname>.<actual res>pk
```

So you may be asked for 600dpi/manfnt.720pk. It is up to you to find a 'reasonable' bitmap file to go with that specification.

4.6.1.11 find_data_file

Like find_font_file, but for embedded files (\pdfobj file '...').

4.6.1.12 find_opentype_file

Like find_font_file, but for OpenType font files.

4.6.1.13 find_truetype_file and find_type1_file

Your callback function should have the following conventions:

```
string actual_name = function (string asked_name)
```

The asked_name is a font file. This callback is called while LuaTEX is building its internal list of needed font files, so the actual timing may surprise you. Your return value is later fed back into the matching read_file callback.

Strangely enough, find_type1_file is also used for OpenType (otf) fonts.

4.6.1.14 find_image_file

You callback function should have the following conventions:

```
string actual_name = function (string asked_name)
```

The asked_name is an image file. Your return value is used to open a file from the harddisk, so make sure you return something that is considered the name of a valid file by your operating system.

4.6.2 File reading callbacks

4.6.2.1 open_read_file

You callback function should have the following conventions:

```
table env = function (string file_name)
```

Argument:

file_name
: the filename returned by a previous `find_read_file` or the return value of `kpse.find_file()` if there was no such callback defined.

Return value:

env
: this is a table containing at least one required and one optional callback functions for this file. The required field is `reader` and the associated function will be called once for each new line to be read, the optional one is `close` that will be called once when LuaTEX is done with the file.
LuaTEX never looks at the rest of the table, so you can use it to store your private per-file data. Both the callback functions will receive the table as their only argument.

4.6.2.1.1 `reader`

LuaTEX will run this function whenever it needs a new input line from the file.

```
function(table env)
    return string line
end
```

Your function should return either a string or `nil`. The value `nil` signals that the end of file has occurred, and will make TEX call the optional `close` function next.

4.6.2.1.2 `close`

LuaTEX will run this optional function when it decides to close the file.

```
function(table env)
    return
end
```

Your function should not return any value.

4.6.2.2 General file readers

There is a set of callbacks for the loading of binary data files. These all use the same interface:

```
function(string name)
    return boolean success, string data, number data_size
end
```


The name will normally be a full path name as it is returned by either one of the file discovery callbacks or the internal version of kpse.find_file().

success
    return false when a fatal error occured (e.g. when the file cannot be found, after all).
data
    the bytes comprising the file.
data_size
    the length of the data, in bytes.

return an empty string and zero if the file was found but there was a reading problem.

The list of functions is:

read_font_file	This function is called when TEX needs to read a ofm or tfm file.
read_vf_file	for virtual fonts.
read_ocp_file	for ocp files.
read_map_file	for map files.
read_enc_file	for encoding files.
read_sfd_file	for subfont definition files.
read_pk_file	for pk bitmap files.
read_data_file	for embedded files (\pdfobj file '...').
read_truetype_file	for TrueType font files.
read_type1_file	for Type1 font files.
read_opentype_file	for OpenType font files.

4.6.3 Data processing callbacks

4.6.3.1 process_input_buffer

This callback allows you to change the contents of the line input buffer just before LuaTEX actually starts looking at it.

```
function(string buffer)
    return string adjusted_buffer
end
```

If you return nil, LuaTEX will pretend like your callback never happened. You can gain a small amount of processing time from that.

4.6.3.2 token_filter

This callback allows you to replace the way LuaTEX fetches lexical tokens.

```
function()
    return table token
end
```

The calling convention for this callback is bit more complicated than for most other callbacks. The function should either return a Lua table representing a valid to-be-processed token or tokenlist, or something else like nil or an empty table.

If your Lua function does not return a table representing a valid token, it will be immediately called again, until it eventually does return a useful token or tokenlist (or until you reset the callback value to nil). See the description of `token` for some handy functions to be used in conjunction with this callback.

If your function returns a single usable token, then that token will be processed by LuaTEX immediately. If the function returns a token list (a table consisting of a list of consecutive token tables), then that list will be pushed to the input stack as completely new token list level, with its token type set to 'inserted'. In either case, the returned token(s) will not be fed back into the callback function.

4.6.4 Node list processing callbacks

The description of nodes and node lists is in **chapter 7**.

4.6.4.1 buildpage_filter

This callback is called whenever LuaTEX is ready to move stuff to the main vertical list. You can use this callback to do specialized manipulation of the page building stage like imposition or column balancing.

```
function(<node> head, string extrainfo)
    return true | false | <node> newhead
end
```

As for all the callbacks that deal with nodes, the return value can be one of three things:

- `boolean true` signals succesful processing
- `node` signals that the 'head' node should be replaced by this node
- `boolean false` signals that the 'head' node list should be ignored and flushed from memory

The string `extrainfo` gives some additional information about what TEX's state is with respect to the 'current page'. The possible values are:

value	explanation
alignment	a (partial) alignment is being added
box	a typeset box is being added
begin_of_par	the beginning of a new paragraph
vmode_par	\par was found in vertical mode
hmode_par	\par was found in horizontal mode
insert	an insert is added
penalty	a penalty (in vertical mode)

before_display	immediately before a display starts
after_display	a display is finished

4.6.4.2 pre_linebreak_filter

This callback is called just before LuaTEX starts converting a list of nodes into a stack of \hboxes. The removal of a possible final skip and the subsequent insertion of \parfillskip has not happened yet at that moment.

```
function(<node> head, string groupcode)
    return true | false | <node> newhead
end
```

The string called groupcode identifies the nodelist's context within TEX's processing. The range of possibilities is given in the table below, but not all of those can actually appear in pre_linebreak_filter, some are for the hpack_filter and vpack_filter callbacks that will be explained in the next two paragraphs.

value	explanation
hbox	\hbox in horizontal mode
adjusted_hbox	\hbox in vertical mode
vbox	\vbox
vtop	\vtop
align	\halign or \valign
disc	discretionaries
insert	packaging an insert
vcenter	\vcenter
local_box	\localleftbox or \localrightbox
split_off	top of a \vsplit
split_keep	remainder of a \vsplit
align_set	alignment cell
fin_row	alignment row

4.6.4.3 post_linebreak_filter

This callback is called just after LuaTEX has converted a list of nodes into a stack of \hboxes.

```
function(<node> head, string groupcode)
    return true | false | <node> newhead
end
```

4.6.4.4 hpack_filter

This callback is called when TEX is ready to start boxing some horizontal mode material. Math items are ignored at the moment.

```
function(<node> head, string groupcode, number size, string packtype)
    return true | false | <node> newhead
end
```

The packtype is either additional or exactly. If additional, then the size is a \hbox spread ... argument. If exactly, then the size is a \hbox to ... . In both cases, the number is in scaled points.

4.6.4.5 vpack_filter

This callback is called when TEX is ready to start boxing some vertical mode material. Math displays are ignored at the moment.

This function is very similar to the hpack_filter. Besides the fact that it is called at different moments, there is an extra variable that matches TEX's \maxdepth setting.

```
function(<node> head, string groupcode, number size, string packtype,  number maxdepth)
    return true | false | <node> newhead
end
```

4.6.4.6 pre_output_filter

This callback is called when TEX is ready to start boxing the box 255 for \output.

```
function(<node> head, string groupcode, number size, string packtype, number maxdepth)
    return true | false | <node> newhead
end
```

4.6.4.7 hyphenate

```
function(<node> head, <node> tail)
end
```

No return values. This callback has to insert discretionary nodes in the node list it receives.

4.6.4.8 ligaturing

```
function(<node> head, <node> tail)
end
```

No return values. This callback has to apply ligaturing to the node list it receives.

You don't have to worry about return values because the head node that is passed on to the callback is guaranteed not to be a glyph_node (if need be, a temporary node will be prepended), and therefore it

cannot be affected by the mutations that take place. After the callback, the internal value of the 'tail of the list' will be recalculated.

The `next` of `head` is guaranteed to be non-nil.

The `next` of `tail` is guaranteed be nil, and therefore the second callback argument can often be ignored. It is provided for orthogonality, and because it can sometimes be handy when special processing has to take place.

4.6.4.9 kerning

`function(<node> head, <node> tail) end`

No return values. This callback has to apply kerning between the nodes in the node list it receives. See `ligaturing` for calling conventions.

4.6.5 Information reporting callbacks

4.6.5.1 start_run

`function()`

Replaces the code that prints LuaTEX's banner

4.6.5.2 stop_run

`function()`

Replaces the code that prints LuaTEX's statistics and 'output written to' messages.

4.6.5.3 start_page_number

`function()`

Replaces the code that prints the `[` and the page number at the begin of `\shipout`. This callback will also override the printing of box information that normally takes place when `\tracingoutput` is positive.

4.6.5.4 stop_page_number

`function()`

Replaces the code that prints the `]` at the end of `\shipout`

4.6.5.5 show_error_hook

```
function()
    return
end
```

This callback is run from inside the TEX error function, and the idea is to allow you to do some extra reporting on top of what TEX already does (none of the normal actions are removed). You may find some of the values in the status table useful.

message
: is the formal error message TEX has given to the user (the line after the '!')

indicator
: is either a filename (when it is a string) or a location indicator (a number) that can means lots of different things like a token list id or a \read number.

lineno
: is the current line number

This is an investigative item for 'testing the water' only. The final goal is the total replacement of TEX's error handling routines, but that needs lots of adjustments in the web source because TEX deals with errors in a somewhat haphazard fashion. This is why the exact definition of indicator is not given here.

4.6.6 Font-related callbacks

4.6.6.1 define_font

```
function(string name, number size, number id) return table font end
```

The string name is the filename part of the font specification, as given by the user.

The number size is a bit special:

- if it is positive, it specifies an 'at size' in scaled points.
- if it is negative, its absolute value represents a 'scaled' setting relative to the designsize of the font.

The internal structure of the font table that is to be returned is explained in chapter 6. That table is saved internally, so you can put extra fields in the table for your later Lua code to use.

4.7 The lua library

This library contains two read-only items:

4.7.1 Variables

```
number n = lua.id
```

This returns the id number of the instance.

```
string s = lua.version
```

This returns a LuaTEX version identifier string. The value is currently lua.version, but it is soon to be replaced by something more elaborate.

4.7.2 LUA bytecode registers

Lua registers can be used to communicate Lua functions across Lua states. The accepted values for assignments are functions and nil. Likewise, the retrieved value is either a function or `nil`.

```
lua.bytecode[n] = function () .. end
lua.bytecode[n]()
```

The contents of the `lua.bytecode` array is stored inside the format file as actual Lua bytecode, so it can also be used to preload Lua code.

Note: The function must not contain any upvalues. Currently, functions containing upvalues can be stored (and their upvalues are set to `nil`), but this is an artefact of the current Lua implementation and thus subject to change.

The associated function calls are

```
function f = lua.getbytecode(number n)
lua.setbytecode(number n, function f)
```

Note: Since a Lua file loaded using `loadfile(filename)` is essentially an anonymous function, a complete file can be stored in a bytecode register like this:

```
lua.bytecode[n] = loadfile(filename)
```

Now all definitions (functions, variables) contained in the file can be created by executing this bytecode register:

```
lua.bytecode[n]()
```

4.8 The kpse library

This library provides an interface to the kpathsea file search method.

Before the search library can be used at all, its database has to be initialized. When LuaTEX is used to typeset documents, this happens automatically (that is, unless explicitly prohibited by the user's startup

script. See section 3.1 for more details). In TEXLua mode, the initialization has to be done explicitly via the `kpse.set_program_name` function.

4.8.1 kpse.set_program_name

Sets the kpathsea executable (and optionally program) name

```
kpse.set_program_name(string name)
kpse.set_program_name(string name, string progname)
```

The second argument controls the use of the 'dotted' values in the `texmf.cnf` configuration file, and defaults to the first argument.

4.8.2 kpse.find_file

The most often used function in the library is find_file:

```
string f = kpse.find_file(string filename)
string f = kpse.find_file(string filename, string ftype)
string f = kpse.find_file(string filename, boolean mustexist)
string f = kpse.find_file(string filename, string ftype, boolean mustexist)
string f = kpse.find_file(string filename, string ftype, number dpi)
```

Arguments:

filename
: the name of the file you want to find, with or without extension.

ftype
: maps to the `-format` argument of kpsewhich. The supported `ftype` values are the same as the ones supported by the standalone `kpsewhich` program:

'gf'
'pk'
'bitmap font'
'tfm'
'afm'
'base'
'bib'
'bst'
'cnf'
'ls-R'
'fmt'
'map'
'mem'
'mf'
'mfpool'
'mft'
'mp'
'mppool'
'MetaPost support'
'ocp'
'ofm'
'opl'
'otp'
'ovf'
'ovp'
'graphic/figure'
'tex'
'TeX system documentation'
'texpool'
'TeX system sources'
'PostScript header'
'Troff fonts'
'type1 fonts'
'vf'
'dvips config'
'ist'
'truetype fonts'
'type42 fonts'
'web2c files'
'other text files'
'other binary files'
'misc fonts'
'web'
'cweb'
'enc files'
'cmap files'
'subfont definition files'
'opentype fonts'
'pdftex config'
'lig files'
'texmfscripts'

The default type is `tex`.

mustexist

is similar to kpsewhich's `-must-exist`, and the default is `false`. If you specify `true` (or a non-zero integer), then the kpse library will search the disk as well as the `ls-R` databases.

dpi

This is used for the size argument of the formats `pk`, `gf`, and `bitmap font`.

4.8.3 kpse.init_prog

Extra initialization for programs that need to generate bitmap fonts.

```
kpse.init_prog(string prefix, number base_dpi, string mfmode)
kpse.init_prog(string prefix, number base_dpi, string mfmode, string fallback)
```

4.8.4 kpse.readable_file

Test if an (absolute) file name is a readable file

```
string f = kpse.readable_file(string name)
```

The return value is the actual absolute filename you should use, because the disk name is not always the same as the requested name, due to aliases and system-specific handling under e.g. msdos.

Returns `nil` if the file does not exist or is not readable.

4.8.5 kpse.expand_path

Like kpsewhich's `-expand-path`:

```
string r = kpse.expand_path(string s)
```

4.8.6 kpse.expand_var

Like kpsewhich's `-expand-var`:

```
string r = kpse.expand_var(string s)
```

4.8.7 kpse.expand_braces

Like kpsewhich's `-expand-braces`:

```
string r = kpse.expand_braces(string s)
```

4.8.8 kpse.var_value

Like kpsewhich's `-var-value`:

```
string r = kpse.var_value(string s)
```

4.9 The status library

This contains a number of run-time configuration items that you may find useful in message reporting, as well as an iterator function that gets all of the names and values as a table.

```
table info = status.list()
```

The keys in the table are the known items, the value is the current value.

Almost all of the values in `status` are fetched through a metatable at run-time whenever they are accessed, so you cannot use `pairs` on `status`, but you *can* use `pairs` on `info`, of course.

If you do not need the full list, you can also ask for a single item by using its name as an index into `status`.

The current list is:

key	explanation
pdf_gone	written pdf bytes
pdf_ptr	not yet written pdf bytes
dvi_gone	written dvi bytes
dvi_ptr	not yet written dvi bytes
total_pages	number of written pages
output_file_name	name of the pdf or dvi file
log_name	name of the log file
banner	terminal display banner
var_used	variable (one-word) memory in use
dyn_used	token (multi-word) memory in use
str_ptr	number of strings
init_str_ptr	number of iniTEX strings
max_strings	maximum allowed strings
pool_ptr	string pool index
init_pool_ptr	iniTEX string pool index
pool_size	current size allocated for string characters
node_mem_usage	a string giving insight into currently used nodes
var_mem_max	number of allocated words for nodes
fix_mem_max	number of allocated words for tokens
fix_mem_end	maximum number of used tokens
cs_count	number of control sequences
hash_size	size of hash
hash_extra	extra allowed hash
font_ptr	number of active fonts
max_in_stack	max used input stack entries
max_nest_stack	max used nesting stack entries
max_param_stack	max used parameter stack entries
max_buf_stack	max used buffer position
max_save_stack	max used save stack entries
stack_size	input stack size
nest_size	nesting stack size
param_size	parameter stack size
buf_size	current allocated size of the line buffer
save_size	save stack size
obj_ptr	max pdf object pointer
obj_tab_size	pdf object table size
pdf_os_cntr	max pdf object stream pointer
pdf_os_objidx	pdf object stream index
pdf_dest_names_ptr	max pdf destination pointer
dest_names_size	pdf destination table size
pdf_mem_ptr	max pdf memory used
pdf_mem_size	pdf memory size

largest_used_mark	max referenced marks class
filename	name of the current input file
inputid	numeric id of the current input
linenumber	location in the current input file
lasterrorstring	last error string
luabytecodes	number of active Lua bytecode registers
luabytecode_bytes	number of bytes in Lua bytecode registers
luastates	number of active Lua interpreters
luastate_bytes	number of bytes in use by Lua interpreters
output_active	true if the \output routine is active

4.10 The texconfig table

This is a table that is created empty. A startup Lua script could fill this table with a number of settings that are read out by the executable after loading and executing the startup file.

key	type	default	explanation
string_vacancies	number	75000	cf. web2c docs
pool_free	number	5000	cf. web2c docs
max_strings	number	15000	cf. web2c docs
strings_free	number	100	cf. web2c docs
nest_size	number	50	cf. web2c docs
max_in_open	number	15	cf. web2c docs
param_size	number	60	cf. web2c docs
save_size	number	4000	cf. web2c docs
stack_size	number	300	cf. web2c docs
dvi_buf_size	number	16384	cf. web2c docs
error_line	number	79	cf. web2c docs
half_error_line	number	50	cf. web2c docs
max_print_line	number	79	cf. web2c docs
ocp_list_size	number	1000	cf. web2c docs
ocp_buf_size	number	1000	cf. web2c docs
ocp_stack_size	number	1000	cf. web2c docs
hash_extra	number	0	cf. web2c docs
pk_dpi	number	72	cf. web2c docs
kpse_init	boolean	true	false totally disables kpathsea initialisation (only ever unset this if you implement *all* file find callbacks!)
trace_file_names	boolean	true	false disables TEX's normal file open-close feedback (the assumption is that callbacks will take care of that)
src_special_auto	boolean	false	source specials sub-item
src_special_everypar	boolean	false	source specials sub-item
src_special_everyparend	boolean	false	source specials sub-item

src_special_everycr	boolean	false	source specials sub-item
src_special_everymath	boolean	false	source specials sub-item
src_special_everyhbox	boolean	false	source specials sub-item
src_special_everyvbox	boolean	false	source specials sub-item
src_special_everydisplay	boolean	false	source specials sub-item
file_line_error	boolean	false	do file:line style error messages
halt_on_error	boolean	false	abort run on the first encountered error
formatname	string		if no format name was given on the commandline, this key will be tested first instead of simply quitting
jobname	string		if no input file name was given on the commandline, this key will be tested first instead of simply giving up

4.11 The font library

The font library provides the interface into the internals of the font system, and also it contains helper functions to load traditional TEX font metrics formats. Other font loading functionality is provided by the fontforge library that will be discussed in the next section.

4.11.1 Loading a TFM file

```
table fnt = font.read_tfm(string name, number s)
```

The number is a bit special:

- if it is positive, it specifies an 'at size' in scaled points.
- if it is negative, its absolute value represents a 'scaled' setting relative to the designsize of the font.

The internal structure of the metrics font table that is returned is explained in **chapter 6**.

4.11.2 Loading a VF file

```
table vf_fnt = font.read_vf(string name, number s)
```

The meaning of the number s, and the format of the returned table is the silimar to the read_tfm() function.

4.11.3 The fonts array

The whole table of TEX fonts is accessible from lua using a virtual array.

```
font.fonts[n] = { ... }
table f = font.fonts[n]
```

See chapter 6 for the structure of the tables. Because this is a virtual array, you cannot call `pairs` on it, but see below for the `font.each` iterator.

The two metatable functions implementing the virtual array are:

```
table f = font.getfont(number n)
font.setfont(number n, table f)
```

Also note the following: assignments can only be made to fonts that have already been defined in TEX, but have not been accessed *at all* since that definition. This limits the usability of the write access to `font.fonts` quite a lot, a less stringent ruleset will likely be implemented later.

4.11.4 Checking a font's status

You can test for the status of a font by calling this function:

```
boolean f = font.frozen(number n)
```

The return value is one of true (unassignable), false (can be changed) or nil (not a valid font at all).

4.11.5 Defining a font directly

You can define your own font into `font.fonts`

```
number i = font.define(table f)
```

The return value is the internal id number of the defined font (the index into `font.fonts`). If the font creation fails, an error is raised. The table is a font structure, as explained in chapter 6.

4.11.6 Currently active font

```
number i = font.current();
font.current(number i);
```

This gets or sets the currently used font number.

4.11.7 Maximum font id

```
number i = font.max();
```

This is the largest used index in `font.fonts`.

4.11.8 Iterating over all fonts

```
for i,v in font.each() do
  ...
end
```

This is an iterator over each of the defined TEX fonts. The first returned value is the index in `font.fonts`, the second the font itself, as a lua table. The indices are listed incrementally, but they do not always form an array of consecutive numbers: in some cases there can be holes in the sequence.

4.12 The `fontforge` library

4.12.1 Getting quick information on a font

```
local info = fontforge.info('filename')
```

This function returns either `nil`, or a `table`, or an array of small tables (in the case of a TrueType collection). The returned table(s) will contain six fairly interesting information items from the font(s) defined by the file:

key	type	explanation
`fontname`	string	the 'PostScript' name of the font
`fullname`	string	The formal name of the font
`familyname`	string	The family name this font belongs to
`weight`	string	A string indicating the color value of the font
`version`	string	The internal font version
`italicangle`	float	The slant angle

Getting information through this function is (sometimes much) more efficient than loading the font properly, and is therefore handy when you want to create a dictionary of available fonts based on a directory contents.

4.12.2 Loading an OPENTYPE or TRUETYPE file

If you want to use an OpenType font, you have to get the metric information from somewhere. Using the `fontforge` library, the basic way to get that information is thus:

```
function load_font (filename)
  local metrics = nil
  local font = fontforge.open(filename)
  if font then
     metrics = fontforge.to_table(font)
     fontforge.close(font)
  end
```

```
  return metrics
end

myfont = load_font('/opt/tex/texmf/fonts/data/arial.ttf')
```

The main function call is

```
f, w = fontforge.open('filename')
```

The first return value is a table representation of the font. The second return value is a table containing any warnings and errors reported by fontforge while opening the font. In normal typesetting, you would probably ignore the second argument, but it can be useful for debugging purposes.

For TrueType collections (when filename ends in 'ttc'), you have to use a second string argument to specify which font you want from the collection. Use one of the `fullname` strings that are returned by `fontforge.info` for that.

```
f, w = fontforge.open('filename','fullname')
```

The font file is parsed and partially interpreted by the font loading routines from FontForge. The file format can be OpenType, TrueType, TrueType Collection, CFF, or Type1.

There are a few advantages to this approach compared to reading the actual font file ourselves:

- The font is automatically re-encoded, so that the `metrics` table for TrueType and OpenType fonts is using Unicode for the character indices.
- Many features are pre-processed into a format that is easier to handle than just the bare tables would be.
- PostScript-based OpenType fonts do not store the character height and depth in the font file, so the character boundingbox has to be calculated in some way.
- In the future, it may be interesting to allow Lua scripts access to the font program itself, perhaps even creating or changing the font.

4.12.3 Applying a 'feature file'

You can apply a 'feature file' to a loaded font:

```
fontforge.apply_featurefile(f,'filename')
```

A 'feature file' is a textual representation of the features in an OpenType font. See http://www.adobe.com/devnet/opentype/afdko/topic_feature_file_syntax.html and http://fontforge.sourceforge.net/featurefile.html for a more detailed description of feature files.

4.12.4 Applying an 'afm file'

You can apply a 'afm file' to a loaded font:

`fontforge.apply_afmfile(f,'filename')`

An 'afm file' is a textual representation of (some of) the metainformation in a Type 1 font. See http://www.adobe.com/devnet/font/pdfs/5004.AFM_Spec.pdf for more information about afm files.

Note: if you `fontforge.open()` a PFB file named `font.pfb`, the library will automatically search for, and apply, `font.afm` if it exists in the same directory as `font.pfb`. In that case, there is no need for an explicit call to `apply_afmfile()`.

4.13 Fontforge font tables

The top-level keys in the returned table are (the explanations in this part of the documentation is not yet finished):

key	type	explanation
table_version	number	indicates the metrics version
fontname	string	PostScript font name
fullname	string	official font name
familyname	string	family name
weight	string	weight indicator
copyright	string	copyright information
filename	string	the file name
version	string	font version
italicangle	float	slant angle
units_per_em	number	1000 for PostScript-based fonts, usually 2048 for TrueType
ascent	number	height of ascender in units_per_em
descent	number	depth of descender in units_per_em
upos	float	
uwidth	float	
vertical_origin	number	
uniqueid	number	
glyphcnt	number	number of included glyphs
glyphs	array	
glyphmax	number	maximum used index the glyphs array
hasvmetrics	number	
order2	number	set to 1 for TrueType splines, 0 otherwise
strokedfont	number	
weight_width_slope_only	number	
head_optimized_for_cleartype	number	
uni_interp	enum	unset, none, adobe, greek, japanese, trad_chinese, simp_chinese, korean, ams
origname	string	the file name, as supplied by the user
map	table	
private	table	

xuid	string
pfminfo	table
names	table
cidinfo	table
subfonts	array
cidmaster	array
commments	string
anchor_classes	table
ttf_tables	table
kerns	table
vkerns	table
texdata	table
lookups	table
gpos	table
gsub	table
chosenname	string
macstyle	number
fondname	string
design_size	number
fontstyle_id	number
fontstyle_name	table
design_range_bottom	number
design_range_top	number
strokewidth	float
mark_classes	array
mark_class_names	array
creationtime	number
modificationtime	number
os2_version	number

1 Glyph items

The glyphs is an array containing the per-character information (quite a few of these are only present if nonzero).

key	type	explanation
name	string	the glyph name
unicodeenc	number	unicode code point, or -1
boundingbox	array	array of four numbers
width	number	(only for horizontal fonts)
vwidth	number	(only for vertical fonts)
lsidebearing	number	(only if nonzero)
glyph_class	number	(only if nonzero)
kerns	array	(only for horizontal fonts, if set)

vkerns	array	(only for vertical fonts, if set)
dependents	array	linear array of glyph name strings (only if nonempty)
lookups	table	(only if nonempty)
ligatures	table	(only if nonempty)
anchors	table	(only if set)
tex_height	number	(only if set)
tex_depth	number	(only if set)
tex_sub_pos	number	(only if set)
tex_super_pos	number	(only if set)
comment	string	(only if set)

The kerns and vkerns are linear arrays of small hashes:

key	type	explanation
char	string	
off	number	
lookup	string	

The lookups is a hash based on lookup subtable names, with the value of each key inside that a linear array of small hashes:

key	type	explanation
type	enum	position, pair, substitution, alternate, multiple, ligature, lcaret, kerning, vkerning, anchors, contextpos, contextsub, chainpos, chainsub, reversesub, max, kernback, vkernback
specification	table	extra data

For the first seven values of type, there can be additional sub-information, stored in the sub-table specification:

value	type	explanation
position	table	a table of the offset_specs type
pair	table	one string: paired, and an array of one or two offset_specs tables: offsets
substitution	table	one string: variant
alternate	table	one string: components
multiple	table	one string: components
ligature	table	two strings: components, char
lcaret	array	linear array of numbers

Tables for offset_specs contain up to four number-valued fields: x (a horizontal offset), y (a vertical offset), h (an advance width correction) and v (an advance height correction).

The ligatures is a linear array of small hashes:

key	type	explanation
lig	table	uses the same substructure as a single possub item
char	string	

components	array	linear array of named components
ccnt	number	

The anchor table is indexed by a string signifying the anchor type, which is one of

key	type	explanation
mark	table	placement mark
basechar	table	mark for attaching combining items to a base char
baselig	table	mark for attaching combining items to a ligature
basemark	table	generic mark for attaching combining items to connect to
centry	table	cursive entry point
cexit	table	cursive exit point

The content of these is an short array of defined anchors, with the entry keys being the anchor names. For all except baselig, the value is a single table with this definition:

key	type	explanation
x	number	x location
y	number	y location
ttf_pt_index	number	truetype point index, only if given

For baselig, the value is a small array of such anchor sets sets, one for each constituent item of the ligature.

For clarification, an anchor table could for example look like this :

```
['anchor']={
  ['basemark']={
   ['Anchor-7']={ ['x']=170, ['y']=1080 }
  },
  ['mark']={
   ['Anchor-1'] ={ ['x']=160, ['y']=810 },
   ['Anchor-4']= { ['x']=160, ['y']=800 }
  },
  ['baselig']={
   [1] = { ['Anchor-2'] ={ ['x']=160, ['y']=650 } },
   [2] = { ['Anchor-2']= { ['x']=460, ['y']=640 } }
  }
 },
```

2 map table

The top-level map is a list of encoding mappings. Each of those is a table itself.

key	type	explanation
enccount	number	
encmax	number	

backmax	number	
remap	table	
map	array	non-linear array of mappings
backmap	array	non-linear array of backward mappings
enc	table	

The remap table is very small:

key	type	explanation
firstenc	number	
lastenc	number	
infont	number	

The enc table is a bit more verbose:

key	type	explanation
enc_name	string	
char_cnt	number	
char_max	number	
unicode	array	of Unicode position numbers
psnames	array	of PostScript glyph names
builtin	number	
hidden	number	
only_1byte	number	
has_1byte	number	
has_2byte	number	
is_unicodebmp	number	(only if nonzero)
is_unicodefull	number	(only if nonzero)
is_custom	number	(only if nonzero)
is_original	number	(only if nonzero)
is_compact	number	(only if nonzero)
is_japanese	number	(only if nonzero)
is_korean	number	(only if nonzero)
is_tradchinese	number	(only if nonzero)
is_simplechinese	number	(only if nonzero)
low_page	number	
high_page	number	
iconv_name	string	
iso_2022_escape	string	

3 private table

This is the font's private PostScript dictionary, if any. Keys and values are both strings.

4 cidinfo table

key	type	explanation
registry	string	
ordering	string	
supplement	number	
version	number	

5 pfminfo table

The pfminfo table contains most of the OS/2 information:

key	type	explanation
pfmset	number	
winascent_add	number	
windescent_add	number	
hheadascent_add	number	
hheaddescent_add	number	
typoascent_add	number	
typodescent_add	number	
subsuper_set	number	
panose_set	number	
hheadset	number	
vheadset	number	
pfmfamily	number	
weight	number	
width	number	
avgwidth	number	
firstchar	number	
lastchar	number	
fstype	number	
linegap	number	
vlinegap	number	
hhead_ascent	number	
hhead_descent	number	
hhead_descent	number	
os2_typoascent	number	
os2_typodescent	number	
os2_typolinegap	number	
os2_winascent	number	
os2_windescent	number	
os2_subxsize	number	
os2_subysize	number	
os2_subxoff	number	

os2_subyoff	number
os2_supxsize	number
os2_supysize	number
os2_supxoff	number
os2_supyoff	number
os2_strikeysize	number
os2_strikeypos	number
os2_family_class	number
os2_xheight	number
os2_capheight	number
os2_defaultchar	number
os2_breakchar	number
os2_vendor	string
panose	table

The panose subtable has exactly 10 string keys:

key	type	explanation
familytype	string	Values as in the OpenType font specification: Any, No Fit, Text and Display, Script, Decorative, Pictorial
serifstyle	string	See the OpenType font specification for values
weight	string	id.
proportion	string	id.
contrast	string	id.
strokevariation	string	id.
armstyle	string	id.
letterform	string	id.
midline	string	id.
xheight	string	id.

6 names table

Each item has two top-level keys:

key	type	explanation
lang	string	language for this entry
names	table	

The names keys are the actual TrueType name strings. The possible keys are:

key	explanation
copyright	
family	
subfamily	
uniqueid	

fullname
version
postscriptname
trademark
manufacturer
designer
descriptor
venderurl
designerurl
license
licenseurl
idontknow
preffamilyname
prefmodifiers
compatfull
sampletext
cidfindfontname

7 anchor_classes table

The anchor_classes classes:

key	type	explanation
name	string	A descriptive id of this anchor class
lookup	string	
type	string	One of 'mark', 'mkmk', 'curs', 'mklg'

8 gpos table

Th gpos table has one array entry for each lookup.

key	type	explanation
type	string	One of 'gpos_single', 'gpos_pair', 'gpos_cursive', 'gpos_mark2base', 'gpos_mark2ligature', 'gpos_mark2mark', 'gpos_context', 'gpos_contextchain'
flags	table	
name	string	
features	array	
subtables	array	

The flags table has a true value for each of the lookup flags that is actually set:

key	type	explanation
r2l	boolean	
ignorebaseglyphs	boolean	

ignoreligatures	boolean
ignorecombiningmarks	boolean

The features table has:

key	type	explanation
tag	string	
scripts	table	
ismax	number	(only if true)

The scripts table within features has:

key	type	explanation
script	string	
langs	array of strings	

The subtables table has:

key	type	explanation
name	string	
suffix	string	(only if used)
anchor_classes	number	(only if used)
vertical_kerning	number	(only if used)
kernclass	table	(only if used)

The kernclass with subtables table has:

key	type	explanation
firsts	array of strings	
seconds	array of strings	
lookup	string	associated lookup
offsets	array of numbers	

9 gsub table

This has identical layout to the gpos table, except for the type:

key	type	explanation
type	string	One of 'gsub_single', 'gsub_multiple', 'gsub_alternate', 'gsub_ligature', 'gsub_context', 'gsub_contextchain', 'gsub_reversecontextchain'

10 ttf_tables table

key	type	explanation
tag	string	
len	number	

maxlen	number
data	number

11 kerns table

Substructure is identical to the per-glyph subtable.

12 vkerns table

Substructure is identical to the per-glyph subtable.

13 texdata table

key	type	explanation
type	string	unset, text, math, mathext
params	array	22 font numeric parameters

14 lookups table

Top-level lookups is quite different from the ones at character level. The keys in this hash are strings, the values the actual lookups, represented as dictionary tables.

key	type	explanation
type	number	
format	enum	One of 'glyphs', 'class', 'coverage', 'reversecoverage'
tag	string	
current_class	array	
before_class	array	
after_class	array	
rules	array	an array of rule items

Rule items have one common item and one specialized item:

key	type	explanation
lookups	array	A linear array of lookup names
glyph	array	Only if the parent's format is 'glyph'
class	array	Only if the parent's format is 'glyph'
coverage	array	Only if the parent's format is 'glyph'
reversecoverage	array	Only if the parent's format is 'glyph'

A glyph table is:

key	type	explanation
names	string	

back	string
fore	string

A class table is:

key	type	explanation
current	array	of numbers
before	array	of numbers
after	array	of numbers

coverage:

key	type	explanation
current	array	of strings
before	array	of strings
after	array	of strings

reversecoverage:

key	type	explanation
current	array	of strings
before	array	of strings
after	array	of strings
replacements	string	

4.14 The lang library

This library provides the interface to LuaTEX's structure representing a language, and the associated functions.

```
<language> l = lang.new()
<language> l = lang.new(number id)
```

This function creates a new userdata object. An object of type <language> is the first argument to most of the other functions in the lang library. These functions can also be used as if they were object methods, using the colon syntax.

Without an argument, the next available internal id number will be assigned to this object. With argument, an object will be created that links to the internal language with that id number.

```
number n = lang.id(<language> l)
```

returns the internal \language id number this object refers to.

```
string n = lang.hyphenation(<language> l)
lang.hyphenation(<language> l, string n)
```

Either returns the current hyphenation exceptions for this language, or adds new ones. The syntax of the string is explained in the next chapter, **section 5.3**.

```
lang.clear_hyphenation(<language> l)
```

Clears the exception dictionary for this language.

```
string n = lang.clean(string o)
```

Creates a hypenation key from the supplied hyphenation value. The syntax of the argument string is explained in the next chapter, **section 5.3**. This function is useful if you want to do something else based on the words in a dictionary file, like spell-checking.

```
string n = lang.patterns(<language> l)
lang.patterns(<language> l, string n)
```

Adds additional patterns for this language object, or returns the current set. The syntax of this string is explained in the next chapter, **section 5.3**.

```
lang.clear_patterns(<language> l)
```

Clears the pattern dictionary for this language.

```
number n = lang.prehyphenchar(<language> l)
lang.prehyphenchar(<language> l, number n)
```

Gets or sets the 'pre-break' hyphen character for this font (initially the hyphen, decimal 45).

```
number n = lang.posthyphenchar(<language> l)
lang.posthyphenchar(<language> l, number n)
```

Gets or sets the 'post-break' hyphen character for this font (initially null, decimal 0).

```
boolean success = lang.hyphenate(<node> head)
boolean success = lang.hyphenate(<node> head, <node> tail)
```

Inserts hyphenation points (discretionary nodes) in a node list. If `tail` is given as argument, processings stops on that node. Currently, `succes` is always true if `head` (and `tail`, if specified) are proper nodes, regardless of possible other errors.

5 Languages and characters, Fonts and glyphs

LuaTEX's internal handling of the characters and glyphs that eventually become typeset is quite different from the way TEX82 handles those same objects. The easiest way to explain the difference is to focus on unrestricted horizontal mode (i.e. paragraphs) and hyphenation first. Later on, it will be easy to deal with the differences that occur in horizontal and math modes.

In TEX82, the characters you type are converted into `char_node` records when they are encountered by the main control loop. TEX attaches and processes the font information while creating those records, so that the resulting 'horizontal list' contains the final forms of ligatures and implicit kerning.

When it becomes necessary to hyphenate words in a paragraph, TEX converts (one word at time) the `char_node` records into a string array by replacing ligatures with their components and ignoring the kerning. Then it runs the hyphenation algorithm on this string, and converts the hyphenated result back into a 'horizontal list' that is consecutively spliced back into the paragraph stream.

The `char_node` records are somewhat misnamed, as they are glyph posisitions in specific fonts, and therefore not really 'characters' in the linguistic sense. There is no language information inside the `char_node` records. Instead, language information is passed along using `language whatsit` records inside the horizontal list.

IN LuaTEX, the situation is quite different. The characters you type are always converted into `glyph_node` records with a special subtype to identify them as being intended as linguistic characters. LuaTEX stores the needed language information in those records, but does not do any font-related processing at the time of node creation.

When it becomes necessary to typeset a paragraph, LuaTEX first inserts all hyphenation points right into the whole node list. Next, it processes all the font information in the whole list (creating ligatures and adjusting kerning), and finally it adjusts all the subtype identifiers so that the records are 'glyph nodes' from now on.

That was the broad overview. The rest of this chapter will deal with the minutiae of the new process.

5.1 Characters and glyphs

TEX82 (including pdfTEX) differentiated between `char_node`s and `lig_node`s. The former are simple items that contained nothing but a 'character' and a 'font' field, and they lived in the same memory are as tokens. The latter also contained a list of components, and a subtype indicating whether this ligature was the result of a word boundary, and it was stored in the same place as other nodes like boxes and kerns and glues.

In LuaTEX, these two types are merged into one, somewhat larger structure called a `glyph_node`. Besides having the old character, font, and component fields, and the new special fields like 'attr' (see **section 7.1.2.12**), these nodes also contain:

- A subtype, split into four main types:

— 'character' – for characters to be hyphenated
— 'glyph' – for specific font glyphs
— 'ligature' – for ligatures
— 'ghost' – for 'ghost objects'

The latter two make further use of two extra fields:

— 'left' – for ligatures: created from a left word boundary. for ghosts: created from `\leftghost`
— 'right' – for ligatures: created from a right word boundary. for ghosts: created from `\rightghost`

for ligatures, both bits can be set at the same time (in case of a single-glyph word).

- `glyph_node`s of type 'character' also contain language data, split into four items that were current when the node was created: the `\setlanguage` (15 bits), `\lefthyphenmin` (8 bits), `\righthyphenmin` (8 bits), and `\uchyph` (1 bit).

Incidentally, LuaTEX allows 32768 separate languages, and words can be 256 characters long.

Because the `\uchyph` value is saved in the actual nodes, its handling is subtly different from TEX82: changes to `\uchyph` become effective immediately, not at the end of the current partial paragraph.

Typeset boxes now always have their language information embedded in the nodes themselves, so there is no longer a possible dependancy on the surrounding language settings. In TEX82, a mid-paragraph statement like `\unhbox0` would process the box using the current paragraph language unless there was a `\setlanguage` issued inside the box. In LuaTEX, all language variables are already frozen.

5.2 The main control loop

In LuaTEX's main loop, almost all input characters that are to be typeset are converted into `glyph_node` records with subtype 'character', but there are a few small exceptions.

First, the `\accent` primitives creates nodes with subtype 'glyph' instead of 'character': one for the actual accent and one for the accentee. The primary reason for this is that `\accent` in TEX82 is explicitly dependant on the current font encoding, so it would not make much sense to attach a new meaning to the primitive's name, as that would invalidate many old documents and macro packages. A secondary reason is that in TEX82, `\accent` prohibits hyphenation of the current word. Since in LuaTEX hyphenation only takes place on 'character' nodes, it is possible to achieve the same effect.

This change of meaning did happen with `\char`, that now generates 'character' nodes, consistent with its changed meaning in XETEX. The changed status of `\char` is not yet finalized, but if it stays as it is now, a new primitive `\glyph` should be added to directly insert a font glyph id.

Second, all the results of processing in math mode eventually become nodes with 'glyph' subtypes.

Third, the Aleph-derived commands `\leftghost` and `\rightghost` create nodes of a third subtype: 'ghost'. These nodes are ignored completely by all further processing until the stage where inter-glyph kerning is added.

Fourth, automatic discretionaries are handled differently. TEX82 inserts an empty discretionary after sensing an input character that matches the `\hyphenchar` in the current font. This test is wrong, in our opinion: wether or not hyphenation takes place should not depend on the current font, it is a language property.

In LuaTEX, it works like this: if LuaTEX senses a string of input characters that matches the value of the new integer parameter \exhyphenchar, it will insert an empty discretionary after that series of nodes. Initex sets the \exhyphenchar=`\-. Incidentally, this is a global parameter instead of a language-specific one because it may be useful to change the value depending on the document structure instead of the text language.

The exact status and meaning of \hyphenchar is still under consideration, it will probably become used in the character to glyph conversion stage. Currently, it is simply ignored.

Fifth, \setlanguage no longer creates whatsits. The meaning of \setlanguage is changed so that it is now an integer parameter like all others. That integer parameter is used in \glyph_node creation to add language information to the glyph nodes. In conjunction, the \language primitive is extended so that it always also updates the value of \setlanguage.

Sixth, the \noboundary command (this command prohibits word boundary processing where that would normally take place) now does create whatsits. These whatsits are needed because the exact place of the \noboundary command in the input stream has to be retained until after the ligature and font processing stages.

Finally, there is no longer a main_loop label in the code. Remember that TEX82 did quite a lot of processing while adding char_nodes to the horizontal list? For speed reasons, it handled that processing code outside of the 'main control' loop, and only the first character of any 'word' was handled by that 'main control' loop. In LuaTEX, there is no longer a need for that (all hard work is done later), and the (now very small) bits of character-handling code have been moved back inline. When \tracingcommands is on, this is visible because the full word is reported, instead of just the initial character.

5.3 Loading patterns and exceptions

The hyphenation algorithm in LuaTEX is quite different from the one in TEX82, although it uses essentially the same user input.

After expansion, the argument for \patterns has to be proper UTF-8, no \char or \chardef-ed commands are allowed. (The current implementation is even more strict, and will reject all non-unicode characters, but that will be changed in the future. For now, the generated errors are a valuable tool in discovering font-encoding specific pattern files)

Likewise, the expanded argument for \hyphenation also has to be proper UTF-8, but here a tiny little bit of extra syntax is provided:

1. three sets of arguments in curly braces ({}{}{}) indicates a desired complex discretionary, with arguments as in \discretionary's command in normal document input.
2. - indicates a desired simple discretionary, cf. \- and \discretionary{-}{}{} in normal document input.
3. Internal command names are ignored. This rule is provided especially for \discretionary, but it also helps deal with \relax commands that may sneak in.
4. = indicates a hyphen in the document input (but that is only useful in documents where \exhyphenchar is not equal to the hyphen).

The expanded argument is first converted back to a space-separated string while dropping the internal command names. This string is then converted into a dictionary by a routine that creates key–value pairs by converting the other listed items. It is important to note that the keys in an exception dictionary can always be generated from the values. Here are a few examples:

value	implied key (input)	effect
`ta-ble`	table	`ta\-ble` (= `ta\discretionary {-}{}{}ble`)
`ba{k-}{}{c}ken`	backen	`ba\discretionary {k-}{}{c}ken`

The resultant patterns and exception dictionary will be stored under the language code that is the present value of `\language`.

In the last line of the table, you see there is no `\discretionary` command in the value: the command is optional in the TEX-based input syntax. The underlying reason for that is that it is conceivable that a whole dictionary of words is stored as a plain text file and loaded into LuaTEX using one of the functions in the Lua `lang` library. This loading method is quite a bit faster than going through the TEX language primitives, but some (most?) of that speed gain would be lost if it had to interpret command sequences while doing so.

The motivation behind the ε-TEX extension `\savinghyphcodes` was that hyphenation heavily depended on font encodings. This is no longer true in LuaTEX, and the corresponding primitive is ignored pending complete removal. The future semantics of `\uppercase` and `\lowercase` are still under consideration, no changes have taken place yet.

5.4 Applying hyphenation

The internal structures LuaTEX uses for the insertion of discretionaries in words is very different from the ones in TEX82, and that means there are some noticable differences in handling as well.

First and foremost, there is no 'compressed trie' involved in hyphenation. The algorithm still reads PATGEN-generated pattern files, but LuaTEX uses a finite state hash to match the patterns against the word to be hyphenated. This algorithm is based on the 'libhnj' library used by OpenOffice. The memory allocation for this new implementation is completely dynamic, so the web2c setting for `trie_size` is ignored.

Differences between LuaTEX and TEX82 that are a direct result of that:

- LuaTEX happily hyphenates the full Unicode character range.
- Pattern and exception dictionary size is limited by the available memory only, all allocations are done dynamically. The trie-related settings in `texmf.cnf` are ignored.
- Because there is no 'trie preparation' stage, language patterns never become frozen. This means that the primitive `\patterns` (and its lua counterpart `lang.patterns`) can be used at any time, not only in initex.
- Only the string representation of `\patterns` and `\hyphenation` is stored in the format file. At format load time, they are simply re-evaluated. It follows that there is no real reason to preload

languages in the format file. In fact, it is usually not a good idea to do so. It is much smarter to load patterns no sooner than the first time they are actually needed.

- LuaTEX uses the language-specific variables `\prehyphenchar` and `\posthyphenchar` in the creation of discretionaries, instead of TEX82's `\hyphenchar`.

Previously, there were problems with changing the node attributes mid-word, but that problem is now solved, as nodes in a word are not converted to and from a string any more (this was required by the old hyphenation code), they are editted in place. Inserted characters and ligatures inherit their attributes from the nearest glyph node item (usually the preceding one, but the following one for the items inserted at the left-hand side of a word).

Word boundaries are no longer implied by font switches, but by language switches. One word can have two separate fonts and still be hyphenated correctly (but it can not have two different languages, the `\setlanguage` command forces a word boundary).

All languages start out with `\prehyphenchar=`\-` and `\posthyphenchar=0`. When you assign the values of `\prehyphenchar` and `\posthyphenchar`, you are actually changing the settings for the current `\language`, this behaviour is compatible with `\patterns` and `\hyphenation`.

LuaTEX also hyphenates the first word in a paragraph.

Words can be up to 256 characters long (up from 64 in TEX82). Longer words generate an error right now, but eventually either the limitation will be removed or perhaps it will become possbile to silently ignore the excess characters (this is what happens in TEX82, but there the behaviour cannot be controlled).

If you are using the Lua function `lang.hyphenate`, you should be aware that this function expects to receive a list of 'character' nodes. It will not operate properly in the presence of 'glyph', 'ligature', or 'ghost' nodes, nor does it know how to deal with kerning. In the near future, it will be able to skip over 'ghost' nodes, and we may add a less fuzzy function you can call as well.

The hyphenation exception dictionary is maintained as key-value hash, and that is also dynamic, so the `hyph_size` setting is not used either.

A technical paper detailing the new algorithm will be released as a separate document.

5.5 Applying ligatures and kerning

After all possible hyphenation points have been inserted in the list, LuaTEX will process the list to convert the 'character' nodes into 'glyph' and 'ligature' nodes. This is actually done in two stages: first all ligatures are processed, then all kerning information is applied to the result list. But those two stages are somewhat dependant on each other: If the used font makes it possible to do so, the ligaturing stage adds virtual 'character' nodes to the word boundaries in the list. While doing so, it removes and interprets `noboundary` nodes. The kerning stage deletes those word boundary items after it is done with them, and it does the same for 'ghost' nodes. Finally, at the end of the kerning stage, all remaining 'character' nodes are converted to 'glyph' nodes.

This work separation is worth mentioning because, if you overrule from Lua only one of the two callbacks related to font handling, then you have to make sure you perform the tasks normally done by LuaTEX itself in order to make sure that the other, non-overrruled, routine continues to function properly.

Work in this area is not yet complete, but most of the possible cases are handled by our rewritten ligaturing engine. We are working hard to make sure all of the possible inputs will become supported soon.

For example, take the word `office`, hyphenated `of-fice`, using a 'normal' font with all the `f-i` ligatures:

Initial:	`{o}{f}{f}{i}{c}{e}`
After hyphenation:	`{o}{f}{{-},{},{}}{f}{i}{c}{e}`
First ligature stage:	`{o}{{f}{-},{f},{ff}}{i}{c}{e}`
Final result:	`{o}{{f}{-},{fi},{ffi}}{c}{e}`

That's bad enough, but if there was a hyphenation point between the `f` and the `i`: `of-f-ice`, the final result should be:

```
{o}{{f}{-},
    {{f}{-},
     {i},
     {fi}},
    {{ff}{-},
     {i},
     {ffi}}}{c}{e}
```

with discretionaries in the post-break text as well as in the replacement text of the top-level discretionary that resulted from the first hyphenation point. And this is only a simple case.

5.6 Breaking paragraphs into lines

This code is still almost unchanged, but because of the above-mentioned changes with respect to discretionaries and ligatures, line breaking will potentially be different from traditional TEX. The actual line breaking code is still based on the TEX82 algoritms, and it does not expect there to be discretionaries inside of discretionaries.

But that situation is now fairly common in LuaTEX, due to the changes to the ligaturing mechanism. And also, the LuaTEX discretionary nodes are implemented slightly different from the TEX82 nodes: the `no_break` text is now embedded inside the disc node where previously, these nodes kept their place in the horizontal list (the discretionary node contained a counter indicating how many nodes to skip).

The combined effect of these two differences is that LuaTEX does not always use all of the potential breakpoints in a paragraph, especially when fonts with many ligatures are used.

6 Font structure

All TEX fonts are represented to Lua code as tables, and internally as C structures. All keys in the table below are saved in the internal font structure if they are present in the table returned by the `define_font` callback, or if they result from the normal tfm/vf reading routines if there is no `define_font` callback defined.

The column 'from vf' means that this key will be created by the `font.read_vf()` routine, 'from tfm' means that the key will be created by the `font.read_tfm()` routine, and 'used' means whether or not the LuaTEX engine itself will do something with the key.

The top-level keys in the table are as follows:

key	from vf	from tfm	used	value type	description
name	yes	yes	yes	string	metric (file) name
area	no	yes	yes	string	(directory)location, typically empty
used	no	yes	yes	boolean	used already? (initial: false)
characters	yes	yes	yes	table	the defined glyphs of this font
checksum	yes	yes	no	number	default: 0
designsize	no	yes	yes	number	expected size (default: 655360 == 10pt)
direction	no	yes	yes	number	default: 0 (LTR)
encodingbytes	no	no	yes	number	default: depends on `format`
encodingname	no	no	yes	string	encoding name
fonts	yes	no	yes	table	locally used fonts
fullname	no	no	yes	string	actual (PostScript) name
header	yes	no	no	string	header comments, if any
hyphenchar	no	no	yes	number	default: TeX's `\hyphenchar`
parameters	no	yes	yes	hash	default: 7 parameters, all zero
size	no	yes	yes	number	loaded (at) size. (default: same as designsize)
skewchar	no	no	yes	number	default: TeX's `\skewchar`
type	yes	no	yes	string	basic type of this font
format	no	no	yes	string	disk format type
embedding	no	no	yes	string	pdf inclusion
filename	no	no	yes	string	disk file name
tounicode	no	yes	yes	number	if 1, LuaTEX assumes per-glyph tounicode entries are present in the font

The key `name` is always required.

The key `used` is set by the engine when a font is actively in use, this makes sure that the font's definition is written to the output file (dvi or pdf). The tfm reader sets it to false.

The `direction` is a number signalling the 'normal' direction for this font. There are sixteen possibilities:

number	meaning	number	meaning
0	LT	8	TT

1	LL	9	TL
2	LB	10	TB
3	LR	11	TR
4	RT	12	BT
5	RL	13	BL
6	RB	14	BB
7	RR	15	BR

These are Omega-style direction abbreviations: the first character indicates the 'first' edge of the character glyphs (the edge that is seen first in the writing direction), the second the 'top' side.

The `parameters` is a hash with mixed key types. There are seven possible string keys, as well as a number of integer indices (these start from 8 up). The seven strings are actually used instead of the bottom seven indices, because that gives a nicer user interface.

The names and their internal remapping:

name	**internal remapped number**
slant	1
space	2
space_stretch	3
space_shrink	4
x_height	5
quad	6
extra_space	7

The keys `type`, `format`, `embedding`, `fullname` and `filename` are used to embed OpenType fonts in the result pdf.

The `characters` table is a list of character hashes indexed by integer number. The number is the 'internal code' TEX knows this character by.

Two very special string indexes can be used also: `left_boundary` is a virtual character whose ligatures and kerns are used to handle word boundary processing. `right_boundary` is similar but not actually used for anything (yet!).

Other index keys are ignored.

Each character hash itself is a hash. For example, here is the character 'f' (decimal 102) in the font cmr10 at 10 points:

```
[102] = {
  ['width'] = 200250
  ['height'] = 455111,
  ['depth'] = 0,
  ['italic'] = 50973,
  ['kerns'] = {
     [63] = 50973,
     [93] = 50973,
```

```
      [39] = 50973,
      [33] = 50973,
      [41] = 50973
    },
    ['ligatures'] = {
      [102] = {
         ['char'] = 11,
         ['type'] = 0
      },
      [108] = {
         ['char'] = 13,
         ['type'] = 0
      },
      [105] = {
         ['char'] = 12,
         ['type'] = 0
      }
    },
}
```

The following top-level keys can be present inside a character hash:

key	from vf	from tfm	used	value type	description
width	yes	yes	yes	number	character's width, in sp (default 0)
height	no	yes	yes	number	character's height, in sp (default 0)
depth	no	yes	yes	number	character's depth, in sp (default 0)
italic	no	yes	yes	number	character's italic correction, in sp (default zero)
tounicode	no	no	maybe	string	character's Unicode equivalent(s), in UTF-16BE hexadecimal format
next	no	yes	yes	number	the 'next larger' character index
extensible	no	yes	yes	table	the constituent parts of an extensible recipe
kerns	no	yes	yes	table	kerning information
ligatures	no	yes	yes	table	ligaturing information
commands	yes	no	yes	array	virtual font commands
name	no	no	no	string	the character (PostScript) name
index	no	no	yes	number	the (OpenType or TrueType) font glyph index
used	no	yes	yes	boolean	typeset already (default: false)?

The usage of `tounicode` is this: if this font specifies a `tounicode=1` at the top level, then LuaTEX will construct a `/ToUnicode` entry for the PDF font (or font subset) based on the character-level `tounicode` strings, where they are available. If a character does not have a sensible Unicode equivalent, do not provide a string either (no empty strings).

If the font-level `tounicode` is not set, then LuaTEX will build up `/ToUnicode` based on the TEX code points you used, and any character-level `tounicodes` will be ignored. *At the moment, the string format is exactly the format that is expected by Adobe CMAP files (UTF-16BE in hexadecimal encoding), minus*

the enclosing angle brackets. This may change in the future.. Small example: the `tounicode` for a `fi` ligature would be `00660069`.

The presence of `extensible` will overrule `next`, if that is also present.

The `extensible` table is very simple:

key	type	description
top	number	'top' character index
mid	number	'middle' character index
bot	number	'bottom' character index
rep	number	'repeatable' character index

The `kerns` table is a hash indexed by character index (and 'character index' is defined as either a non-negative integer or the string value `right_boundary`), with the values the kerning to be applied, in scaled points.

The `ligatures` table is a hash indexed by character index (and 'character index' is defined as either a non-negative integer or the string value `right_boundary`), with the values being yet another small hash, with two fields:

key	type	description
type	number	the type of this ligature command, default 0
char	number	the character index of the resultant ligature

The `char` field in a ligature is required.

The `type` field inside a ligature is the numerical or string value of one of the eight possible ligature types supported by TEX. When TEX inserts a new ligature, it puts the new glyph in the middle of the left and right glyphs. The original left and right glyphs can optionally be retained, and when at least one of them is kept, it is also possible to move the new 'insertion point' forward one or two places. The glyph that ends up to the right of the insertion point will become the next 'left'.

textual (Knuth)	number	string	result
l + r =: n	0	`=:`	|n
l + r =:| n	1	`=:|`	|nr
l + r |=: n	2	`|=:`	|ln
l + r |=:| n	3	`|=:|`	|lnr
l + r =:|> n	5	`=:|>`	n|r
l + r |=:> n	6	`|=:>`	l|n
l + r |=:|> n	7	`|=:|>`	l|nr
l + r |=:|>> n	11	`|=:|>>`	ln|r

The default value is 0, and can be left out. That signifies a 'normal' ligature where the ligature replaces both original glyphs. In this table the | indicates the final insertion point.

The `commands` array is explained below.

6.1 Real fonts

Whether or not a TEX font is a 'real' font that should be written to the pdf document is decided by the `type` value in the top-level font structure. If the value is `real`, then this is a proper font, and the inclusion mechanism will attempt to add the needed font object definitions to the pdf.

Values for `type`:

value	description
real	this is a base font
virtual	this is a virtual font

The actions to be taken depend on a number of different variables:

- Whether the used font fits in an 8-bit encoding scheme or not
- The type of the disk font file
- The level of embedding requested

A font that uses anything other than an 8-bit encoding vector has to be written to the pdf in a different way.

The rule is: if the font table has `encodingbytes` set to 2, then this is a wide font, in all other cases it isn't. The value 2 is the default for OpenType and TrueType fonts loaded via Lua. For Type1 fonts, you have to set `encodingbytes` to 2 explicitly. For pk bitmap fonts, wide font encoding is not supported at all.

If no special care is needed, LuaTEX currently falls back to the mapfile-based solution used by pdfTEX and dvips. This behaviour will be removed in the future, when the existing code becomes integrated in the new subsystem.

But if this is a 'wide' font, then the new subsystem kicks in, and some extra fields have to be present in the font structure. In this case, LuaTEX does not use a map file at all.

The extra fields are: `format`, `embedding`, `fullname`, `cidinfo` (as explained above), `filename`, and the `index` key in the separate characters.

Values for `format` are:

value	description
type1	this is a PostScript Type1 font
type3	this is a bitmapped (pk) font
truetype	this is a TrueType or TrueType-based OpenType font
opentype	this is a PostScript-based OpenType font

(`type3` fonts are provided for backward compatibility only, and do not support the new wide encoding options.)

Values for `embedding` are:

value	description
no	don't embed the font at all

subset	include and atttempt to subset the font
full	include this font in its entirety

It is not possible to artificially modify the transformation matrix for the font at the moment.

The other fields are used as follows: The `fullname` will be the PostScript/pdf font name. The `cidinfo` will be used as the character set (the CID `/Ordering` and `/Registry` keys). The `filename` points to the actual font file. If you include the full path in the `filename` or if the file is in the local directory, LuaTEX will run a little bit more efficient because it will not have to re-run the `find_xxx_file` callback in that case.

Be careful: when mixing old and new fonts in one document, it is possible to create PostScript name clashes that can result in printing errors. When this happens, you have to change the `fullname` of the font.

Typeset strings are written out in a wide format using 2 bytes per glyph, using the `index` key in the character information as value. The overall effect is like having an encoding based on numbers instead of traditional (PostScript) name-based reencoding. The way to get the correct `index` numbers for Type1 fonts is by loading the font via `fontforge.open`; use the table indices as `index` fields.

This type of reencoding means that there is no longer a clear connection between the text in your input file and the strings in the output pdf file. Dealing with this is high on the agenda.

6.2 Virtual fonts

You have to take the following steps if you want LuaTEX to treat the returned table from `define_font` as a virtual font:

- Set the top-level key `type` to `virtual`.
- Make sure there is at least one valid entry in `fonts` (see below)
- Give a `commands` array to every character (see below)

The presence of the toplevel `type` key with the specific value `virtual` will trigger handling of the rest of the special virtual font fields in the table, but the mere existance of 'type' is enough to prevent LuaTEX from looking for a virtual font on its own.

Therefore, this also works 'in reverse': if you are absolutely certain that a font is not a virtual font, assigning the value `base` or `real` to `type` will inhibit LuaTEX from looking for a virtual font file, thereby saving you a disk search.

The `fonts` is another Lua array. The values are one- or two-key hashes themselves, each entry indicating one of the base fonts in a virtual font. An example makes this easy to understand

```
fonts = { { name = 'ptmr8a', size = 655360},
          { name = 'psyr', size = 600000},
          { id = 38 } }
```

says that the first referenced font (index 1) in this virtual font is ptrmr8a loaded at 10pt, and the second is psyr loaded at a little over 9pt. The third one is previously defined font that is known to LuaTEX as fontid '38'.

The array index numbers are used by the character command definitions that are part of each character.

The commands array is a hash here each item is another small array, with first entry representing a command and the extra items the parameters to that command. The allowed commands and their arguments are:

command name	arguments	arg type	description
font	1	number	select a new font from the local fonts table
char	1	number	typeset this character number from the current font, and move right by the character's width
node	1	node	output this node (list), and move right by the width of this list
slot	2	number	a shortcut for the combination of a font and char command
push	0		save current position
nop	0		do nothing
pop	0		pop position
rule	2	2 numbers	output a rule $w * h$, and move right.
down	1	number	move down on the page
right	1	number	move right on the page
special	1	string	output a \special command
comment	any	any	the arguments of this command are ignored

Here is a rather elaborate glyph commands example:

```
...
commands = {
  {'push'},                     -- remember where we are
  {'right', 5000},              -- move right about 0.08pt
  {'font', 3},                  -- select the fonts[3] entry
  {'char', 97},                 -- place character 97 (ASCII 'a')
  {'pop'},                      -- go all the way back
  {'down', -200000},            -- move upwards by about 3pt
  {'special', 'pdf: 1 0 0 rg'}  -- switch to red color
  {'rule', 500000, 20000}       -- draw a bar
  {'special','pdf: 0 g'}        -- back to black
}
...
```

The default value for font is always 1 at the start of the commands array. Therefore, if the virtual font is essentially only a re-encoding, then you do usually not have create an explicit 'font' command in the array.

Rules inside of commands arrays are built up using only two dimensions: they do not have depth. For correct vertical placement, an extra down command may be needed.

Regardless of the amount of movement you create within the commands, the output pointer will always move by exactly the width that was given in the width key of the character hash. Any movements that take place inside the commands array are ignored on the upper level.

6.2.1 Artificial fonts

Even in a 'real' font, there can be virtual characters. When LuaTEX encounters a commands field inside a character when it becomes time to typeset the character, it will interpret the commands, just like for a true virtual character. In this case, if you have created no 'fonts' array, then the default (and only) 'base' font is taken to be the current font itself. In practise, this means that you can create virtual duplicates of existing characters which is useful if you want to create composite characters.

Note: this feature does *not* work the other way around. There can not be 'real' characters in a virtual font! You cannot use this technique for font re-encoding either; you need a truly virtual font for that (because characters that are already present cannot be altered).

6.2.2 Example virtual font

Finally, here is a plain TEX input file with a virtual font demonstration:

```
\directlua0 {
  callback.register('define_font',
    function (name,size)
      if name == 'cmr10-red' then
        f = font.read_tfm('cmr10',size)
        f.name = 'cmr10-red'
        f.type = 'virtual'
        f.fonts = {{ name = 'cmr10', size = size }}
        for i,v in pairs(f.characters) do
          if (string.char(i)):find('[tacohanshartmut]') then
             v.commands = {
               {'special','pdf: 1 0 0 rg'},
               {'char',i},
               {'special','pdf: 0 g'},
              }
          else
             v.commands = {{'char',i}}
          end
        end
      else
        f = font.read_tfm(name,size)
      end
```

```
      return f
    end
  )
}

\font\myfont = cmr10-red at 10pt \myfont  This is a line of text \par
\font\myfontx= cmr10 at 10pt \myfontx Here is another line of text \par
```


7 Nodes

7.1 LUA node representation

TEX's nodes are represented in Lua as userdata object with a variable set of fields. In the following syntax tables, such the type of such a userdata object is represented as ⟨node⟩.

The current return value of `node.types()` is: `hlist` (0), `vlist` (1), `rule` (2), `ins` (3), `mark` (4), `adjust` (5), `disc` (7), `whatsit` (8), `math` (9), `glue` (10), `kern` (11), `penalty` (12), `unset` (13), `style` (14), `choice` (15), `ord` (16), `op` (17), `bin` (18), `rel` (19), `open` (20), `close` (21), `punct` (22), `inner` (23), `radical` (24), `fraction` (25), `under` (26), `over` (27), `accent` (28), `vcenter` (29), `left` (30), `right` (31), `margin_kern` (32), `glyph` (33), `align_record` (34), `pseudo_file` (35), `pseudo_line` (36), `page_insert` (37), `split_insert` (38), `expr_stack` (39), `nested_list` (40), `span` (41), `attribute` (42), `glue_spec` (43), `attribute_list` (44), `action` (45), `temp` (46), `align_stack` (47), `movement_stack` (48), `if_stack` (49), `unhyphenated` (50), `hyphenated` (51), `delta` (52), `passive` (53), `shape` (54), `fake` (100), but as already mentioned, the math and alignment nodes in this list are not supported at the moment. The useful list is described in the next sections.

7.1.1 Auxiliary items

A few node-typed userdata objects do not occur in the 'normal' list of nodes, but can be pointed to from within that list. They are not quite the same as regular nodes, but it is easier for the library routines to treat them as if they were.

7.1.1.1 glue_spec items

Skips are about the only type of data objects in traditional TEX that are not a simple value. The structure that represents the glue components of a skip is called a `glue_spec`, and it has the following accessible fields:

key	type	explanation
`width`	number	
`stretch`	number	
`stretch_order`	number	
`shrink`	number	
`shrink_order`	number	

These objects are reference counted, so there is actually an extra field named `ref_count` as well. This item type will likely disappear in the future, and the glue fields themselves will become part of the nodes referencing glue items.

7.1.1.2 attribute_list and attribute items

The newly introduced attribute registers are non-trivial, because the value that is attached to a node is essentially a sparse array of key-value pairs.

It is generally easiest to deal with attribute lists and attributes by using the dedicated functions in the `node` library, but for completeness, here is the low-level interface.

An `attribute\_list` item is used as a head pointer for a list of attribute items. It has only one user-visible field:

field	type	explanation
`next`	`<node>`	pointer to the first attribute

A normal node's attribute field will point to an item of type `attribute_list`, and the `next` field in that item will point to the first defined 'attribute' item, whose `next` will point to the second 'attribute' item, etc.

Valid fields in `attribute` items:

field	type	explanation
`next`	`<node>`	pointer to the next attribute
`number`	number	the attribute type id
`value`	number	the attribute value

7.1.1.3 action item

Valid fields: `action_type`, `named_id`, `action_id`, `file`, `new_window`, `data`, `ref_count`

These are a special kind of item that only appears inside pdf start link objects.

field	type	explanation
`action_type`	number	
`action_id`	number or string	
`named_id`	number	
`file`	string	
`new_window`	number	
`data`	string	
`ref_count`	number	

7.1.2 Main text nodes

These are the nodes that comprise actual typesetting commands.

A few fields are present in all nodes regardless of their type, these are:

field	type	explanation
`next`	`<node>`	The next node in a list, or nil

id	number	The node's type (id) number
subtype	number	The node subtype identifier

The subtype is sometimes just a stub entry. Not all nodes actually use the subtype, but this way you can be sure that all nodes accept it as a valid field name, and that is often handy in node list traversal. In the following tables next and id are not explicitly mentioned.

Besides these three fields, almost all nodes also have an attr field, and there is a also a field called prev. That last field is always present, but only initialized on explicit request: when the function node.slide() is called, it will set up the prev fields to be a backwards pointer in the argument node list.

7.1.2.1 hlist nodes

Valid fields: attr, width, depth, height, dir, shift, glue_order, glue_sign, glue_set, list

field	type	explanation
subtype	number	unused
attr	<node>	The head of the associated attribute list
width	number	
height	number	
depth	number	
shift	number	a displacement perpendicular to the character progression direction
glue_order	number	a number in the range 0–4, indicating the glue order
glue_set	number	the calculated glue ratio
glue_sign	number	
list	<node>	the body of this list
dir	number	the direction of this box

7.1.2.2 vlist nodes

Valid fields: As for hlist, except that 'shift' is a displacement perpendicular to the line progression direction.

7.1.2.3 rule nodes

Valid fields: attr, width, depth, height, dir

field	type	explanation
subtype	number	unused
attr	<node>	
width	number	rule size. The special value −1073741824 is used for 'running' glue dimensions
height	number	' '
depth	number	' '
dir	number	the direction of this rule

7.1.2.4 ins nodes

Valid fields: attr, cost, depth, height, top_skip, list

field	type	explanation
subtype	number	the insertion class
attr	<node>	
cost	number	the penalty associated with this insert
height	number	
depth	number	
list	<node>	the body of this insert
top_skip	<node>	a pointer to the \splittopskip glue spec

7.1.2.5 mark nodes

Valid fields: attr, class, mark

field	type	explanation
subtype	number	unused
attr	<node>	
class	number	the mark class
mark	table	a table representing a token list

7.1.2.6 adjust nodes

Valid fields: attr, list

field	type	explanation
subtype	number	0 = normal, 1 = 'pre'
attr	<node>	
list	<node>	adjusted material

7.1.2.7 disc nodes

Valid fields: attr, pre, post, replace

field	type	explanation
subtype	number	indicates the source of a discretionary. 0 = the \discretionary command, 1 = the \- command, 2 = added automatically following a -, 3 = added by the hyphenation algorithm
attr	<node>	
pre	<node>	pointer to the pre-break text
post	<node>	pointer to the post-break text
replace	<node>	pointer to the no-break text

7.1.2.8 math nodes

Valid fields: attr, surround

field	type	explanation
subtype	number	0 = 'on', 1 = 'off'
attr	<node>	
surround	number	width of the \mathsurround kern

7.1.2.9 glue nodes

Valid fields: attr, spec, leader

field	type	explanation
subtype	number	0 = \skip, 1–18 = internal glue parameters, 100 = \leaders, 101 = \cleaders, 102 = \xleaders
attr	<node>	
spec	<node>	pointer to a glue_spec item
leader	<node>	pointer to a box or rule for leaders

7.1.2.10 kern nodes

Valid fields: attr, kern

field	type	explanation
subtype	number	0 = from font, 1 = from \kern or \/, 2 = from \accent
attr	<node>	
kern	number	

7.1.2.11 penalty nodes

Valid fields: attr, penalty

field	type	explanation
subtype	number	not used
attr	<node>	
penalty	number	

7.1.2.12 glyph nodes

Valid fields: attr, char, font, lang, left, right, uchyph, components, xoffset, yoffset

field	type	explanation
subtype	number	bitfield, with bits:
		bit 0 character
		bit 1 glyph
		bit 2 ligature
		bit 3 ghost
		bit 4 left
		bit 5 right
attr	<node>	
char	number	
font	number	
lang	number	
left	number	
right	number	
uchyph	boolean	
components	<node>	pointer to ligature components
xoffset	number	
yoffset	number	

See section 5.1 for a detailed description of the subtype field.

7.1.2.13 margin_kern nodes

Valid fields: attr, width, glyph

field	type	explanation
subtype	number	0 = left side, 1 = right side
attr	<node>	
width	number	
glyph	<node>	

7.1.3 whatsit nodes

Whatsit nodes come in many subtypes, that you can ask for my running node.whatsits(): write (1), close (2), special (3), local_par (6), dir (7), pdf_literal (8), pdf_refobj (10), pdf_refxform (12), pdf_refximage (14), pdf_annot (15), pdf_start_link (16), pdf_end_link (17), pdf_dest (19), pdf_thread (20), pdf_start_thread (21), pdf_end_thread (22), pdf_save_pos (23), pdf_thread_data (24), pdf_link_data (25), open (0), pdf_setmatrix (40), pdf_restore (42), fake (100), late_lua (35), user_defined (44), pdf_colorstack (39), pdf_save (41), cancel_boundary (43), close_lua (36),

7.1.3.1 open nodes

Valid fields: attr, stream, name, area, ext

field	type	explanation
attr	<node>	
stream	number	TEX's stream id number
name	string	file name
ext	string	file extension
area	string	file area

7.1.3.2 write nodes

Valid fields: attr, stream, data

field	type	explanation
attr	<node>	
stream	number	TEX's stream id number
data	table	a table representing the token list to be written

7.1.3.3 close nodes

Valid fields: attr, stream

field	type	explanation
attr	<node>	
stream	number	TEX's stream id number

7.1.3.4 special nodes

Valid fields: attr, data

field	type	explanation
attr	<node>	
data	string	the \special information

7.1.3.5 language nodes

LuaTEX does not have language whatsits any more. All language information is already present inside the glyph nodes themselves. This whatsit subtype will be removed in the next release.

7.1.3.6 local_par nodes

Valid fields: attr, pen_inter, pen_broken, dir, box_left, box_left_width, box_right, box_right_width

field	type	explanation
attr	<node>	
pen_inter	number	interline penalty
pen_broken	number	broken penalty
dir	number	the direction of this par
box_left	<node>	the \localleftbox
box_left_width	number	width of the \localleftbox
box_right	<node>	the \localrightbox
box_right_width	number	width of the \localrightbox

7.1.3.7 dir nodes

Valid fields: attr, dir, level, dvi_ptr, dvi_h

field	type	explanation
attr	<node>	
dir	number	the direction
level	number	nesting level of this direction whatsit
dvi_ptr	number	a saved dvi buffer byte offset
dir_h	number	a saved dvi position

7.1.3.8 pdf_literal nodes

Valid fields: attr, mode, data

field	type	explanation
attr	<node>	
mode	number	the 'mode' setting of this literal
data	string	the \pdfliteral information

7.1.3.9 pdf_refobj nodes

Valid fields: attr, objnum

field	type	explanation
attr	<node>	
objnum	number	the referenced pdf object number

7.1.3.10 pdf_refxform nodes

Valid fields: attr, width, height, depth, objnum.

field	type	explanation
attr	<node>	

width	number	
height	number	
depth	number	
objnum	number	the referenced pdf object number

Be aware that pdf_refxform nodes have dimensions that are used by LuaTEX.

7.1.3.11 pdf_refximage nodes

Valid fields: attr, width, height, depth, objnum

field	type	explanation
attr	<node>	
width	number	
height	number	
depth	number	
objnum	number	the referenced pdf object number

Be aware that pdf_refximage nodes have dimensions that are used by LuaTEX.

7.1.3.12 pdf_annot nodes

Valid fields: attr, width, height, depth, objnum, data

field	type	explanation
attr	<node>	
width	number	
height	number	
depth	number	
objnum	number	the referenced pdf object number
data	string	the annotation data

7.1.3.13 pdf_start_link nodes

Valid fields: attr, width, height, depth, objnum, link_attr, action

field	type	explanation
attr	<node>	
width	number	
height	number	
depth	number	
objnum	number	the referenced pdf object number
link_attr	table	the link attribute token list
action	<node>	the action to perform

7.1.3.14 pdf_end_link nodes

Valid fields: attr

field	type	explanation
attr	<node>	

7.1.3.15 pdf_dest nodes

Valid fields: attr, width, height, depth, named_id, dest_id, dest_type, xyz_zoom, objnum

field	type	explanation
attr	<node>	
width	number	
height	number	
depth	number	
named_id	number	is the dest_id a string value?
dest_id	number or string	the destination id
dest_type	number	type of destination
xyz_zoom	number	
objnum	number	the pdf object number

7.1.3.16 pdf_thread nodes

Valid fields: attr, width, height, depth, named_id, thread_id, thread_attr

field	type	explanation
attr	<node>	
width	number	
height	number	
depth	number	
named_id	number	is the tread_id a string value?
tread_id	number or string	the thread id
thread_attr	number	extra thread information

7.1.3.17 pdf_start_thread nodes

Valid fields: attr, width, height, depth, named_id, thread_id, thread_attr

field	type	explanation
attr	<node>	
width	number	
height	number	
depth	number	

named_id	number	is the tread_id a string value?
tread_id	number or string	the thread id
thread_attr	number	extra thread information

7.1.3.18 pdf_end_thread nodes

Valid fields: attr

field	type	explanation
attr	<node>	

7.1.3.19 pdf_save_pos nodes

Valid fields: attr

field	type	explanation
attr	<node>	

7.1.3.20 late_lua nodes

Valid fields: attr, reg, data

field	type	explanation
attr	<node>	
reg	number	Lua state id number
data	string	data to execute

7.1.3.21 close_lua nodes

Valid fields: attr, reg

field	type	explanation
attr	<node>	
reg	number	Lua state id number

7.1.3.22 pdf_colorstack nodes

Valid fields: attr, stack, cmd, data

field	type	explanation
attr	<node>	
stack	number	colorstack id number

cmd	number	command to execute
data	string	data

7.1.3.23 pdf_setmatrix nodes

Valid fields: attr, data

field	type	explanation
attr	<node>	
data	string	data

7.1.3.24 pdf_save nodes

Valid fields: attr

field	type	explanation
attr	<node>	

7.1.3.25 pdf_restore nodes

Valid fields: attr

field	type	explanation
attr	<node>	

7.1.3.26 user_defined nodes

User-defined whatsit nodes can only be created and handled from Lua code. In effect, they are an extension to the extension mechanism. The LuaTEX engine will simply step over such whatsits without ever looking at the contents.

Valid fields: attr, user_id, type, value

field	type	explanation
attr	<node>	
user_id	number	id number
type	number	type of the value
value	number	
	string	
	<node>	
	table	

The type can have one of five distinct values:

value	explanation
97	the value is an attribute node list
100	the value is a number
110	the value is a node list
115	the value is a token list in string form
116	the value is a token list in lua table form

8 Modifications

Besides the expected changes caused by new functionality, there are a number of not-so-expected changes. These are sometimes a side-effect of a new (conflicting) feature, or, more often than not, a change necessary to clean up the internal interfaces.

8.1 Changes from TEX 3.141592

- See chapter 5 for many small changes related to paragraph building, language handling, and hyphenation.
- There is no pool file, all strings are embedded during compilation.
- `plus 1 fillll` does not generate an error. The extra 'l' is simply typeset.
- The `\endlinechar` can be either added (values 0 or more), or not (negative values). If it is added, the character is always decimal 13 a/k/a `^^M` a/k/a carriage return (This change may be temporary).
- The banner line and the statistics messages are different, as well as many warnings and error texts.

8.2 Changes from ε-TEX 2.2

- The ε-TEX functionality is always present and enabled (but see below about TEXXeT), so the prepended asterisk or `-etex` switch for iniTEX is not needed.
- TEXXeT is not present, so the primitives

  ```
  \TeXXeTstate
  \beginR
  \beginL
  \endR
  \endL
  ```

  are missing
- Some of the tracing information that is output by ε-TEX's `\tracingassigns` and `\tracingrestores` is not there.
- Register management in LuaTEX uses the Aleph model, so the maximum value is 65535 and the implementation uses a flat array instead of the mixed flat&sparse model from ε-TEX.
- `savinghyphcodes` is a no-op and may possibly be removed. See chapter 5 for details.

8.3 Changes from PDFTEX 1.40

- The (experimental) support for snap nodes has been removed, because it is much more natural to build this functionality on top of node processing and attributes. The associated primitives that are now gone are: `\pdfsnaprefpoint`, `\pdfsnapy`, and `\pdfsnapycomp`.
- A number of 'utility functions' is removed:

\pdfelapsedtime
\pdfescapehex
\pdfescapename
\pdfescapestring
\pdffiledump
\pdffilemoddate
\pdffilesize
\pdflastmatch
\pdfmatch
\pdfmdfivesum
\pdfresettimer
\pdfshellescape
\pdfstrcmp
\pdfunescapehex

- A few other experimental primitives are also provided without the extra pdf prefix, so they can also be called like this:
  \primitive
  \ifprimitive
  \ifabsnum
  \ifabsdim
- The definitions for new didot and new cicero are patched.
- The \pdfprimitive is bugfixed.
- The \pdftexversion is set to 200.

8.4 Changes from ALEPH RC4

- The input translations from Aleph are not implemented, the related primitives are not available
  \DefaultInputMode
  \noDefaultInputMode
  \noInputMode
  \InputMode
  \DefaultOutputMode
  \noDefaultOutputMode
  \noOutputMode
  \OutputMode
  \DefaultInputTranslation
  \noDefaultInputTranslation
  \noInputTranslation
  \InputTranslation
  \DefaultOutputTranslation
  \noDefaultOutputTranslation
  \noOutputTranslation
  \OutputTranslation
- A small series of bounds checking fixes to \ocp and \ocplist has been added to prevent the system from crashing due to array indexes running out of bounds.
- The \hoffset bug when \pagedir TRT is fixed, removing the need for an explicit fix to \hoffset
- A bug causing \fam to fail for family numbers above 15 is fixed.
- Some bits of Aleph assumed 0 and null were identical. This resulted for instance in a bug that sometimes caused an eternal loop when trying to \show a box.
- A fair amount of other minor bugs are fixed as well, most of these related to \tracingcommands output.
- The number of possible fonts, ocps and ocplists is smaller than their maximum Aleph value (around 5000 fonts and 30000 ocps / ocplists).
- The internal function scan_dir() has been renamed to scan_direction() to prevent a naming clash.
- The ^^ notation can come in five and six item repetitions also, to insert characters that do not fit in the BMP.
- Glues *immediately after* direction change commands are not legal breakpoints.
- The \ocp and \ocplist statistics at the end of a run are only printed if OCP's are actually used.

8.5 Changes from standard WEB2C

- There is no mltex
- There is no enctex
- The following commandline switches are silently ignored, even in non-Lua mode:

  ```
  -8bit
  -translate-file=TCXNAME
  -mltex
  -enc
  -etex
  ```

- \openout whatsits are not written to the log file.
- Some of the so-called web2c extensions are hard to set up in non-kpse mode because texmf.cnf is not read: `shell-escape` is off (but that is not a problem because of Lua's `os.execute`), and the paranoia checks on `openin` and `openout` do not happen (however, it is easy for a Lua script to do this itself by overloading `io.open`).

9 Implementation notes

9.1 Primitives overlap

The primitives

```
\pdfpagewidth   \pagewidth
\pdfpageheight  \pageheight
\fontcharwd     \charwd
\fontcharht     \charht
\fontchardp     \chardp
\fontcharic     \charic
```

are all aliases of each other.

9.2 Memory allocation

The single internal memory heap that traditional TEX used for tokens and nodes is split into two separate arrays. Each of these will grow dynamically when needed.

The `texmf.cnf` settings related to main memory are no longer used (these are: `main_memory`, `mem_bot`, `extra_mem_top` and `extra_mem_bot`). 'Out of main memory' errors can still occur, but the limiting factor is now the amount of RAM in your system, not a predefined limit.

Also, the memory (de)allocation routines for nodes are completely rewritten. The relevant code now lives in the C file `luanode.c`, and basically uses a dozen or so avail lists instead of a doubly-linked model. An extra function layer is added so that the code can ask for nodes by type instead of directly requisitioning a certain amount of memory words.

Because of the split into two arrays and the resulting differences in the data structures, some of the Pascal web macros have been duplicated. For instance, there are now `vlink` and `vinfo` as well as `link` and `info`. All access to the variable memory array is now hidden behind a macro called `vmem`.

The implementation of the growth of two arrays (via reallocation) introduces a potential pitfall: the memory arrays should never be used as the left hand side of a statement that can modify the array in question.

The input line buffer and pool size are now also reallocated when needed, and the `texmf.cnf` settings `buf_size` and `pool_size` are silently ignored.

9.3 Sparse arrays

The `\mathcode`, `\delcode`, `\catcode`, `\sfcode`, `\lccode` and `\uccode` tables are now sparse arrays that are implemented in C. They are no longer part of the TEX 'equivalence table' and because

each had 1.1 million entries with a few memory words each, this makes a major difference in memory usage.

These assignments do not yet show up when using the etex tracing routines `\tracingassigns` and `\tracingrestores` (code simply not written yet)

A side-effect of the current implementation is that `\global` is now more expensive in terms of processing than non-global assignments.

See `mathcodes.c` and `textcodes.c` if you are interested in the details.

Also, the glyph ids within a font are now managed by means of a sparse array and glyph ids can go up to index $2^{21} - 1$.

9.4 Simple single-character csnames

Single-character commands are no longer treated specially in the internals, they are stored in the hash just like the multiletter csnames.

The code that displays control sequences explicitly checks if the length is one when it has to decide whether or not to add a trailing space.

9.5 Compressed format

The format is passed through zlib, allowing it to shrink to roughly half of the size it would have had in uncompressed form. This takes a bit more CPU cycles but much less disk I/O, so it should still be faster.

9.6 Binary file reading

All of the internal code is changed in such a way that if one of the `read_xxx_file` callbacks is not set, then the file is read by a C function using basically the same convention as the callback: a single read into a buffer big enough to hold the entire file contents. While this uses more memory than the previous code (that mostly used `getc` calls), it can be quite a bit faster (depending on your I/O subsystem).

10 Known bugs and limitations

The bugs below are going to be fixed eventually.

The top ones will be fixed soon, but in the later items either the actual problem is hard to find, or the code that causes the bug is going to be replaced by a new subsystem soon anyway, or it may not be worth the hassle and the limitations will eventually be documented.

- The current linebreaking implementation does not yet take all possible breakpoints into account where ligatures are involved in the process. This means that line breaks may change in future versions.
- Sometimes font loading via fontforge generates a message like this

  ```
  Bad call to gww_iconv_open, neither arg is UCS4 (EUC-CN->UTF-8)
  ```

  during font loading. This is a limitation of the internal iconv implementation.
- Font expansion does not work quite as it should. On the mailing list (sep 21), Jonathan Sauer posted a very nice test file along with an explanation.
- `tex.print()` and `tex.sprint()` do not work if `\directlua` is used in an otp file (in the output of an `expression` rule).
- Handling of attributes in math mode is not complete. The data structures in math mode are quite different from those in text mode, so this will take some extra effort to implement correctly.
- When used inside `\directlua`, `pdf.print()` should create a literal node instead of flushing immediately.
- At the moment, only characters in plane 0 and plane 1 can be assigned catcode 13 (i.e. turned into active characters). This is a temporary measure to reduce the memory requirements of LuaTEX. In general, LuaTEX's memory footprint is a bit larger that we would like (with `plain.fmt` preloaded it needs about 55MB).
- Not all of Aleph's direction commands are handled properly in pdf mode, and especially the vertical scripts support is missing almost completely (only TRT and TLT are routinely tested).
- Letter spacing (`\letterspacefont`) is currently non-functional due to massive changes in the virtual font handling. This functionality may actually be removed completely in the future, because it is straightforward to set up letterspacing using the Lua 'define_font' interface.
- Node pointers are not always checked for validity, so if you make a mistake in the node list processing, LuaTEX may terminate itself with an assertion error or 'Emergency stop'.
- In dvi generation mode, using a `\textdir` switch inside the preamble of a `\halign` results in overprinted text in the dvi file, because the column width is not taken into account during the final placement phase (this is a bug inherited from Aleph). Also, Aleph apparently dislikes having more than one non-grouped `\textdir` command in a single lined paragraph.
- Certain constructs in math mode leak memory nodes.

11 TODO

On top of the 'normal' extensions that are planned, there are some more specific small feature requests. Whether these will all be included is not certain yet, (and new requests are welcome).

- Implement the TEX primitive `\dimension`, cf. `\number`
- Change the Lua table `tex.dimen` to accept and return float values instead of strings
- Do something about `\withoutpt` and/or a new register type `\real`?
- Create callback for the automatic creation of missing characters in fonts
- Implement the TEX primitive `\htdp`?
- Do boxes with dual baselines.
- A way to (re?)calculate the width of a `\vbox`, taking only the natural width of the included items into account.
- Make the number of the output box configurable.
- Complete the attributes in math and switch all the nodes to a double-linked list.
- Finish the interface from Lua to TEX's internals, specially the hash and equivalence table (a small subpart is implementing `\csname` lookups for `tex.box` access).
- Integrate the various pdfTEX extended font codes for hz en protruding into the font table.
- Use of Type1C for embedded PostScript font subsets in traditional 8-bit encodings.
- Support font reencoding of 8-bit fonts via char index instead of via map files.
- Attempt to parse OFM level 0 fonts that are masquerading as level 1.
- Add line numbers and input context information to the lua errors